To cut or not to cut

An experimental study of Dutch forest managers' harvesting decisions

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Abstract

In a world where overconsumption and environmental degradation is becoming a pressing issue, there is a real need for circular products such as wood. Satisfying an increasing wood demand for material and energy will, however, be a big challenge. Therefore, it is important to improve our understanding of the future availability of wood. This research contributes to this improved understanding by investigating forest managers' harvesting decisions. It is based on a novel type of behavioral economics experiment specifically constructed to incorporate the different trade-offs which are made in modern day multifunctional forest management. Dutch forest managers have been asked in an online set-up to choose between various harvests interventions options for model forest stands in a model forest context. Based on the input of 53 forest managers, correlations between these choices and extensive set of forest managers' individual characteristics and organizational factors have been investigated using multinomial logistic regression. This study shows that ground area, volume of standing dead wood, and the diameter of the middle tree are good predictors for explaining harvest intervention choices, which are related to stand characteristics. Furthermore, individual characteristics, including forestry education, different specializations, forest manager identity, and self-assessed professionalism are most successful in explaining individuals' choices. All in all, this novel study has provided promising insights in the forest manager's decision process by combining forestry science with insights from behavioral economics, which can be used by policy makers and should serve as a great starting point for future research.

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1 Introduction and problem statement

1.1 Fueling the circular economy with wood

This year, Earth Overshoot Day fell on the 29th of July (Global Footprint Network, 2019). This day marks the date on which humans have used up more resources than the earth can regenerate. According to the Global Footprint Network (2019), we would need 1.75 earths to accommodate our current consumption pattern. Dialing back the pressure of the current world population on the planet would be challenging enough by itself. However, the world population is projected to increase by around 2 billion people in 2050, reaching a total level of 9.8 billion according to current estimates (United Nations, 2017). All those additional people have needs of their own, making the problem of overconsumption ever more unsustainable. In 2017, 15.371 scientists from 184 countries wrote, in a second warning to humanity, how we are failing to address foreseen environmental challenges ranging from rising greenhouse gasses, to deforestation, and increasing biodiversity loss, following a first warning by 1,700 scientists in 1992 (Ripple et al., 2017).

One of the solutions to deal with these issues, which has been gaining popularity over the last years, is the idea that we should strive towards a circular economy. The circular economy concept has been defined, most notably, by the Ellen MacArthur Foundation (2013, p7) as: 'an industrial economy that is restorative or regenerative by intention and design'. In the extreme this means that there will be no waste produced in any part of a production cycle and what is now classified as waste, will be used as input materials for other products. Nutrient cycles will be closed and nonrenewable resources will no longer be depleted. It is likely that the circular economy concept will become increasingly important considering the number of adopted policies over the past years, including: the 1996 Closed Substance Cycle and Waste Management Act in Germany, the 2002 Basic Law for Establishing a Recycling-Based Society in Japan, the 2009 Circular Economy Promotion Law of the People's Republic of China, the European Union's 2015 Circular Economy Strategy, and the 2016 Dutch program Nederland Circulair in 2050 (Rijksoverheid, 2016; Geissdoerfer et al., 2017).

The Ellen MacArthur Foundation (2013) explains the importance of cascading down materials in the circular economy. Products need to be used at the highest trophic level possible, after which they need to be given a second life at the second highest trophic level and so on. There are two types of product cycles to consider. The first would be the technological cycle in which materials are reused, refurbished, and eventually recycled which prevents them from becoming waste. The second cycle is the nutrient cycle. In the nutrient cycle, a product is eventually 'consumed' by humans or animals, after a number of cascades, and is brought back to its nutrient state. This is only possible for biological materials as they decompose easily. Wood is a perfect material to use in the circular economy as it will function in both the technological cycle (many wood products can be reused, refurbished and recycled) and in the biological cycle (wood products can easily decompose to its base nutrients). Moreover, wood can be produced with less energy and pollution compared to materials such as steel and plastic (WWF, 2012). This makes wood a perfect candidate to substitute non-renewable materials, products and fossil based-energy (Rüter et al., 2016).

The usefulness of wood in the circular economy means that future demand for wood and wood products is likely to increase. The WWF (2012) expects wood consumption to double worldwide in 2030 and triple in 2050. This could result in a large pressure on the supply side of wood production. In the past there has not been much concern, which is reflected in around 15 studies which have been conducted in the 1990s which predict that overall supply and demand will be met, up to 2050 (Nilsson and Bull, 2005). However, since the 1990s there have been major developments, all around the world, which influence future wood availability. First of all, there has been a rapid increase of wood use in emerging economies such as China and India (Nilsson and Bull, 2005). While the FAO (2009) projects no global supply issues up to 2030, they do predict that there will be round wood shortages in Asia and the Pacific. Secondly, there has been an increase in environmental constraints on the use of forest (Nabuurs et al., 2003). Fewer forests are managed for economic use and due to the Kyoto protocol, one can make money by harvesting less and claiming carbon credits instead (Nabuurs et al., 2003). Finally, there is an increasing demand for forest biomass in the energy sector. Forest biomass is currently used to provide half of the worlds and EU's sustainable energy (Jonsson et al., 2016; FAO, 2018). Future climate ambitions will drive up the demand for wood even further (Jonsson et al., 2016). Taking these factors into consideration, the question is if future demand will still be met with (local) supply in the near future.

1.2 Problem statement

In the previous section we have established that it is likely that demand for wood will not be met with (local) supply, without governmental action. In this future scenario two major issues arise. First of all, it is likely that wood prices would increase rapidly (Hagemann, 2016). A rapid increase of wood prices would hinder the full transition to from a carbon based economy to a waste free economy (Hagemann, 2016). A second issue of supply not easily meeting demand is an increased pressure on the forest and concerns of forest degradation. If no additional supply is added to the (local) standing stock, there will be a decreasing amount of production forests which will have to provide more and more wood (Nabuurs et al., 2003). Additionally, high prices would make illegal logging more rewarding (Elias & Boucher, 2014). It is important to realize that forest mangers cannot react on changes on the market on the short term, e.g. when the demand increases. Forest management deals with long time spans (Hoogstra, 2008). As there is a large time gap between planting a tree and harvesting a tree. For forest managers to adapt to a new situation would take time, during which the circular economy transition might be slowed down and during which forest degradation could have serious consequences for our (production) forests.

To prevent a discrepancy between market demand and supply and in order to ensure future wood security, policy makers need two things. First of all, they need studies (e.g. agent based model simulations) which provide them with information about the future wood availability (Mantau et al., 2007). Secondly, they need information about the choices made by forest managers in order to nudge or steer their behavior (Petucco et al., 2015; Sauter et al., 2016). Forest managers decide how the future forest will look like and the amount of wood that will be available on the market now and in the future. Insights in forest managers' harvesting decisions are also useful for the type of studies which investigate future wood availability. In other words, gaining insight in the behavior of forest managers serves a double function: it can be both used to improve research which helps policy makers in securing future wood availability and used directly by policy makers to target their policies more effectively.

1.3 To use behavioral economics in forestry science: a new frontier

Summarizing the above, it is important to gain an understanding about the way forester managers make harvest decisions. That is not to say that no research has been carried out on harvesting decisions in the past. Examples include Dennis (1990), Mußhoff and Maart-Noelck (2014), Petucco et al., (2015), Sauter et al. (2016), and Brunette et al. (2017). Most of these studies rely on empirical data of private land owners' harvest decisions, while some used economic experiments based on optimal rotation models. These are both viable methods, which resulted in interesting insights. However, the empirical studies which use private land owners suffer from endogenous variable bias. It is very difficult to test for causal relationships when many (unknown) factors influence the decisions. The economic experiments did not suffer from this issue but were very one-sided. Their controlled setting, took out so many variables which relate to forest management which gives their results very little external validity. The study which is introduced in this report makes use of behavioral economics to explore the decision-making of forest managers, without real life data availability. Other than previous research it makes use of a realistic controlled setting, which should result in unbiased results with external validity.

Behavioral economics has only received limited attention in the field of forestry science (Amacher et al., 2009; Mußhoff and Maart-Noelck, 2014; Sauter et al., 2016). This is unfortunate as behavioral economics has much to offer. ‘At the core of behavioral economics is the conviction that increasing the realism of the psychological underpinnings of economic analysis will improve the field of economics on its own terms – generating theoretical insights, making better predictions of field phenomena, and suggesting better policy’ (Camerer et al., 2011, p.3). Economic experiments are the preferred research method in the field of behavioral economics (Camerer et al., 2011). These experiments have the benefit that they can simplify a decision-making situation, by setting the scene only through those parameters that are relevant to the researcher. Non-controllable and endogenous variables will have a smaller influence on the results. This improves the internal validity of experimental results (Mußhoff and Maart-Noelck, 2014). Economic experiments also enable the researcher to gather data which is not readily available, which is unfortunately the case in the field of decision-making in forestry.

This thesis report tries to bridge behavioral economics and forestry science by introducing a novel decision experiment. This experiment is inspired by (discrete) choice theory, in which different trade-offs can be evaluated. It is different from a classical stated choice experiment in the sense that the choice options reflect real decision situations more closely. How this was done in the most efficient and realistic way possible was part of the research and will be explained in later chapters.

Besides by building up a novel decision experiment, this thesis research is also novel in the amount of factors which are considered in the analysis. Earlier work which investigated forestry decision-making, focused on evaluating the difference which education and training makes on choices made (cf. Cosyns et al., 2018). Other work looked into socio-economic factors of private land owners, and forests characteristics as determinates of harvest decisions (cf. Dennis, 1989; Petucco et al., 2015). This report focuses on the same kinds of factors. However, it will be more complete by also including additional factors. Finally, it will be, as far as the author is aware, the first of its kind in the field of forest science.

1.4 Research objective and research question

The goal of this thesis project is to get a better understanding of forest managers’ decisions about harvesting trees in order to get a better understanding of the supply side of wood production. There are many reasons why a forest manager would decide to make use of harvest intervention[1]. By taking the Netherlands as a case study, the goal is to figure out which individual and institutional factors can explain these decisions. This information can be used by policy makers, who want to increase future wood supply, in order to target specific types of forest managers. Moreover, this information can be

[1] A harvest intervention, in this report, refers to both the practice of thinning and the practice of regeneration cutting of trees in a forest stand.

used to model future wood supply in the Netherlands based on the type of forest managers which are being educated and are present in the work field. The Netherlands makes an interesting case as forests in the Netherlands are often multifunctional (Den Ouden et al., 2010). The high population density in the Netherlands has put pressure on the remaining forests to provide all kinds of services. Moreover, past budget cuts have made wood production more prominent in recent times (e.g. Nieuwsblad de Kaap, 2019). This is, for example, reflected in the 2016 action plan (Actieplan Bos en Hout) which calls for large scale reforestation of the Netherlands and an increase of wood production (Nabuurs, 2019).

The main research question that needs to be answered in order to achieve the research objective is the following:

What harvest intervention decisions are taken by Dutch forest managers and which factors determine these decisions?

If we know why certain forest manager makes decisions, then it is possible to steer those forest manger’s behavior. If this study, for example, would show that young forest managers always harvest too early and are therefore not optimizing wood production, it would be useful to look at the forest and nature conservation curriculum and try to find out if optimal rotation models are part of the lecture program. Sub-questions are necessary to make it more concrete how this thesis research is going to answer the main research question. In order to come up with sub-questions this report will first explore the theory. Based on the theory, the sub-research questions will be formulated.

1.5 Structure of the report

In chapter 2, the theoretical framework is discussed. It explains how different ideas about rational choice making have developed over the years and how these ideas can be used as a base for choice experiments. Chapter 3 describes the methodology. The choices which had to be made with regard to the various parts of the experiment are explained. Moreover, this chapter explains how data was gathered and how the results were analyzed. The results of the experiment are described in chapter 4. Chapter 5 discusses the various results, the theoretical framework and the methodology. Recommendations for policy and science are made. Chapter 6 concludes.

2 Theoretical framework

This chapter starts in section 2.1 with defining rational choice. Section 2.2 describes rational choice in forest management, both from a historical perspective and by looking at the development and critiques on rational forest management. A more general discussion in the social sciences on decision-making is described in section 2.3. Section 2.4 explains how (bounded) rational choice can be used in experiments. Finally, section 2.5 focuses on the explanatory variables which can be used in these types of experiments by introducing a conceptual model and looking into previous research.

2.1 *Defining rational choice*

This report makes use of rational choice theory. Rational choice theory can best be described as a model which attempts to describe human behavior. Fully rational decision makers 'calculate the likely costs and benefits of any action before deciding what to do' (Scott, 2000, p.671). Heracleous (1994) summarized rational decision-making in a sequential process diagram (Figure 1). In order for a decision maker to make rational decisions they needs to have a clear and unambiguous understanding of the problem, its objectives, and of the way these objectives are related to the problem (Heracleous, 1994). The decision-maker should be able to gain a full understanding of all possible courses of action and the consequences of each of these outcomes. Furthermore, probabilities of achieving each desired objective are assumed to be known and up to date.

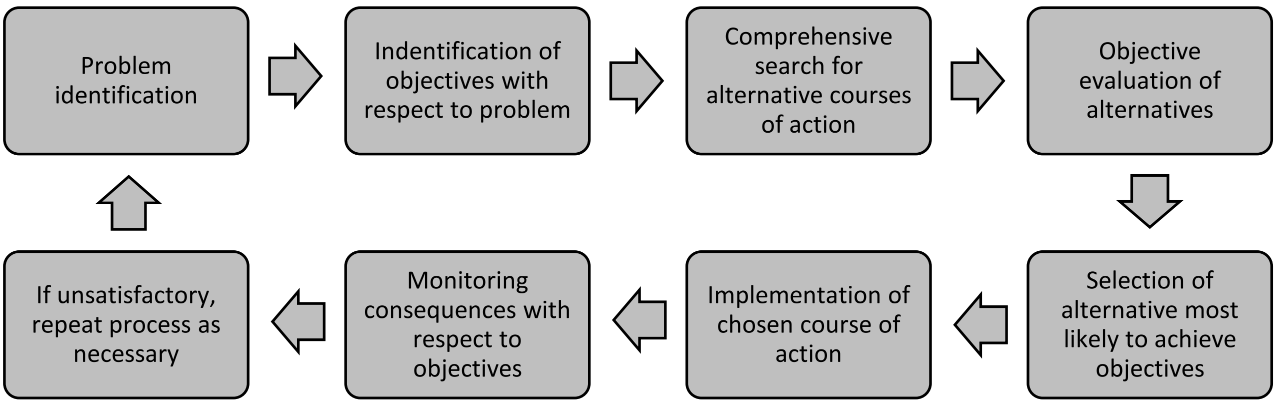


Figure 1: The rational decision-making process under uncertainty (Redrawn from Heracleous, 1994).

Wittek (2013) makes a distinction between thick and thin rational choice theory. Thin models, which so far have been described, assume unbounded rationality. They assume that actors have selfish utility maximizing preferences and that there is no role for social structures or institutions (methodological individualism) (Wittek, 2013). Thick rational models, on the contrary, assume bounded rationality, in which people make satisfying choices. In thick rational models there is a large role for social preferences (concern for the wellbeing of others) and an embeddedness of decisions in social and institutional structures (structural individualism).

2.2 Rational choice in forest management

2.2.1 Historical background

Thin rational choice theory has long been the leading paradigm in forest management. Fully tracing back the origin and evolution of decision-making in forest management is difficult. Many concepts, theories and technologies have developed separately all over the world on how to optimally manage a forest and to decide when to harvest (Kant and Alavalapati, 2014). Due to cultural and communicational barriers, it was not always possible for groundbreaking theories to be transmitted to other areas. This sometimes led to convergent evolution of ideas where scholars in different regions came up with the same concepts, theories and technologies (Kant and Alavalapati, 2014).

We do know that ideas about forest resource management have been discussed as early as the 4^{th} century BC. There is evidence in the Arthashastra (a book about statecraft, economic policy and military strategy) that forest management was one of the topics which was important in ancient India (Deshkar, 2010). In this book it is recommended that for each forest zone a 'Superintendent of Forest Produce' is appointed whose goal it is to protect the forest. This Superintendent would need to keep the forest healthy and make sure it maintains wildlife in order for it to produce forest products, such as: timber, firewood, and medicine (Olivelle, 2013).

Research on the optimal rotation decision can be traced back to the Middle Ages (Amacher et al., 2009). Discussions about harvesting in Germany are believed to have taken place as early as the 1100s in the monasteries of Maurer Munster. However, the real highpoint of systematic discussions on the basic optimal rotation model arose in the 17^{th} century (Amacher et al., 2009). Key in the evolution of forestry is the development of the concept of sustainability, which can be traced back to Hans Carl von Carlowitz, a German who was the chief mining official of the Principality of Saxony (Gottschlich and Friedrich, 2014). Many parts of Europe relied at that time on large quantities of wood for mining and ore-smelting, which resulted in large scale deforestation. In 1713, Von Carlowitz explained in his book Sylvicultura oeconomica that wood shortages would become an imminent threat if this practice continued without replanting of trees and sound forest management practices. The theory of maximum sustainable yield is a direct result of this notion of sustainability in which the goal is to maintain a maximum amount of harvest, indefinitely (Perman et al., 2013). It can be considered the most basic rotation model.

The early production oriented models, which were based on the simple concept of sustainable yield, have, in hindsight, booked both incredible success and lead to unforeseen failures (Luzzi, 2001). Success in the sense that Scott (1998) shows that the productivity of the first harvest rotation in 18th century Prussia's and Saxony's forests increased through the use of these models. Failures came from ignoring the full complexity of forest ecosystems and solely focusing on maximizing volumes. In order for the simple rotation model to work, forests had to be converted to normal forests. These normal forests consisted of a number of even-aged, one-species stands, which were harvested through clear cutting (Den Ouden et al., 2010). Clear cutting resulted in soil erosion (Scott, 1998) and the monocultures were more susceptible to disturbances. Additionally, the monocultures did not make optimal use of available growth space (Townsend et al., 2008), as in monocultures the same type of species competes for the same resources. The harvest, therefore, reduced in sequential yields (Scott, 1998).

Inspire of the failures, the theory of maximum sustainable yield gained traction by forest professionals (Scott, 1998). Economists on the other hand believed that a more complex (production orientated) rotation model was needed (Samuelson, 1967). This led to lively discussions, with foresters one the one side and economists on the other, on the necessity of improving the basic rotation model (Amacher et al., 2009). Eventually, new models could be developed due to extensive empirical research from authors such as the Danish Christian Ditlev who analyzed optimal forest management as a financial return in the early 1800s (Helles and Linddal, 1997). Foresters such as Wilhelm Leopold Pfeil, as early as 1822, concluded that the highest volume production of wood should not be the goal of forestry. Instead one should strive to reach the highest land rent (Pfeil, 1822), which both incorporates the value of the standing stock, as well, as the value of the land itself. However, Pfeil could not formulate a correct mathematical model for his findings (Möhring, 2001). In the end it was William Marshall who improved the 'Jevon's wine ageing formula' (Aronsson and Löfgren, 2002) which is considered a major breakthrough in forest economics thought (Amacher et al. 2009). By including the opportunity costs of growing trees and the opportunity cost of occupying land with trees, Marshall ensured that the agricultural calculation could be used for determining the optimal forest rotation (Aronsson and Löfgren, 2002). His model was most likely the first to offset the marginal benefits of letting a forest stand grow for another period of time to the two marginal opportunity costs of not harvesting. This cost consists of the marginal opportunity cost of letting the forest grow for another time period and not investing the proceeds, which would have been gained if the stand had been cut down, over the next period; as well as the opportunity cost of the land being occupied by trees and not being able to start the next rotation sooner (Amacher et al., 2009).

However, it is not Marshall but Martin Faustmann (1849) who is credited for coming up with a new dominant forest economic thought by writing his seminal paper in 1849 in which, similar to Marshall, the importance of opportunity costs of the forest stand and the opportunity cost of the land are emphasized. The German Pressler (1860) and Swedish Ohlin (1921), independently from each other, formulated the mathematical formulation of Faustmann's approach to forest management (see equation 1). In the Faustman forumula, the mariginal benefits of letting a forest stand grow for an extra period of time ($\frac{dS(t)}{dt}$) is in an equilibrium with the sum of the forgone interest on the stumpage value of the current stand ($rS(t)$) and the forgone interest on the value of the site in its best alternative use ($r\{\frac{S(t)}{((1+r)^t-1)}\}$).

$$\frac{dS(t)}{dt} = rS(t) + r\{\frac{S(t)}{((1+r)^t-1)}\} \quad [1]$$

Where: $S(t)$ = the value of the standing stock at time t;

t = the optimal rotation time;

r = the discount rate.

As all three of these authors wrote in their respective language it took over a century for the English-speaking world to take notice. The tipping point arose when Gaffney (1957) and Samuelson (1967) compared the known methods for determining optimal forest management and gave credit to Faustmann for coming up with the best model. Samuelson (1967) challenged the idea that free market thinking, as devised by Adam Smith, works in forest management. According to Samuelson (1967) it is not the 'goal of good policy to have sustained forest yield, or even maximum sustained yield' (Samuelson, 1967, p.466). History has shown ample examples in which forests in both the old and new world have been cut down completely in order to gain short term profits (Samuelson, 1967). This could only be explained by taking into account the opportunity costs of the land rent.

Over the years Faustmann's model has been expanded in many ways. Newer models allow, for example, for timber prices not to be constant, for uncertainty to be included or for factors, such as, debt obligation to influence the decision process (Fina et al., 2001; Touza et al., 2008). The most notable extension was made by Hartmann which included non-timber values in the optimal rotation model (Sills and Abt, 2013). Hartmann's version of the Faustmann model is still a thin rational choice model. However, the scope of the decision is widened from one financial goal to include multiple goals. The rise of broader rational choice models can be explained by the high demand for timber during the World Wars and their aftermath (Luzzi, 2001). Market demands were outpacing planning efforts. Moreover, many forests in Europe had been converted to plantations around the 1950s (Den

Ouden et al., 2010). These plantations were very susceptible to disturbances. Forests, therefore, were under serious pressure.

While the aftermath of the wars led to high demand for wood, it also led to increased welfare and more free time. A recreation boom brought people to the forests (Hirt, 1996). More people started to appreciate recreational and environmental values of the forest. Transnational environmental group networks make successfully use of this new situation by promoting political consumerism (Kortelainen, 2008). Public concern that intensive harvesting would harm other values of the forest cleared the way for multifunctional forest management (Luzzi, 2001). Decreasing wood prices and increasing subsidies for nature conservation and recreation, additionally, opened forest managers up for the concept of multifunctional forest management (Verbij, 2008).

Real political attention for the multifunctionality of forests came in 1992 through the United Nations Conference on Environment and Development (the so called Earth Summit) (Cesaro and Gatto, 2008). There they recognized that there were 'major weaknesses in the policies, methods, and mechanisms adopted to support and develop the multiple ecological, economic, social and cultural roles of trees, forest and forest lands' (United Nations, 1992, p.91). The European Union adopted its Forest strategy in 1998 in which multifunctionality was stressed as the leading principle for sustainable forest management (Cesaro and Gatto, 2008).

2.2.2 Critiques and development

Multifunctional forest management, in the Netherlands, has in recent times developed into integrated forestry in which multiple goals are tried to be achieved in the same stand (Den Ouden et al., 2010). However, multifunctional forest management and integrated forest management were not effective enough to stop soil erosion and biodiversity loss. In the Netherlands, ecosystem management, is suggested as a new management strategy, in which forest are managed in a way to retain the ecosystem without preset (production) goals. These ideas are reflected in the principles of the Pro Silva movement (Kant, 2002; Den Ouden et al., 2010).

With the new multifunctional forest paradigm in which 'timber management changed to ecosystem management and sustained timber yield management changed to sustainable forest management' (Kant, 2002, p.40), there also came critique on rational forest management decision-making models. While these models could be extended to include non-timber values and amenities (e.g. the Hartman model (see section 2.2.1), they still assumed preset extraction goals of timber and non-timber products. This might explain why according to Kant (2002) there is evidence that rational choice models are, nowadays, less used in practice and why there is 'a lot of freedom for machine operators and field staff to implement harvesting recommendations in a way that personally seems most appropriate to them' (Pommerening, 2018, p.2).

Despite rational choice being under critique, (thick) rational theory is still strong in strategic forest management and planning (Wolfslehner and Seidl, 2010). Multi-criteria decision-analysis methods are, for example, being developed which use rational decision making to 'create aggregated, preference based rankings for management alternatives, while analyzing the trade-offs among indicators' (Wolfslehner and Seidl, 2010, p.854) as there is an increasing societal demand for transparent rational decision making and ways to incorporate new challenges, such as, climate change in forest management trade-offs (Wolfslehner and Seidl, 2010). Moreover, there is an increased use of computer simulations to test forest management strategies at higher levels of aggregation (e.g. Schelhaas et al., 2015). These simulations try to find the 'best' management strategy based by maximizing a broad set of indicators for a set of alternative scenarios.

2.3 Rational choice in social sciences

In the sections above, it has been explained how scientific (rational) decision-making in forestry has developed over the centuries. Thin rational choice theory has been the most prominent paradigm in the course of history, and in spite of rising criticism, thick rational choice theory is still dominant in strategic forest management. At a broader level, a similar situation can be found in the social sciences. Early economical models made use of thin rational choice theory (Kant, 2002). Critique of the use of this theory came from psychologists, sociologists and behavioral economists. In recent times, thick rational choice theory is still being used in the social sciences to describe and analyze decision making.

The theory of rational choice gained much traction by standing at the base of classical economics. Utilitarians, such as the famous philosopher and economist John Stuart Mill, believed that we should all strive towards the greater good (Persky, 1995). They believed that 'pleasure' and 'pain' were well-defined entities and they defined 'utility' as the sum of pleasure minus pain (Jehle and Reny, 2011) Utilitarians believed that people could rationally make decisions which optimize utility and that we should morally strive towards the highest possible utility levels for the world's population.

Rational knowledge gained a special status over other forms of knowledge in the philosophic revolutions of the 16th and 17th century and the social revolution of the Enlightenment (Luzzi, 2001). As the scientific worldview developed, rational decision-making became the main source of certainty and truth. Intuitive, imaginative and emotional knowledge were reduced to a lesser status (Luzzi, 2001). Following classical economics and these philosophic and social revolutions, thin rational decision making became an integral part of neo-classical economics. Neo-classical economists, such as Francis Edegeworth built equilibrium models around the premise that consumers maximize their utility by buying the most products for the lowest price and that producers maximize their utility by maximizing their profit (Persky, 1995; Kant, 2002). In these models, it is assumed that humans are some kind of 'economic man'. This economic man has constant preferences and society is simply a mathematical aggregation of homogenous rational agents in which public inputs work though market signals, and in which there is only a role for the market and not for any other institutions (Kant, 2002).

While unbounded rationality became a leading paradigm, it did not remain unchallenged. Critique on the theory of the economic man and thin rational choice arose in the 1980s (Hoogstra-Klein and Burger, 2013). Three unrealistic traits of the economic man were the main focus of this critique: unbounded willpower, unbounded selfishness, and unbounded rationality (Mullainathan and Thaler, 2000).

Humans do not have unbounded willpower according to Mullainathan and Thaler (2000). People have self-control problems which we are, at least partly, aware of. We procrastinate, exhibit unhealthy behavior, and show contradicting behavior. We are also not unboundedly selfish. We donate to charity, do volunteer work and act as communities (Mullainathan and Thaler, 2000). The groundbreaking work of Elinor Ostrom shows that commons can be managed optimally through working together as long as good behavior is rewarded and bad behavior is punished (Ostrom, 1990). It should be noted that enlightened self-interest has also been suggested to explain rational altruistic decision making (Frimer et al., 2011).

The main point of critique on the economic man, however, is that he makes decisions with unbounded rationality (Mullainathan and Thaler, 2000). Herbert Simon (1955) criticized the paradigm of economic agents having unlimited information processing. According to Simon (1955) there are psychological limits to the computational and predictive abilities of humans, which makes people act as Homo sapiens instead of Homo economicus (Kant, 2002). Or as Gigerenzer and Selten (2001, p37) put it: 'Humans and animals make inferences about unknown features of their world under constraints of limited time, limited knowledge, and limited computational capacities'. Simon (1955) introduced the concept of bounded rationality which describes 'rational behavior that is compatible with the access to information and the computational capacities that are actually possessed by organisms, including man, in the kinds of environments in which such organisms exist (Simon, 1955, p.99). More realistic economic agents according to Simon (1955) try to seek a satisfactory solution when making a decision instead of an optimal solution. The concept of bounded rationality is, therefore, related to the concept of thick rationality (Wittek, 2013).

The bounded rational man makes use of heuristics to make decisions (Tversky and Kahneman, 1974). Heuristics are mental shortcuts based on previous experiences which make it possible to quickly come up with a satisfactory decision when faced with uncertainty. Some examples are: complicity, familiarity, salience, format, framing, starting point bias, hypothetical bias, setting, reference state, learning, loss aversion, and lexicographic preferences (Valatin et al., 2016). As (more) realistic decision-maker uses these mental short cuts to quickly come up with a satisfactory decision, they are influenced by the way information is presented, as Tversky and Kahneman (1981), for example, have shown by studying the framing effect. People can also be nudged by making use of heuristics to make certain decisions as shown by groundbreaking research from Thaler and Sunstein (2009).

2.4 (Bounded) rational choice in choice experiments

It is clear from the previous sections that rational choice theory has had a major influence on forestry and the social sciences. Rational choice theory proves to be a very useful theory in explaining decisions. The starting point of this thesis, is therefore, (thin) rational choice theory, which is used as a base for multinomical logistic regression (section 2.4.1). These statistical models need the assumption that people maximize their utility, in order to work. However, the previous sections have also shown that thick rational choice theory is perhaps better suited to explain behavior. This theory is, therefore, used to describe which factors might explain behavior and which are going to be used as input for the model simulation (see section 2.5). Moreover, it bounded rationality has shown that is important to be aware of heuristics when conducting experiments. The way an experiment is set-up can potentially bias the results. In section 2.4.2 it is discussed how heuristics have been accounted for.

2.4.1 Discrete choice theory

In this section it is explained how decision-making can be evaluated. Decision-making is a complex process. With discrete choice theory, which has been developed to map the influence of inputs of a decision, one can omit some of this complexity by making behavioral assumptions. Discrete choice experiments are, therefore, becoming the most prominent approach used to investigate importance of choice characteristics (and other factors which might influence choices) in a decision-making process (Hanley et al., 2001). Walker (2001) shows visually how in discrete choice theory one assumes the decision-making process to be a black box (Figure 2 and 3). Discrete choice theory avoids some of the complexity of decision-making by just looking at the outcome of a decision-making process.

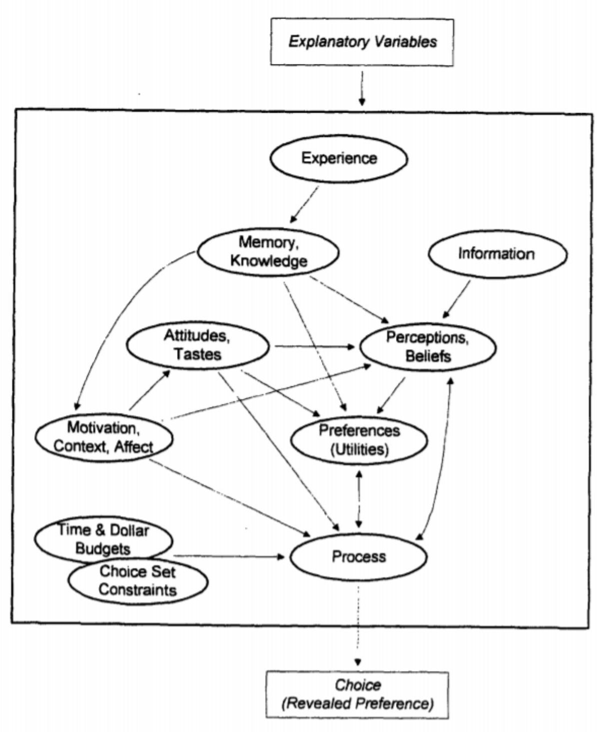


Figure 2: The complexity of behavior in decision-making according to Walker (2001).

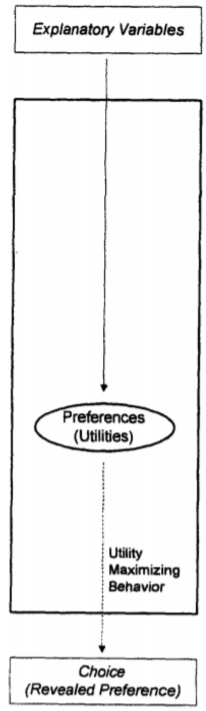


Figure 3: The simplification that is made in (discrete) choice theory (Walker, 2001)

Discrete choice theory is theoretically underpinned by random utility theory (Lancaster, 1999). This theory assumes a choice alternative consist of several characteristics (Lancaster, 1999). Forest managers are assumed to choose the choice alternative which yields them the highest utility. Think, for example, of a forest stand which has a certain volume, biodiversity levels, etc. The preference of a forest manager for certain levels of these stand characteristics (e.g. high or low volume, many or few rare species, etc.) can partly be observed and are partly unknown. The observed part of these preferences is the result of analyzing many choices by many forest managers. Every choice that is made, shows which variables are maximizing utility and by exploiting variation in these choices, and can dissect the relative contribution of each attribute to the utility. The unknown part of the choice alternatives is assumed to be randomly distributed.

Mathematically random utility can be expressed in the following two general formulas (Walker, 2001, p.18):

The structural equation: $U_{in} = \mu(X_{in}; \theta) + \epsilon_{in}$ [2]

The measurement equation: $Y_n = f(U_n)$ [3]

Where: n = the individual, n=1, …, N;

i, j = the alternatives, i, j = 1, …, J;

J_n = the number of alternatives considered by individual n;

U_{in} = the utility of alternative i as perceived by individual n; Un is the (J_n*1) vector of utilities;

y_{in} = the choice indicator (equal to 1 if alternative i is chosen, and 0 otherwise); y_n is the vector (J_n*1) vector of choice indicators;

μ = the function that expresses the systematic utility in terms of explanatory variables;

f = the function that represents the decision protocol as a function of the utility vector;

θ = a set of unknown parameters;

ϵ_{in} = a random disturbance term;

X_{in} = a (1*K) vector describing n and i; X_n is the (J_n*K) matrix of stacked Xi_n.

In McFadden's (1974) multinomial logit model (MNL) the two formulas can be expressed as (Walker, 2001, p.19):

The structural equation: $U_{in} = \beta X_{in} + \varepsilon_{in},$ where ε_{in} errors are Gumbel distributed [4]

The measurement equation: $Y_n = 1$ if $U_{in} = \max_j\{U_{jn}\}$ and $Y_n = 0$, otherwise [5]

These two formulas combined give the individual choice probability (Pr) through:

$$\Pr(y_{in} = 1|X_n; \beta) = \frac{\exp(\mathrm{V}(\beta \mathrm{x}_{in}))}{\sum_{j \in C_n}^{J} \exp(\mathrm{V}(\beta \mathrm{x}_{jn}))} \quad [6]$$

Where: C_n = the choice set faced by individual n, compromised of J_n alternatives;

β = a (K*1) vector of unknown parameters;

V = the function that expresses the systematic utility in terms of explanatory variables.

In section 3.5 it will be explained how these functions can be used to answer the (sub)-research questions. In the mathematical Appendix (A) it is shown how these logit models can be derived for a discrete number of choice alternatives in order to get a better understanding on the mathematics behind these econometric formulas.

2.4.2 Dealing with biases

The goal of the thesis is to purely measure the effect of the variables related to questions described in section 3.2.2 on the harvesting interventions made by Dutch forest managers. The results would be biased if the influence of heuristics is picked up by accident instead of these factors. The overview of Valantin et al (2016), and specifically the suggestions for mitigation the effect of heuristics, was therefore used as checklist while building the experiment. Valatin et al. (2016) provide a complete overview of all heuristics used by respondents in nature related choice experiments. This overview is based on many studies which investigated separate biases. Most of these studies looked at the effect of a bias on the estimation of Willingness To Pay (WTP) for ecosystem services. This is a different setup than this report's experiment, but the methodical issues are very similar.

Valatin et al. (2016) has grouped various heuristics in order to discuss them systematically. First of all, there are heuristics which influence the processing of information. Secondly, there are heuristics which relate to the way information is presented. Thirdly, there are heuristics which are related to the context of the experiment. Fourthly, there is the problem of learning and loss aversion. Finally, there is the bias which results from lexicographic preferences. In the next section it is discussed how in the experiment each heuristic was taken into account.

2.4.2.1 Information processing impacts

Table 1 shows that the complexity heuristic leads to larger standard errors. Asking too complex questions will confuse respondents. Thus, it is suggested to keep the choice experiment simple. The experiment will, therefore, only look at the most important goals of modern Dutch forestry and provide the least amount of information necessary for forest managers to make decisions (while still trying to provide all information which might be relevant). Forest managers will need to be able to recognize themselves in the experimental situation, whether they will do so, will partly depend on the type of stands in the experiment. One should be careful not to include very different stands where one is very familiar and the other is not, or where one contains rare species and the other not. Therefore, the type of model forest that will be used has to be a common forest in the Netherlands and not contain rare species which would impact the results through the familiarity and salience heuristic, see Valatin et al. (2016).

Table 1: Information processing impacts (redrawn from Valatin et al., 2016).

		Impact on stated values		
Aspect	**Focus**	**Level**	**Variance**	**Mitigation**
Complexity	Use of overarching scenarios or simpler resource-specific trade-offs		8 times higher variance for more complex formats	Pre-testing and attempt to identify and control for complexity, including by restricting options to different levels of resources
Familiarity	Awareness of threatened status of species	68% if aware versus 40% if unaware*		Need for initial assessment of awareness of what is being valued, but cautiously (see perception of own identity impacts (Pouta, 2004))
Salience	Focus upon charismatic species as a proxy for biodiversity value	6 times higher		Use less iconic species or less familiar terms (e.g. scientific name for species)

* Proportion of respondents willing to pay a stated amount.

2.4.2.2 Information presentation impacts

The information in the questionnaire will be presented in a tabular rather than a textual format to combat format heuristics (Table 2). Framing will be avoided as much as possible in the introduction of the experiment by avoiding wording that assigns value to the attributes. Sauter et al. (2015) found no large differences between the versions of their experiment in which they used explicit wording compared to the versions of their experiment in with they used neutral wording, which suggest that framing might not be a large issue.

Table 2: Information presentation impacts (redrawn from Valatin et al., 2016).

		Impact on stated values		
Aspect	**Focus**	**Level**	**Variance**	**Mitigation**
Format	Textual compared to tabular information	2.5 to 4 times higher*	2 times higher	Present information in a tabular rather than textual format
Framing	Structural (species groups) compared to functional (water levels) description	2 times higher		Ensure questionnaires are framed in relation to attributes respondents can relate to/care about
	Named species compared to a group of five unnamed species	1.7 to 1.8 times higher marginal rate of substitution		Care needs to be taken to treat all attributes to be valued in a similar way (as naming a species can alter stated value relative to unnamed species
	Label effect	1.3 times higher when 'National Park' label used		Ensure the attribute is not being valued on its association with another factor or identify by the use of follow-up questions

* Acreage of new habitat considered sufficient to compensate for lost habitat

2.4.2.3 Impacts of context

Anchoring is a cognitive bias which can influence a choice experiment by offering a piece of start information which respondents are going to base all their responses on (Table 3). This is less of a problem in our experiment than in discrete choice experiments as we use realistic choice options. The anchoring effects which could be displayed in the experiment could also be present in real life and are, therefore, just part of the decision-making process. Although, one can never be 100% sure that this is the case. Hypothetical bias is a larger problem as respondents might not put as much effort in the choices made in the experiment compared to real life choices. Respondents might also give desired answers to come across better or to please the researcher. Hypothetical bias is partly solved by putting the choice stands in broader context of a model forest (see section 3.2.2). Hypothetical bias can also be tackled by using a 'cheap talk' script in which the researcher explains to the respondent that the experiment might not be real, but that they should try to make choices as if it were real. In this cheap talk, respondents also need to be made aware that they should answer as individuals but also as if they were employed by their current employer to avoid setting bias, in which the role of the respondent is unclear. The fact that the questionnaire is anonymous will reduce social desirability bias (Leggett et al., 2003). Respondents can deal with up to eighteen choice sets before their attention is lost according to Mangham et al. (2009). The experiment should therefore be short enough to keep respondent's attention. The reference state bias should be avoided by starting with the choice sets and ending with the other parts of the experiment.

Table 3: Impacts of context (redrawn from Valatin et al., 2016).

		Impact on stated values		
Aspect	**Focus**	**Level**	**Variance**	**Mitigation**
Anchoring (starting point bias)	One question ('single-bound') compared to initial question with follow-up ('double-bound') choice experiment	1.3 times higher		Use a model to account for anchoring effects. For example, DeShazo (2002) suggests removing all answers which could be influenced by framing effects complexity, including by restricting options to different levels of resources
	Participation in single choice experiment compared to a series of choice experiments	1.3 to 2.7 times higher		Use of a payment ladder
Hypothetical bias	Lack of payment mechanism compared to expectation of payment based upon response	2 to 10 times higher		Using 'cheap talk' to make respondents aware of hypothetical bias and thus take this into account in their bids
Setting	Individual compared to group values	3.5 times higher		Both approaches are useful. The group setting provides good context and refinement of WTP as it enables a wider range of information to be considered. However, the individual setting allows private information to be disclosed and therefore both approaches should be used
	Citizen compared to individual values	2.1 to 2.4 times higher		Ensure respondents answer consistently with either community or individual views
Reference state	Initial question on environmental beliefs and values	1.8 times higher		Attitude and belief items should not be used as warm-up questions in contingent valuation questionnaires

2.4.2.4 Learning and loss aversion impacts

Learning effects can impact the results of the experiment if the respondent does not have enough knowledge on the attributes of the choice experiment. Valatin et al. (2016) discuss two papers in which learning takes place through group discussions (Table 4). The thesis experiment does not provide a group discussion as it is assumed that professional forest managers have all necessary information to make harvest decisions. Most forest managers have made harvest intervention decisions in their working life and therefore should be able to make this trade-off. This assumption is confirmed by Sauter et al. (2015) who also did not find a learning effect in their experiment by testing if respondents made different choices in later choice sets, compared to earlier choice sets. Loss aversion might impact the results. People tend to give more value to things they own compared to things they can gain. Loss aversion however is not expected to be different in the experiment, compared to the way this heuristic would work in a real life harvest decision.

Table 4: Learning and loss aversion impacts (redrawn from Valatin et al., 2016).

Aspect	Focus	Impact on stated values Level	Variance	Mitigation
Learning	Workshop discussion compared to no discussion		Reduce	Discussion preferable because it can improve understanding of concepts, allowing WTP to be stated more precisely
	Discussion with friends and family compared to no discussion	1.2 times higher		Need to consider where respondents already have sufficient knowledge and consider time required to make choices
Loss aversion	WTP may provide underestimates			Use WTA for ecosystem services and ecosystem sustainability valuations
	Losses in the future are often undervalued			Attitude and belief items should not be used as warm-up questions in contingent valuation questionnaires

2.4.2.5 Lexicographic preferences impacts

Protest votes could result in biased results (Table 5). Respondents might, for example, choose to never harvest regardless of the attribute levels to influence the overall results of the experiment. Normally this could be mitigated by asking respondents to rank choices. In this thesis experiment this will not possible. Follow-up questions will be asked instead to get insight in the reasoning of respondents to make decisions. Protest votes are more common when dealing with trade-offs for culturally or psychologically 'protected' resources (Valatin et al., 2016). This is not relevant for the thesis experiment.

Table 5: Lexicographic preferences impacts (redrawn from Valatin et al., 2016).

Aspect	Focus	Impact on stated values Level	Variance	Mitigation
Lexicographic preferences	Trade-offs for culturally or psychologically 'protected' resources			Ranking the different elements based upon their protected or utilitarian values
	Protest votes	Median 3 times lower		Asking respondents to rank choices and use follow-up questions

2.5 *Explanatory variables*

In this section we get a closer look on the decision-making process and to introduce the various factors which will be put to the test in the discrete choice experiment. In section 2.5.1, the Engel Kollat Blackwell model is introduced as conceptual model which can be used to explain which factors influence decision making. In section 2.5.2, previous findings are described.

2.5.1 The Engel Kollat Blackwell model

We make thousands of decisions every day without too much effort. The Engel, Kollat, Blackwell (EKB) model, which was originally derived for consumer decision-making tries to capture this complexity. The EKB-model is a thick rational choice model and is considered one of the most important models in consumer behavior studies (Schiffman and Kanuk, 2008). Due to a lack of decision making models in forestry science the EKB-model is used in this report to structures the various factors which influence decision making. Figure 4 shows an early (1982) attempt of Engel, Kollat Blackwell to systematically describe the decision-making process.

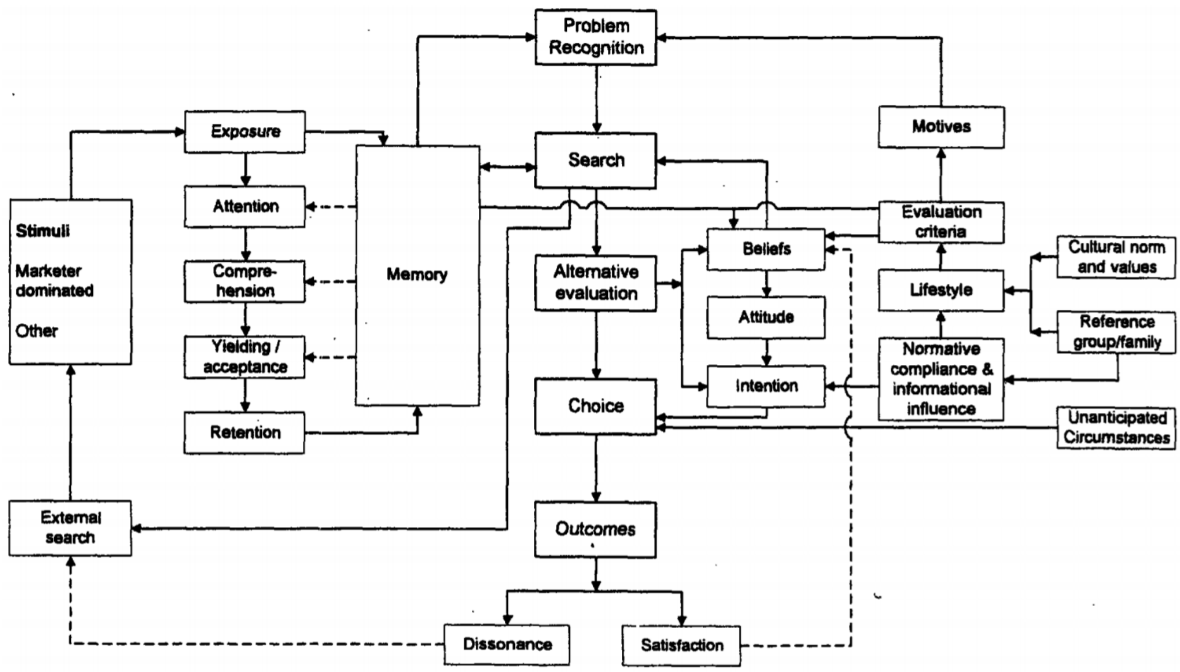


Figure 4: The 1982 Engel Kollat Blackwell (EKB) model of consumer behavior (Walker, 2001).

What is clear from the EKB-model is that consumers make choices by evaluating alternatives. In order to do so, they make use of an internal and external process. Consumers look internally at their memories which are formed through past experiences and are influenced externally by environmental influences, individual differences, and unanticipated circumstances. In the case of consumer behavior, one can also think of advertising influencing the past experiences in the internal process. The external environmental process is influenced by culture, social class, personal influence, family, and situation (Blackwell et al., 2001). The decision-making process is adaptive in such a way that after having made a choice it gets evaluated. Good experiences with certain products strengthen the belief that those are good alternatives. Bad experiences with previous choices (dissonance) influence the way how the external search is approached. Next time one might search for more external information before making a choice (Abdallat and El-Eman, 2001).

In 1995 the authors decided to restructure some of the blocks (Figure 5). This figure shows in a more structured way how four types of factors influence the decision-making process. The 1995 version of the EKB-model also differs from the 1982 version in that an interaction between retention and external search is added. With this the authors show that, when information is locked in the long term memory (retention), it will influence the way how external information is sought after. A third difference is the relation between dissatisfaction (dissonance) and beliefs. A bad experience can also alter the way a type product is believed to perform.

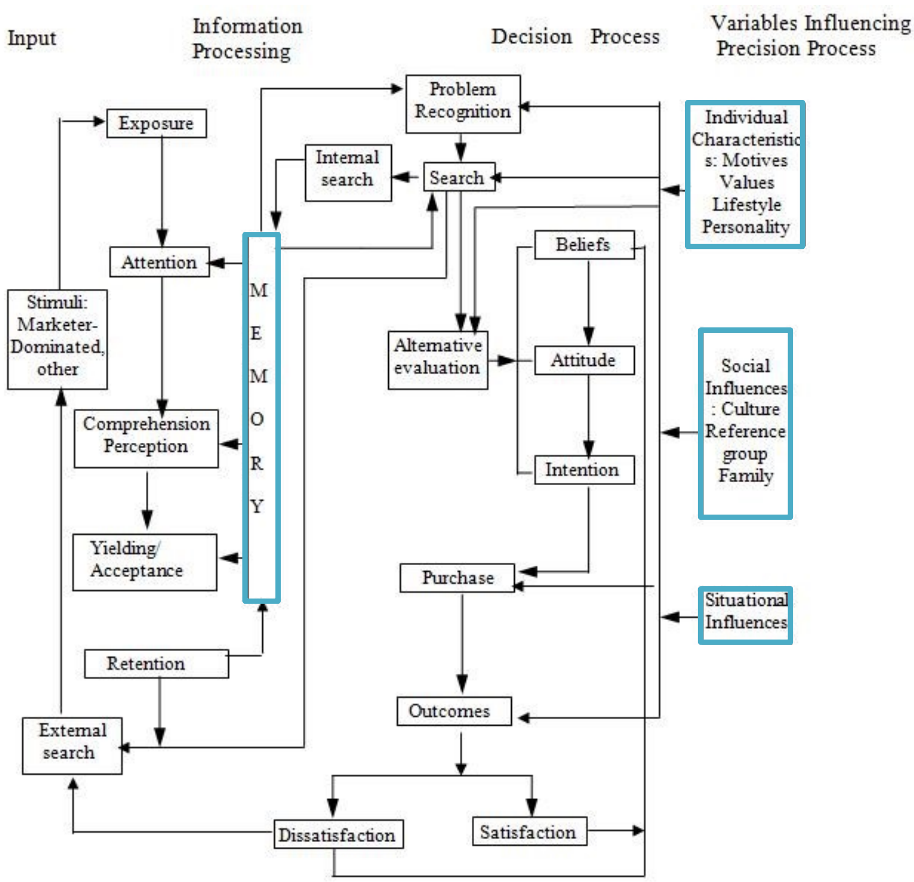


Figure 5: The 1995 Engel Kollat Blackwell (EKB) model of consumer behavior (Abdallat and El-Eman, 2001). Blue boxes are the main factors influencing the choice process, while black boxes show the decision process and information processing process.

When translating the EKB model to this research, the outlined boxes show the most important factors in the decision making process of a forest manager (Figure 5). If it is assumed that a harvest decision is made the same way as a consumer's buying decision, then these are types of factors which need to be investigated and included in a choice experiment.

In this report it is assumed that when a forest manager has to decide when they would like to implement a harvest intervention for a certain choice stand they will first look at the stand characteristics (e.g. wood volume, amount of biodiversity, etc.). This decision is, furthermore, influenced by memory, individual characteristics, social influences, and situational influences. Figure 6 shows a redrawn simplified version of the EKB-model with the elements which just have been discussed and their influence on the choice for a certain alternative.

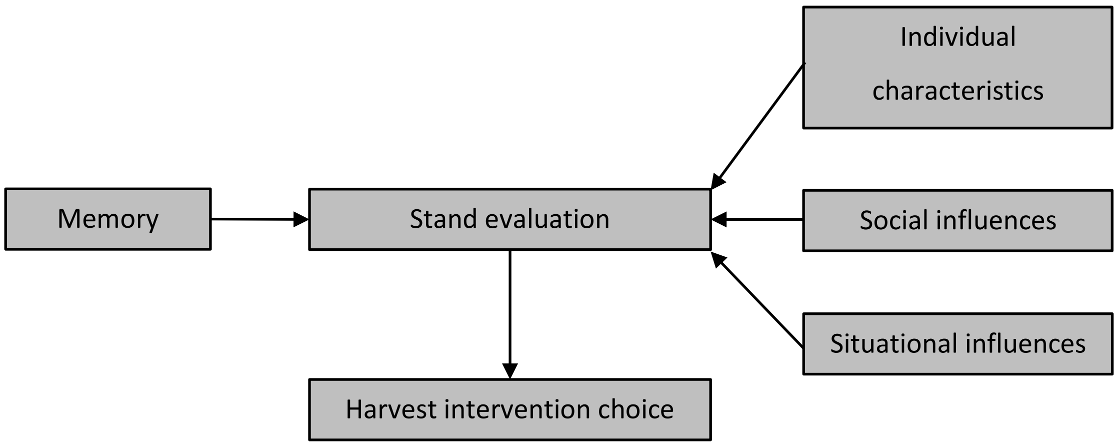


Figure 6: Conceptual framework of the harvest decision made by forest managers.

From Figure 6 it is possible to derive the following sub-research questions for thesis research:

(1) *How do individual characteristics contribute to Dutch forest managers' harvest intervention decisions?*
(2) *How do social influences contribute to Dutch forest managers' harvest intervention decisions?*
(3) *How do situational influences contribute to Dutch forest managers' harvest intervention decisions?*
(4) *How does memory contribute to Dutch forest managers' harvest intervention decisions?*

2.5.2 Previous findings in literature

This section discusses a literature review of the most important papers which investigate which factors explain harvest decision making. Five of these papers are focused on econometric analysis of harvesting decisions of private land owners. Binkley (1981), Dennis (1998) and Joshi and Arno (2009) conducted their study in the United States. Garcia et al. (2014) and Petucco et al. (2015) used a French database. The two other studies by Mußhoff and Maart-Noelck (2014) and Sauter et al.

(2015) used a decision tree type of experiment which was based on the changing economic value of a forest stand over time. Both of these studies used German foresters as their respondents. Table 6 shows a quick overview of the most important variables which were included in these studies.

Table 6: A quick overview of previous results. Plus signs (+) show which variables have been found to be positively or negatively significant at least α=0.05. Minus signs (-) show for which variables no significant relations are found. Blank cells indicate a certain variable was not included in a study.

VARIABLES	Binkley (1981)	Dennis (1998)	Joshi and Arno (2009)	Garcia et al. (2014)	Petucco et al. (2015)	Mußhoff and Maart-Noelck (2014)	Sauter et al. (2015)
Gender				-		+	+
Age	+	-	+		+	+	+
Education	-	+	+			+	-
Income	+	+			+		
Expertise			+	+	-	+	-
Views on forest management			-		+		-
Risk attitude					+	-	-
Professional environment				+	+		-/+
Real-life work environment	+	- /+		+	-/+		-

Gender

Each possible relationship between gender and harvest decisions has been found. Garcia et al. (2014) did not find a significant direct effect of gender on the harvesting decisions. Mußhoff and Maart-Noelck (2014) did found a possible correlation between gender and harvest decisions; males are likely to harvest earlier. Sauter et al. (2015), on the other hand, found that women are significantly more likely to harvest too early compared to a real options approach benchmark.

Age

Various results have also been found for the age variable of the forest managers. Dennis (1989) found no relation between age and the amount of wood harvested. Joshi and Arano (2009), Mußhoff and Maart-Noelck (2014), and Petucco et al. (2015) did found differences. Younger land owners in France, Germany, and the United States were to be found more likely to harvest frequently compared to older land owners. Binkley (1981) found, on the other hand, that older forest owners are more likely to harvest. Binkley (1981) explains this by suggesting that older forest owners have a shorter financial planning horizon, which makes is more likely for them to liquidate their growing stock. The later only holds for decision-makers who own the forest themselves. Similar results are found by Sauter et al. (2015) who find that older forest managers harvest significantly too late compared to the a Faustmann benchmark.

Education

Binkley (1981) found no effect of education level on harvesting decisions, while Dennis (1989) did find a negative relation between the years of formal education private forest owners had and the volumes of timber harvested. He tries to explain this difference by suggesting that more educated landowners may have a higher appreciation for forest amenities. However, he also states that using a tobit approach[2] he did not correct for income levels which could also explain this correlation. Joshi and Arno (2009) and correct for income and other variables and finds the opposite significant effect of education level on the decision to engage in timber harvesting activities. An increase of education is associated with a higher level of harvesting. This is confirmed by Mußhoff and Maart-Noelck (2014). Their study shows that more education leads to more wood being harvested, especially if one also had studied economics (Mußhoff and Maart-Noelck, 2014). However, Sauter et al. (2015) did found no significant results for education or having had economic education.

Income

Petucco et al. (2015) find a positive correlation between landowners' gross annual income and the ratio between income from timber and total income, with the likelihood of timber being extracted.

These results are contradictory to the results of Blinkley (1981) and Dennis (1998). Income is unambiguously negatively associated with harvest probability according to (Blinkey 181). Dennis (1989) also finds a negative correlation between exogenous income (from other sources than the forest) of private landowners and the amount of timber extracted in both his theoretical model and empirical model. When forest owners are less dependent on income from the forest, they do not have to harvest for financial reasons.

Expertise

Joshi and Arano (2009) show that private forest owners who have owned a forest for longer, are more likely to harvest, possibly due to the expertise they have built up over the years. These results match with the results of of Mußhoff and Maart-Noelck (2014) who find that individuals who had forestry-related job training are likely to harvest earlier and the results of Petucco et al. (2015), which find that it is more likely that harvesting takes place in a forest which is managed by a forestry expert. Garcia et al. (2014) also finds that forest managers who read forestry journals, and which therefore might have more expertise, are more likely to harvest. However, Joshi and Arano (2009) find the exact opposite result and conclude that professionals are less likely to engage in harvesting decisions. Sauter et al. (2015) finds no significant results of having had an apprenticeship in forestry.

[2] A linear regression approach which assumes that the dependent variable has a number of its values clustered at a limiting value (McDonald and Moffitt, 1980).

Views on forest management

Petucco et al. (2015), similar to Dennis (1989), state that the appreciation for amenities might have large impact on the harvest decision. However, Petucco et al. (2015) are not able to derive preferences for amenities directly from their data using an empirical research approach. Therefore, they ask forest managers to rank a number of management priorities in order of importance. Based on these rankings they made group variables in which respondents were assumed to have a certain level of appreciation for amenities. Land owners who had a higher appreciation for amenities were found to harvest less compared to land owners which were more production orientated. Sauter et al. (2015) does not confirm this finding. They find no significant effect of regarding the forest enterprise as an ecological or social service provider. Joshi and Arano (2009) also find no significant correlation between appreciation for non-timber values and harvest decisions.

Risk attitude

Forestry differs from agriculture by having a relatively long time span. Compared to crops, trees grow slowly. During such a long time span much can happen which means that external effects such as windthrow, forest fires, and disease outbreaks often undermine even the best laid out management plans (Hoogstra-Klein and Burger, 2013). The impact of uncertainty on forest management is reflected in the very small amount of forest managers (4%) in Germany and the Netherlands which never deviates from their preset plans according to Hoogstra and Schanz (2009). This uncertainty is related to risk-attitude which can be measured through a Holt and Laury task. Using this type of method, Mußhoff and Maart-Noelck (2014), Petucco et al. (2015), and Sauter et al. (2016) found that most respondents are risk averse. Risk takers harvest later according to Petucco et al. (2015) and Sauter et al. (2015), while Mußhoff and Maart-Noelck (2014) found no significant effect of risk attitude on harvest intervention decisions.

Professional environment

There are various ways the professional environment of forest mangers is taken into account in previous studies. Sauter et al. (2015) uses broad employment categories. They find little evidence for a significant correlation of being a forest owner of working for a forest service provider. Sauter et al. (2015) did find that forest managers who work for a private forest enterprise harvest significantly too early compared to a real options approach benchmark. Binkley (1981) only looked at being a farmer. They find that farmers are twice as likely to harvest forests compared to non-farmers. Petucco et al. (2015), also find a positive significant effect of being a farmer or being retired. They find on no effect of being a forester. Garcia et al. (2014), on the other hand, finds no effect of being a farmer or forester, but only a positive significant effect of being retired. Dennis (1989), in the case of private landowners, found that those who were employed in a professional position (a white collar occupation) harvested significantly more than landowners employed elsewhere. Finally, being a member of a forestry cooperative can significantly explain a higher harvesting rate (Petucco et al., 2015).

Real-life work environment

One aspect that is related to the professionalism of an organization is the size of the prosperity. Individuals or organizations with large forests can use economies of scale. Petucco et al. (2015) look into the size of a forest property as a possible forest characteristics variable which might influence the harvest decisions made. Land owners which own a larger forest are more likely to harvest. Similar results are found by Binkley (1981) and Garcia et al. (2014), but not by Sauter et al. (2015). Petucco et al. (2015) also looked at the influence of the standing volume of the forest which was managed by their respondents and the harvest decision made in the experimental setting. They found a positive correlation between the standing volume of the forest and the likelihood to of it being harvested, although this effect was not to be found significant. Petucco et al. (2015) found no significant differences between harvesting decisions of land owners which manage a broadleaf, conifer, mixed species or undetermined forest. These results are similar to Garcia et al. (2014) their results which find no significant effect of the percentage of hard wood in the forest. Dennis (1998) finds that the proportion of white pine is positively and significantly related to the volume of harvested wood. The proportion of oak is only significant at a=0.10 (Dennis, 1998).

Conclusion of the literature review of previous findings

The large differences between the studies are striking. There is great variation in the type of variables which are included in the various studies and many ambiguous results are found. Similar variables can be positively significant, negatively significant or not significant at all, depending on the type of study which is looked into. It is clear that a more complete list of variables should be included in this report to shed light on the various relationships between the explanatory variables. Especially, as correcting for some variables change the outcome of other variables.

3 Methodology

This chapter starts in section 3.1 by describing the general research approach. The experiment is described in section 3.2. This section will introduce and elaborate on the three parts of which the experiment consists, namely: (1) the choice questions, (2) the risk attitude test, and (3) the questions related to other characteristics of the respondents. The pretest results of the experiment are discussed in section 3.3. In section 3.4 one can read about the data collection and the respondents. Finally, section 3.5 explains how the data will be analyzed if the analysis requirements are met.

3.1 Research approach

A quantitative approach is chosen to investigate the trade-offs made by Dutch forest managers when making a harvest decision. More specifically, this thesis research will make use of an experimental approach inspired by Mußhoff and Maart-Noelck (2014) and Sauter et al. (2016), where an experiment is defined by the Cambridge dictionary as: a test done in order to learn something or to discover if something works or is true. Specifically, this report is focused on a laboratory setting experiment, where the 'laboratory setting' refers to the controlled circumstances under which respondents are asked to partake in the experiment.

There are two advantages of using a laboratory type of experiment over field experiments:

1. By creating an artificial setting, one can reduce the number of factors that might influence the harvesting decision. This increases the internal validity of an experiment (Mußhoff and Maart-Noelck, 2014). As Falk and Heckman (2009, p535) put it: 'Controlled variation is the foundation of empirical scientific knowledge and the laboratory allows tight control of decision environments'.
2. It is possible to investigate harvesting decisions of forest managers for which there is little or no empirical data available (Sauter et al., 2015). With the experiment, one can investigate multiple harvest decisions for each respondent. In theory, this would result in much information on choices and the social context of those choices in a short amount of time, which makes laboratory experimetns more efficient than field experiments.

There are also some negative effects of using a laboratory type of experimental approach:

1. The external validity of the results can be lower if respondents are too much influenced by heuristics and do not provide the same answers as they would in a real life setting (Valatin et al., 2016). Online laboratory type experiments are, for example, prone to respondent bias, as younger people are more likely to participate (Sauter et al., 2015). Similar studies from Petucco et al. (2015), Joshi and Arano (2009) and Sauter et al. (2015) had to deal with a low response bias.
2. Field data would allow the use of more sophisticated statistics such as 2SLS estimation and regression discontinuity designs (Angrist, 2009).

With this overview of advantages and disadvantages one can argue whether one should use laboratory setting type of experiments in the case of investigating harvest intervention decisions. There is both a theoretical argument and a practical argument to be made for using these types of experiments. The theoretical argument is that one should weigh the benefits of a controlled setting to the downside of heuristics influencing the results. The point taken in this research is that that forestry is so complex, as previous studies have shown that many factors influence decisions (e.g. Petucco et al., 2015), that a controlled setting is a necessity. Heuristics can be controlled for and there are studies conducted on how to deal with heuristics (e.g. Valatin et al., 2016) which is easier than controlling for unknown endogenous factors. The practical argument is that there is simply not much field data available and collecting enough field data to make proper inferences would take years. Sophisticated statistical methods, which make use of field data, are only viable if there is a large amount of data, as they rely on variation in additional variables. Therefore, a laboratory setting type experiment seems to be the best fit for this report. It is, however, important to note that this type of experiment is not commonly used in the field of forestry science and implementing it will have its challenges which will become clear in the next chapters.

Figure 7 illustrates the main stages of the experiment as developed in this research. The first two boxes have been explained in this section. Section 3.2 will explain the next stage of Figure 7 (the experimental design).

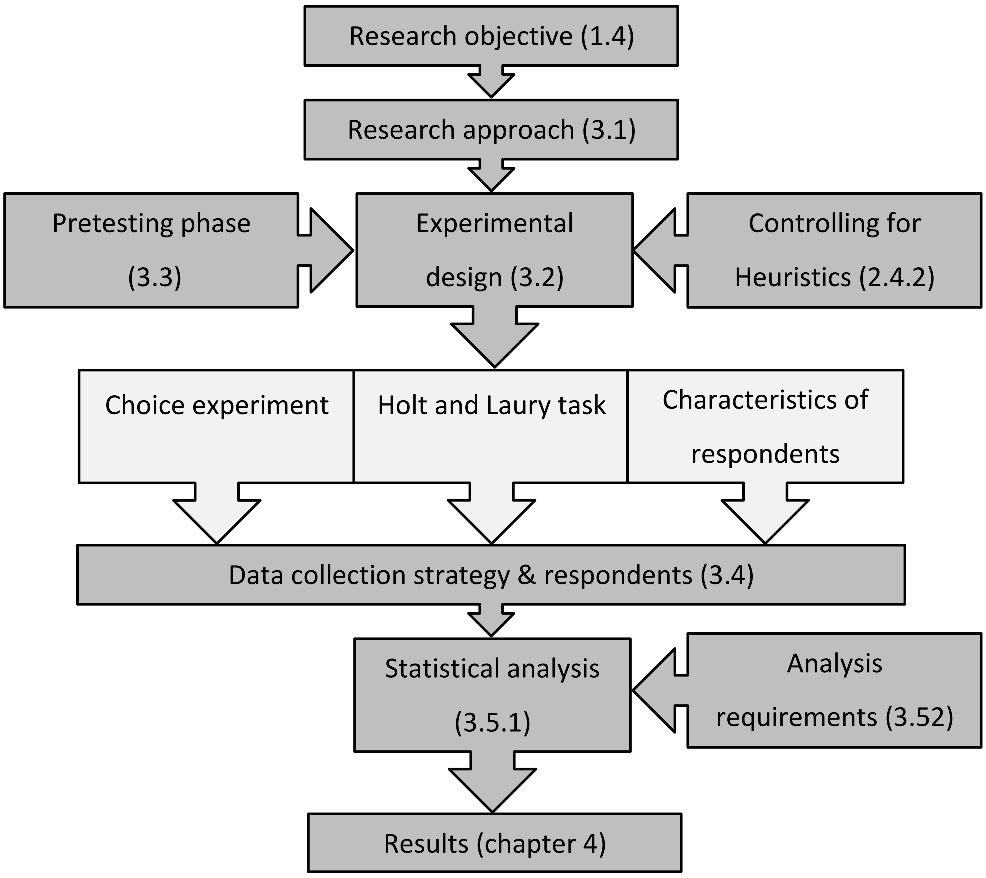


Figure 7: Stages of developing a laboratory type of choice experiment in this report (based on Johnson et al., 2013). Each block refers to a specific section in the report which in indicated by the section number in brackets. The lighter grey blocks refer to subsections of section 3.2.

3.2 Experimental design

3.2.1 Short intro of questionnaire based stated choice experiments

The first part of the experiment is a type of questionnaire based stated choice experiment. This is methods is used because it is very well suited to emulate preferences without field data and because it has a theoretical underpinning in micro-economic theory (Mangham et al., 2009). Choice experiments make use of random utility as explained in section 2.4.1. 'They involve asking individuals to state their preference over hypothetical alternative scenarios, goods or services' (Mangham et al., 2009, p.151). A black box is assumed for the choice process and just by looking at the outcomes of choices, one tries to explain preference for certain aspects of the choice alternatives.

The main output of the experiment is the likelihood of a forest manager making a harvesting intervention which is based on the different individual characteristics, social influences, situational influences and memory of the respondents. Using Qualtrics, an online questionnaire platform, various hypothetical forest stands have been offered to the respondents. They could show their preference for certain harvest intervention options by choosing a certain harvest intervention approach for each hypothetical forest stand. These choices are linked through a multinomial logistic regression with the results of various questions about forest manger's characteristics.

3.2.1 Background on choice experiments

In 'normal' discrete choice experiments each choice alternative is described by a number of attributes, where each attribute can have various levels. Responses are used to test which attributes can significantly explain preferences (choices made) and to test the relative importance of each attribute (Mangham et al., 2009). Think, for example, of a situation where a consumer is looking for a new garden table (see Schuurbiers, 2016). Each possible table the consumer can buy has a different attributes. For example: price, being certified, and country of origin. In the case of discrete choice experiment, each attribute has two levels. Some tables might be €350, while others are €375. Some tables are certified, others are not. Some tables are made in the Netherlands, others are made abroad. In the set-up of the experiment as much variation is exploited as possible between each choice option by using orthogonal and balanced designs (Huber and Zwerina, 1996). In the case of Schuurbiers (2016) this meant that each respondent had to make a choice between a table A or table B in eight different choice scenarios with chancing levels for the attributes for table A and B in each choice scenario.

Orthogonal and balanced designs are analytically preferred in choice experiments. However, they do result in unrealistic choice options in a harvest decision setting. We know for a fact that the age of a forest is, for example, related to production, biodiversity and recreation levels (Den Ouden et al., 2010). A young forest will have less volume than an older forest which had time to grow. However, a choice option in which a very young forest would have the highest wood volume could be the unrealistic result of an orthogonal and balanced design.

3.2.2 The actual choice experiment

As a 'normal' choice experiment could not be used it was necessary design a realistic choice experiment (see Appendix B: Original script and Appendix C: Translated script). Besides literature, interviews with forest managers and experts were used to find exactly which data is relevant to a forest manager in his decision process and in which units this data should be presented. The following experts were consulted: G. Koopmans, J.M van Laar, and H. Schreppers. Mr. Koopmans is a forest manager working for the 'Bosgroepen'. Mr. Van Laar is a scientist with expertise in forestry and nature management at the Wageningen University. He is also a small forest owner (<5 ha). Mr. Schreppers works as forest manager at 'Schreppers Bos- en Natuurbeheer' and teaches forestry at the applied university of Van Hall Larenstein.

Harvest intervention decisions are normally made at stand level (H. Schreppers, personal communication 16-03-2019). Therefore, it makes sense to come up with hypothetical forest stands as the choice objects of this novel experiment. These stands need to be recognizable for the respondents. The stand size, for example, is relevant for the decision process. If a stand is too small, it might not be interesting to intervene at all. If a stand is too big, it might be too heterogeneous for one type of intervention decision. A stand size of 3 ha was selected, following the advice of H. Schreppers (personal communication 16-03-2019) who indicated that a stand size of 3 ha would be a realistic number and workable for most forest managers. Choosing a range of different aged stands will ensure that each stand has different characteristics (Den Ouden et al., 2010).

The main tree species also are relevant to the decision process as each species has different qualities, which means that some are more likely to be harvested than others (Den Ouden et al., 2010). It was decided to consider two types of main tree species: common oaks ((Quercus robur) and scots pines *Pinus sylvestris*), as one species is more nature orientated and one more production orientated which keeps the experiment interesting and broadens the external validity of the results. The *Betulo-Quercetum roboris* (birch and common oak) forest type is a very common forest type in the Netherlands on the poor and sandy soils (Den Ouden et al., 2010). Schelhaas et al. (2014) find that oaks are the most common broadleaf species in the Netherlands (10% of the ground area). While *Betulo-Quercetum roboris* forest on poor sandy soils do not have the highest nature value overall, they do have a slightly higher nature potential when compared to the other common forest type on poor sandy soils, namely the *Leucobryo-Pinetum* (pillow moss and pine) forest type. *Betulo-Quercetum roboris* forests contain over twice as much insect species (Moraal, 2011) and when atmospheric nitrogen deposition is reduced they can achieve more diversity in plant structures (Van Dobben et al., 2003). The *Leucobryo-Pinetum* forest type is the most common forest type in the Netherlands (Al, 1995), as many scots pines have been planted in the 19th century on the sandy slopes which were the result of overexploitation of heather grounds. Schelhaas et al. (2014) shows that harvesting mainly takes place in coniferous forest and that scots pine is the most harvested species in the Netherlands (28% of the total volume of wood which has been harvested). The *Leucobryo-Pinetum* forest is, therefore, a representative type of forest for the multifunctional forest. It has been decided work with even-aged forests. This reflects the current situation of Dutch forests, as 82% of the oak stands and 71% of the scots pine stands are even aged (Schelhaas et al., 2014). This choice could result in respondents trying to convert the even-aged stand to an uneven-aged forest. Whether they will attempt to do so, will be part of the analysis.

So far, the hypothetical stands have been described in a general way. However, what is likely to matter the most to the forest managers in their decision process are the forest characteristics (attributes) of each forest stand. It is hypothesized in this report that a forest manager should be able to decide whether they would like to intervene in a stand based on these key figures. The forest characteristics presented to the respondents are based on a hypothetical forest inventory of a part of the hypothetical stand. This is similar to the way forest managers would get their information in practice. The hypothetical forest inventory for each choice stand is based on the 6th Dutch forest inventory (NBI), which is the most recent national forest inventory in the Netherlands (Schelhaas et al., 2014).

The most important stand characteristics can be classified according to the goals of a forest stand (J.M. van Laar, personal communication 18-03-2019; G. Koopmans, personal communication 08-03-2019; H. Schreppers, personal communication 16-03-2019). In the case of multifunctional forest management the most important goals are: wood production, nature protection, and recreation (Hoogstra-Klein et al., 2017).

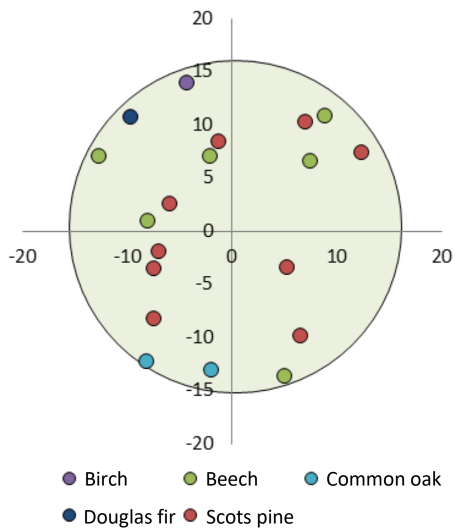
Wood production potential can be expressed by the (1) volume of the standing stock and (2) the growth of volume over time (Cornelis et al., 2018). (3) The ground area of the stems can be used as an indicator for the density of the forest and is often used as a measure to express the intensity of a thinning intervention (Cornelis et al., 2018). (4) The spatial clustering of trees over the stand, which can be deduced from the circle plot image (see Appendix A: Mathematics), is also indicative for the density of the forest and shows whether trees are competing for the same resources (Den Ouden et al, 2010). For the later, one can also look at (5) the level of crown closure (Den Ouden et al., 2010). Finally, harvest decisions are often based on a goal diameter in the Netherlands (H. Schreppers, personal communication 16-03-2019). (6) The diameter of the middle tree (of the main tree species) is a good indicator which can be used in determining whether a goal diameter is reached (M.J. Schelhaas, personal communication 06-07-2019) (see Appendix A: Mathematics).

The natural value of a stand is assessed by looking at (7) the tree species composition (G. Koopmans, personal communication 08-03-2019). This is reflected in the experiment by providing a figure of the circle plot measurements that were conducted in each hypothetical stand. The Shannon-index of each circle plot is used to reflect the tree species diversity in the analysis (see Appendix A: Mathematics). (8) The vertical structure of stand is also an important factor related to the natural value of a stand (G. Koopmans, personal communication 08-03-2019). Unfortunately, there is no information about tree height in the forest inventory. Luckily, there is information about the level of undergrowth which is used as an indicator for vertical structure. (9) Dead wood is also a relevant to the natural value (G. Koopmans, personal communication 08-03-2019). The volumes of standing and lying dead wood are therefore included as key figures.

Finally, recreation is important for forest managers according to G. Koopmans (personal communication 08-03-2019), but not necessarily in terms of visitor numbers. According to G. Koopmans (personal communication 08-03-2019), forest managers do care about how beautiful the forest is considered to be by visitors. Edwards et al., (2012) shows that for Europeans the most important positive factors that influence how beautiful a forest is, are in order of importance: the size of trees, the variation between stands, and the variation in tree size. The most negative factors which reduce beauty are: the size of clear cuts and the amount of residue left after harvesting. Some factors are positive if the values are not too low and not too high, these were: the visual penetration of the forest, the extent of tree cover, the variation in tree spacing, the ‘naturalness’ of forest edges, the amount of dead wood, and the density of ground vegetation. For not all these variables there is information in the forest inventory. The experiment does incorporate the earlier mentioned (3) ground area as proxy for the size of the trees, (4) the spatial clustering of trees for the variation in tree spacing, (5) the level of tree closure for the extent of tree cover, (7) the species composition of the circle plot as indicator of the number of tree species in the whole stand, (8) level of undergrowth for the density of the ground vegetation, (9) and the volumes of standing and lying dead wood for the amount of dead wood.

Figure 8 below shows how a stand was presented to the respondents in the questionnaire with respect to the choice object. The table called stand information contains the key variables. The figure shows the circle plot measurements which were conducted in the forest inventory.

Plot information	
Stand size	3 ha
Age	36 year
(3) Ground area	14 m^2/ha
(1) Volume	118 m^3
(2) Estimated increment	6 m^3
(5) Crown closure	10-25%
(8) Shrub layer cover	0.01-01%
(9) Volume lying dead wood	19 m^3
(9) Volume standing dead wood	0 m^3
Main tree species	Grove den
(6) Diameter of the middle tree of the main tree species	15 cm
Main tree species count	1100 ha^{-1}



(4) (7)

Figure 8: Visual representation of the way the choice objects are presented to the respondents. The numbers in brackets refer to the key characteristics discussed above. The variable ‘main tree species count’ is introduced later.

Realistic choice options

The next step in building this experiment is determining the choice options. These choice options will be the depended variable in the analysis. Simply offering the option to either clear-cut or not for each stand, such as Mußhoff and Maart-Noelck (2014) and Sauter et al. (2016) did, is unrealistic in the Dutch forest setting (Den Ouden et al., 2010). Based on the Dutch situation, it is more realistic to determine harvesting interventions in terms of (1) doing nothing, (2) thinning practices, and (3) regeneration cut choices (see Table 7). Three types of thinning are common practice, while there are many regeneration cut options.

Table 7: The most important harvest intervention options in the Netherlands (based on Den Ouden et al., 2010).

Main harvest intervention option	Theoretical sub-options
Doing nothing	-
Thinning	Thinning from below Free thinning from above Future tree thinning
Regeneration cut	Clear cutting Strip cutting Seed tree cutting Shelter wood cutting Selection cutting Etc.

Doing nothing

It may seem strange but not intervening is a very common approach in forest management. Some forest managers do not believe that one should intervene at all in forests (Oosterveld, 1977). These types of forest managers believe that the forest can regulate itself and that the highest ecosystem services can be reached by not intervening in natural processes (Oosterveld, 1977). Moreover, sometimes doing nothing is an appropriate choice if the forest needs to recover from a previous measure. If a forest has recently been thinned then it does not make sense to intervene again from both an ecological as economical perspective (Cosyns et al., 2018).

Thinning

According to Den Ouden et al. (2010) and G. Koopmans (personal communication 08-03-2019), three common types of thinning practices are used in the Netherlands. The first is thinning from below, in which understory trees are removed. This negative selection used to be very popular, but is nowadays rarely being used in the Netherlands (Cornelis et al., 2018). The second is free thinning from above in which trees, which compete in the crown layer of the stand, are removed. The third is future crop tree thinning. This is a special form of thinning from above in which the competitors of future crop trees are removed in order to promote the growth of previously selected future crop trees.

To keep the choice options within a reasonable number, it was decided to work with a low and a high intensity option for each form of thinning. The intensity of thinning from below and free thinning from above can be expressed by the part of the ground area which is removed per ha. According to the State forest commission, for both oaks and scots pines, an open forest would be a forest with a ground area of below 18 m2/ha, where a closed forest would have a ground area of at least 24 m2/ha (Cornelis et al., 2018). A low intensity thinning would therefore reduce the ground area to 24 m2/ha, where a high intensity thinning would reduce the ground area to 18 m2/ha. The intensity of future crop tree thinning can be expressed through the number of future crop trees appointed and the number of competitors removed per future crop tree. In this experiment, the number of future crop trees is fixed as there is no way for the forest manager to do the assessment themselves. For oaks, a reasonable number would be forty trees per ha, for scots pine it would be ninety trees per ha (Cornelis et al., 2018). An additional variable about the amount of trees present in each choice object was added in order for forest managers to decide whether future crop tree thinning with either forty or ninety trees makes sense. The respondents have to choose which percentage of the neighbouring trees, which interfere in the forest crown, they want to remove. For scots pines it would be normal to reduce 50% of the trees which compete with the tree crown of the future crop tree (Cornelis et al., 2018). For oaks, 30% is a realistic number (Cornelis et al., 2018). So either 50% for scots pines or 30% for oaks is the low intervention option. The other option would be to remove 100% of neighbouring trees which compete for crown space. This is a common practice for future crop systems which are fully focused on producing high quality stems (Cornelis et al., 2018).

Regeneration cut

The final choice option to be added to the experiment is the regeneration cut option. A regeneration cut can be conducted in various ways (see Table 8). Allowing all possible regeneration cut types as discrete choice options would be impractical. Adding so many extra levels to the depended variable (the harvest intervention option) would result groups which are too small to analyze. Therefore, respondents are simply asked whether they want to do a regeneration cut. When choosing this option, an open field is provided in which respondents can specify the type of regeneration cut.

Table 8 below shows in the third column a summary of the sub-options which are possible to choose from in the experiment in the case of thinning. The numbers in brackets reflect the eight discrete choice options which can be made by the respondents.

Table 8: The choice options in this report's experiment for each stand.

Main harvest intervention option	Theoretical sub-options	Sub-options in the experiment
(1) Doing nothing	-	-
Thinning	Thinning from below Free thinning from above Future tree thinning	**(2)** Thin the ground area to 24 m2/ha **(3)** Thin the ground area to 18 m2/ha **(4)** Thin the ground area to 24 m2/ha **(5)** Thin the ground area to 18 m2/ha **(6)** Thin 30%/50% of the crown area of 40/90 future crop trees per ha **(7)** Thin 100% of the crown area of 40/90 future crop trees per ha
(8) Regeneration cut	Clear cutting Strip cutting Seed tree cutting Shelter wood cutting Selection cutting Etc.	Open question

A realistic context

In the case of decision-making in forest management, the context matters. Harvest intervention decisions for one stand are always made in the context of a larger forest area (J.M. van Laar, personal communication 18-03-2019; G. Koopmans, personal communication 08-03-2019; H. Schreppers, personal communication 16-03-2019). The choice stands are, therefore, imbedded in a model forest to provide context. The external validity of the experiment depends on the type of model forest description provided. The results of the study are valid in a certain context. Therefore, it makes sense to start with a common type of forest which matches with the previously discussed choice objects.

Schelhaas and Clerkx (2015) describe that Dutch forests are either multifunctional or nature orientated. Both of these forest types would therefore be suitable for the experiment. The first version of the experiment therefore included stands which situated in both forest types. They were described by the type of nature subsidy from the 'Subsidiestelsel Natuur en Landschap' (SNL) (subsidy scheme for nature and landscapes) which is provided by the national government to managers of specific types of nature. This is also a useful indicator for forest managers in understanding the goals for the specific type of forest (G. Koopmans (personal communication 08-03-2019). The natural forest was classified as N15.02 Dennen-, eiken-, en beukenbos' (pine, oak, and beech forest). The multifunctional forest is classified as 'N16.03 (up to 2018 known as N16.01) 'Droog bos met productie' (dry forest with production). After the pretest it was decided to scrap the nature orientated forest to reduce the amount of choice options. It was decided to focus on the multifunctional forest as harvest interventions are expected to take place more commonly in this type of forest. The model forest as a whole is described as a 60 ha forest of which 36 ha is multifunctional. In total there are therefore twelve stands in the study area (see Figure 9). The size of the forest is relevant with respect to scale advantages of harvest intervention decisions and should be recognizable for both small scale individual forest owners and large scale employed forest managers (see Compendium voor de Leefomgeving, 2014).

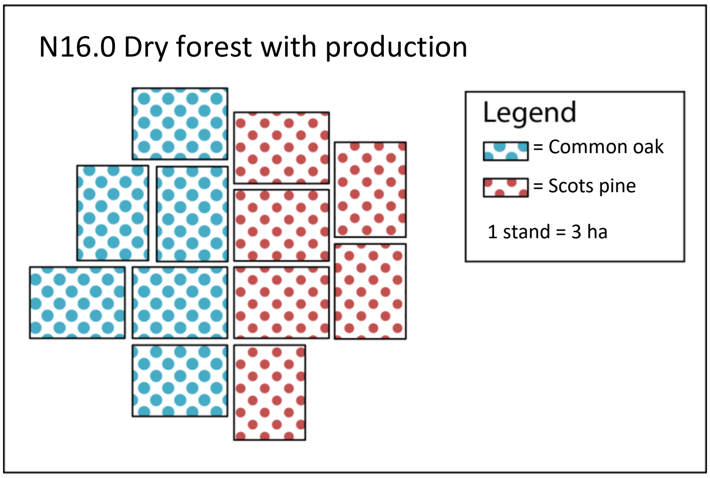


Figure 9: Map of the study site which is made up of twelve stands multifunctional forest. The main tree species, common oak and scots pine are equally present.

The model forest is put on a sandy soil type which is being fed by rainwater, which is poor in nutrients. Due to historical reasons over half of the Dutch forests are located on poor sandy soils, making it by far the most common soil type of forest in the Netherlands (Hekhuis and den Ouden, 2016). This type of environment also matches with the main tree species which were selected for the choice objects as poor and sandy soils in the Netherlands are associated with common oaks and scots pines. A low grazing pressure was reported as it is common practice to keep the grazing pressure low in multifunctional forests (Kennisnetwerk OBN, n.d.). Table 9 shows a short summary of the context part of the choice experiment.

Table 9: Summary of the context part of the choice experiment.

General forest information	
SNL-classification	Dry forest with production
Soil type	Poor sandy soil
Hydrological environment	Deep groundwater level; Fed by rainwater
Grazing pressure	Low

Stand selection

The original experiment contained 20 choice objects, aged between one and 100 years to ensure enough young stands were included for which thinning is relevant. Ten of those stands were located within the natural forest. The other ten stands were located within the multifunctional forest. As described earlier, it was decided to drop the natural forest plots to shorten the experiment. In correspondence with that decision two additional plots were added to reflect older aged forest. In hindsight these were missing in the original experiment.

As has been discussed, the stands used in the choice experiment are based on the 6th forests inventory (Schelhaas et al., 2014). The Microsoft Access database of the forest inventory contains 3393 plots. Based on the previous sections, selection criteria were used to narrow down the plots relevant to the experiment. To match the choice objects and context, plots needed to be:

- Located at poor sandy soils with an average highest groundwater level of >80 cm;
- Aged between one and 100 (for the first ten plots) or aged between 100 and 150 (for the additional two plots);
- Part of large scale even aged forests;
- Not recently clear cut;
- Having scots pine or common oak as main tree species;
- Having a SNL-type N16.01 goal;
- Selected by the researchers of the forest inventory to have the angels and distance measured of each tree to the center.

Table 10: Descriptive statistics for the choice stands (n=12).

VARIABLES	Mean	St. dev.
Age stand	71.5	32.1
Ground area	24.1 [m^2]	7.9
Volume	194.3 [m^3]	71.2
Estimated increment	8.1 [m^3]	9.1
Crown closure (25-50%)	16.7%	-
Crown closure (50-75%)	16.7%	-
Crown closure (75-90%)	41.7%	-
Crown closure (90-100%)	25%	-
Shrub layer cover (0.0-0.1%)	16.7%	-
Shrub layer cover (0.1-1%)	16.7%	-
Shrub layer cover (1-5%)	8.3%	-
Shrub layer cover (5-10%)	16.7%	-
Shrub layer cover (25-50%)	25.0%	-
Shrub layer cover (50-75%)	16.7%	-
Volume lying dead wood	6.8 [m^3]	9.1
Volume standing dead wood	5.1 [m^3]	6.6
Main tree species (scots pine)	50%	-
Main tree species (common oak)	50%	-
Diameter of the middle tree of the main tree species	27.3 [cm]	8.4
Main tree species count	519.8	580.3
Average distance	11.0 [m]	4.4
Shannon index	0.8	0.4

214 plots matched these criteria. The twelve plots used in the experiment were selected randomly from these 214 plots. Table 10 shows the descriptive statistics for the selected stands. Each individual stand can be found in

Appendix D: Choice objects.

3.2.3 Format for measuring risk attitude

Previous studies have shown that risk perception can be an important element in harvesting decisions (see section 2.5.2), as individual forest managers' can have different perceptions on the amount of risk one should take with regard to forest management. Some studies show that these differences are reflected in the moment when a stand is harvested (Petucco et al., 2015; Sauter et al., 2016). These studies show that risk averse forest managers harvest earlier compared to risk seeking forest managers. As a young stand becomes older, the volume increases and, therefore, the value of the stand increases. Economically it can make sense to wait until a certain optimum age/volume is reached (Den Ouden et al., 2010). However, the longer the stand grows the larger the chance that that particular stand which is increasing in value is hit by bad weather, a disease, or another negative external factor. Risk averse forest managers therefore harvest (slightly) earlier to bank their profits instead of waiting for the optimum (Petucco et al., 2015; Sauter et al., 2016).

Mußhoff and Maart-Noelck (2014), Petucco et al. (2015), and Sauter et al. (2016) all use some form of a Holt and Laury task (Holt and Laury, 2002) to determine the range of constant relative risk aversion (CRRA) of their respondents. This Holt and Laury task is a type of lottery experiment, which makes use of expected utility theory. Respondents in Holt and Laury tasks have to choose between various expected pay-outs of a hypothetical lottery and whether they are willing to take a risk for a higher pay-out, than the expected pay-out (the chance of winning a certain amount times the amount) shows whether they are risk seeking.

In this thesis, the Holt and Laury task, follows the setup as applied by Holt and Laury (2002), Mußhoff and Maart-Noelck (2014) and Vollmer et al. (2017) (Table 11). Respondents will have to choose between two lottery pairs. Lottery pair A is always the safe option, while lottery pair B is more risky. The setup is such that a (rational) risk neutral person would initially choose option A and switch to option B at the fifth choice task, as the expected payoff difference becomes negative. This is shown in the fourth column of Table 11. This column is added here to indicate the expected payoff; it is not included in the actual experiment (see Appendix B: Original script).

Table 11: Holt and Laury task setup (based on Holt and Laury, 2002; Mußhoff and Maart-Noelck, 2014; Vollmer et al., 2017)

Choice number	Choice A	Choice B	Expected payoff difference
1	10% chance of €200; 90% chance of €160	10% chance of €385; 90% chance of €10	€117
2	20% chance of €200; 80% chance of €160	20% chance of €385; 80% chance of €10	€83
3	30% chance of €200; 70% chance of €160	30% chance of €385; 70% chance of €10	€50
4	40% chance of €200; 60% chance of €160	40% chance of €385; 60% chance of €10	€16
5	50% chance of €200; 50% chance of €160	50% chance of €385; 50% chance of €10	-€18
6	60% chance of €200; 40% chance of €160	60% chance of €385; 40% chance of €10	-€51
7	70% chance of €200; 30% chance of €160	70% chance of €385; 30% chance of €10	-€85
8	80% chance of €200; 20% chance of €160	80% chance of €385; 20% chance of €10	-€118
9	90% chance of €200; 10% chance of €160	90% chance of €385; 10% chance of €10	-€152
10	100% chance of €200; 0% chance of €160	100% chance of €385; 0% chance of €10	-€185

The number of times option A is chosen can be used as relative measure of risk aversion and is further referred to as the HL-value. A respondent who chooses option A fewer than four times is considered to be risk prone, a respondent who chooses option A exactly four times is considered to be risk neutral, and a respondent who chooses option A more than four times is considered to be risk averse.

3.2.4 Other characteristics of respondents

Finally, the third part of the experiment includes questions on (1) individual characteristics (such as gender and age, (2) social influences (such as employment and activity in a professional organization), (3) situational influences (such as the market trend of wood prices and the chance of extreme weather), and (4) memory (such as the size and type of forest which is being managed in real life). This part of the experiment is necessary to measure all forest managers' characteristics which can be correlated to the choices made in the first part of the experiment. These factors mentioned here correspond to the factors which are used in the EKB-model to explain the decision-making process (see section 2.5.1)

Individual characteristics in this research are defined as factors which relate to general and physiological traits of individual forest managers. In general, they are assumed to be relatively stable and well defined. Social influences are limited to factors which relate to the work environment of the forest manager. It is assumed, in this study, that work culture is the most important social factors which might influence choice. It assumes that the non-work related social relations that forest managers might have do not influence harvest intervention decision making. This study also does not look into, for instance, country culture, as it is only uses Dutch forest managers as respondents. Situational influences are defined as factors over which one has little to no control. It is assumed that economic and environmental situational factors are the most important factors in play, based on expert interviews. Finally, there is the memory. Memory cannot directly be incorporated in the model. We do not know the types of decisions which previously have been made by each individual forest manager and the way this has influenced their decision making process. There is also no easy way of getting to know these memories. We could, however, ask questions about the setting in which each individual forest manager has made decisions in the past. If we assume that forest managers in a similar setting have shared similar experiences, then we can use this setting as a proxy for memory. Therefore, this study asks questions about the type of forest which is managed in real life by the respondents.

The questions asked to the respondents are described in Table 12 which gives a complete overview of the type of decision factor, the question category, the question itself, and possible answering options.

Table 12: Overview of questions and answering possibilities in part three of the questionnaire.

Type decision factor	Question category	Questions	Answering options
Individual characteristics	General personal information	In which region of the Netherlands are you mainly managing forests?	**DISCRETE** 0 = The North 1 = The East 2 = The South 3 = The East
		What is your gender?	**DISCRETE** 0 = Male 1 = Female 2 = Other (specify)
		What age are you?	**OPEN**
	Education	What is the highest level of education you have completed?	**DISCRETE** 0 = Less than high school degree 1 = High school degree 2 = Secondary vocational education (MBO) 3 = Higher professional education (HBO) 4 = University bachelor degree (WO) 5 = University master degree (WO) 6 = University specialized

			degree (PHD)
		Do you have a degree in forest and nature conservation (at MBO, HBO or WO level)?	**DISCRETE** 0 = Yes 1 = No
		What did you specialize on within your studies? (multiple answers are possible)	**DISCRETE** 0 = Ecology 1 = Economics 2 = Timber trade 3 = Recreation/tourism 4 = Stewardship 5 = None of the above/not relevant
	Expertise	How many years have you been active in forest management?	**OPEN**
		How professional do you consider yourself to be in the role of forest manager?	**SD-SLIDER** 0 = Amateur 1000 = Professional
		Is forest management your main or side occupation?	**DISCRETE** 0 = Main occupation 1 = Side occupation
	Self-image	To what extent do you identify yourself as a forest manager?	**SD-SLIDER** 0 = Not at all 1000 = Completely
		To what extent do you identify yourself as a forester?	**SD-SLIDER** 0 = Not at all 1000 = Completely
		To what extent do you identify yourself as a nature manager?	**SD-SLIDER** 0 = Not at all 1000 = Completely
	Views on forest management	How important are financial aspects in forest management?	**SD SLIDER** 0 = Not important at all 1000 = Very important
		How important are natural values for forest management?	**SD-SLIDER** 0 = Not important at all 1000 = Very important
		How important are recreational values for forest management?	**SD-SLIDER** 0 = Not important at all 1000 = Very important
	Risk attitude	Holt and Laury test: Which lottery option do you prefer?	**DISCRETE** 0 = Option A 1 = Option B
Social influences	Professional environment	Where are you employed?	**DISCRETE** 0 = ‘Bosgroepen’ 1 = Own consultancy firm 2 = Municipality 3 = University of applied science 4 = ‘Landschappen NL’ 5 = Ministery of Defence 6 = Ministery of Finance 7 = ‘Natuurmonumenten’ 8 = Province 9 = State forest commission 10 = University 11 = Unemployed

			12 = Other (specify)
		How active are you in a professional association (such as the 'KNBV', 'NVR', etc.)?	**SD-SLIDER** 0 = Not active at all 1000 = Very active
Situational influences	Market trend	How do you consider the current (June 2019) wood prices to be?	**SD-SLIDER** 0 = They are very low 1000 = They are very high
	External environmental factors	Did you experience any large disturbances such as windthrow or forest fires in the forest you manage in the past five years?	**DISCRETE** 0 = Yes 1 = No
Memory	Real-life work environment	How large is the forest which you manage (in hectares)?	**OPEN**
		Which type of forest do you manage?	**DISCRETE** 0 = Mainly broadleaf forest 1 = Mainly coniferous forest 2 = Mainly mixed forest
		How are the growing conditions of the forest in which you manage?	**SD-SLIDER** 0 = Very bad 1000 = Very good

Similar to Hoogstra-Klein and Burger (2009), semantic differential scale questions (SDs) are used where possible in this final section of the experiment to 'measure people's reactions to concepts in terms of ratings on bipolar scales defined with contrasting adjectives at each end' (Hoogstra-Klein and Burger, 2009, p.711). SDs allow for more flexibility for respondents to express their own identity. There is an ongoing debate on whether to treat results derived from rating scales, such as the SD-scale, as ordinal or interval data. This is mainly a fundamental debate. Stevens (1946) writes about not adhering to this principle and states: 'This 'illegal' statisticizing can be invoked with a kind of pragmatic sanction: In numerous instances it leads to fruitful results. While the outlawing of this procedure would probably serve no good purpose …' (Stevens, 1946, p.696). The difference between the two types of data is that the space between options in an interval scale is assumed to be equal where this is not the case with a nominal scale (Stevens, 1946). Where the commonly used Likert scales are, more closely related to nominal data (Boone, 2012) it can be argued that this is not the case for SD scales. In Likert scales a name is given to each option, while this is not the case in an SD scale. As opposing concepts are put on both sides of the scale, everything inside the scale can be assumed to be divided in equal steps. Therefore, in this report it has been decided to threat SD data as interval data.

3.3 *Pretest results*

The novelty of the experiment meant balancing was necessary to prevent issues such as fatigue of respondents or ambiguous lines of questioning. This was done after a pretesting phase. The pretest was conducted with forest and nature conservation students from the Wageningen University. As future professionals in nature type jobs, they are most likely to answer in similar way as professional forest managers. Additionally the following experts have been consulted in the pretesting phase: G.M. Hengeveld, M.A. Hoogstra, J.M van Laar, B.J.W. Lerink, and M. Schelhaas. Each of these experts is working for Wageningen University and Research on topics related to forestry and has experience with scientific research in this field.

Four students made it through the entire experiment in the pre-testing phase. Google forms, the questionnaire program which was being used in this phase, unfortunately does not record partially filled in questionnaires. The author of this report knows for a fact that at least three students quit before finishing the experiment, as they conveyed their comments outside of the questionnaire. The experts each successfully completed the experiment. Comments collected in the pretesting phase are briefly explained in this section as well as the changes made to the experiment in accordance to these comments. In total, three main changes were implemented with regard to the questions in the survey: (1) removals, (2) additions, (3) changes. Additionally, there was a software change.

3.3.1 Removals

The main issue that was addressed after the pretest was the size of the questionnaire. Many complained that they were losing their attention span and some even quit before finishing the experiment because it took them to long to finish. Unfortunately, Google forms does not track time thus it is unknown how long the pretest took. The original experiment included 20 choice tasks. Ten of them were related to a natural forest (N15.02 Dennen-, eiken-, en beukenbos' (pine, oak, and beech forest)), ten of them were similar to a multifunctional forest as was used in the definitive version of the experiment. It was decided to leave out the stands which were related to the natural forest to make the experiment more manageable. This also took care of the issue that the choice options (e.g. thinning from below) were very much related to harvesting which is only a small part of the management toolkit used by forest managers in more nature orientated forests.

3.3.2 Additions

While ten stands were removed to cut back the size of the experiment, two additional choice tasks were added to represent two older forests (age 100-150). The original selection criteria resulted in relative young stands which is good for testing whether forest managers would like to make use of thinning but less useful for testing whether forest managers would like to make use of some form of a regeneration cut.

Based on the results of the pretest two additions were also made to the choice object characteristics. The number of trees per hectare was added to give respondents a feeling whether future crop tree thinning would make sense with the preset amount of future crop trees. The DBH of the middle tree was added to help decide when it would sense to choose a regeneration cut as wood processing industry can only deal efficiently with stems up to a certain size.

3.3.3 Changes

Besides removing or adding information some of the questions from the pretest were also altered. The main reason for these changes was to remove ambiguity found by the pre-testers. A question which related to the percentage of forest cover, of each forest type, of the real life forest managed by respondent was simplified to asking whether the respondent mainly owns broadleaf, coniferous or mixed forest. A question related to location (where do you work?) was made less ambiguous by adding a map showing which areas were related to the answering options and by asking respondents where they spend most of their time working.

The original circle plot was a bubble plot instead of a scatter plot. Each bubble reflected the size of the respective tree. This was changed as respondents did not understand how to interpret the bubbles. Moreover, the bubbles could only be scaled relative to each other but not to the axis and because they provided information (on the size distribution of the trees) to the respondent which could not easily be captured by a variable in the analysis.

The SD-questions were originally coupled to a five-point scale answering option. Google forms, the software originally used, comes with limited question types. By making a switch to Qualtrics, specific questionnaire software used to build elaborate questionnaires, it was possible to change these five-point scales to sliders ranging from 0 to a 1000.

3.3.4 Software change

As described above, Google forms was used as software to build the experiment with. Unfortunately, besides limited question types, Google forms also had three serious issues. The first was that time spent on the survey was not being measured by Google forms. The second issue was that partially filled in attempts were not recorded. Both serve as useful indicators for the complexity of the survey. Finally, the graphical quality of Google forms was very low. Therefore, a switch to Qualtrics was made. Qualtrics does record time and partially filled in questionnaires. Moreover, it displays images at a much higher quality. This is especially important in terms of engagement. It can be reasonably assumed that a good looking questionnaire is more likely to be completed.

3.4 Data collection strategy & respondents

Unfortunately, with the discontinuation of the 'Bosschap' in 2015, there is no longer one central database in which all Dutch forest owners are registered. Therefore, it is difficult to assess how large the target population is. The tasks of the 'Bosschap' were taken over by the 'Vereniging van bos- en natuurterreineigenaren' (VNBE) (association of forest and nature area owners) and the 'Stichting Kwaliteit Bos- en Natuur- en Landschapswerk' (SBKNL) (foundation for the quality of forest, nature and landscape work). These organizations do not have individual forest managers as members but only organizations. The only numbers that are publicly available on the total population of forest managers are those from Van Blitterswijk et al. (2001) which state that in 2001 there were 1900 forest owners with forests larger than 5 ha, where it is important to note that forest owners and forest managers are two different groups. A forest owner is not necessarily involved in forest management and a forest manager does not necessarily have to own forest as they could also be employed by an organization which is responsible for the management of forest.

Figure 10 shows an overview of the ownership of Dutch forests. Ideally, sample of the experiment is representative for each ownership situation.

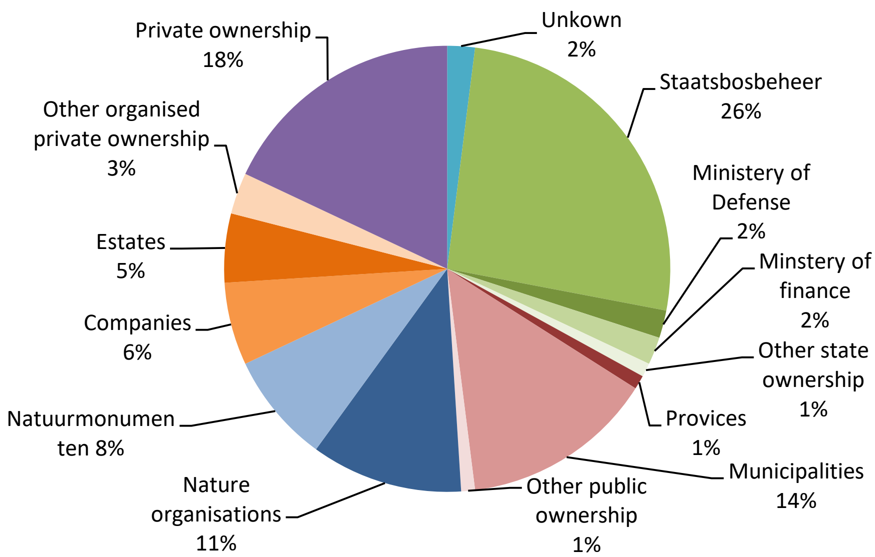


Figure 10: Distribution of forest ownership in the Netherlands (Schelhaas and Clerkx, 2015)

The main approach to reach forest managers is through a personal e-mail, as forest managers are expected to have a higher response rate when contacted personally (Keusch, 2015). An e-mail list was compiled from known addresses at the Forest and Nature Policy Group, personal contacts of

M.A. Hoogstra, J.M van Laar, and H. Schreppers, the 2010 KNBV membership list, and publicly known e-mail addresses which could be found online. In the end, 132 personal e-mails were sent out over a period of five weeks. Prior to the last week of data collection a reminder was sent to 103 forest managers.

Additionally a link to the questionnaire was posted in six LinkedIn-groups related to forestry:

1. Bos- en Natuurbeheer - Hogeschool Van Hall Larenstein;
2. Close-to-nature forest management using the QD-strategy;
3. Eco2eco, over bosbeheer en houtvermarkting in multifunctionele topnatuur;
4. Forest and nature conservation Wageningen University;
5. PEFC Netherlands;
6. Natuurmonumenten.

Various people shared this link on LinkedIn. The link was also posted on the Twitter page of the Forest and Nature Policy Group and shared by the Twitter account of the 'Vereniging van bos- en natuurterreineigenaren' (VNBE).

The sample size that is required to make statistical inferences depends on the set-up of an experiment. In the case of this report's experiment, the minimum sample size is difficult to assess as the experiment is neither a simple logistic set-up, nor a normal choice experiment. Orme (2010) in Rose and Bliemer (2013) suggests a minimum of 200 to 300 respondents for stated choice experiments, to give some indication of what is most likely a reliable number for a minimum sample size. McFadden's (1973) rule of thumb states that at least 30 respondents should be present per alternative. Using this rule of thumb one would need 240 respondents in this experiment.

In total, 53 forest managers participated in the experiment. It is clear that the sample size of the experiment was too small to make reliable inferences about all factors in the experiment when comparing the number of respondents to the minimum sample size suggested by Orme (2010) or McFadden (1973). 53 respondents is also a relatively low amount of respondents when compared to similar studies. Mußhoff and Maart-Noelck (2014), for example, had 79 respondents, while Sauter et al. (2016) had 107 respondents. It was decided to still continue with the analysis to test whether there were trends which were so strong, that they could even be picked up in a small data set.

On average, it took the respondents 36 minutes to complete the experiment, which includes time spend away from the desk. One outlier was removed when calculating this average time to completion, as the recorded time for that respondent was over four days. An average completion time of 36 minutes is much higher than the estimated time to complete the experiment, which was believed to be 15 minutes. It seems that respondents were very serious in answering the questions and took their time to consider each answering possibility.

41 of the 53 responses can be traced back to the personal e-mails which were sent out. The other twelve responses could also stem from the personal e-mails or from the public link which was shared on social media. This means that the response rate of the personal e-mails was between 31% and 40%. 51 respondents did start the experiment but did not reach the end. These respondents are not taken into consideration for calculating the response rate and their responses are not analyzed. 78% of the respondents which started the experiment but did not finish, did not come further than the first pages of the experiment. This means that many respondents were curious after receiving the link to the experiment but were no longer interested after looking at the introduction, which can be the result of finding out that they did not belong to the target audience or because they did not felt they wanted to spent the time/effort to finish the questionnaire.

3.5 Data analysis

3.5.1 Multinomial logistic regression

The likelihood of a forest manager making a harvesting intervention is analyzed through a multinomial logistic regression model (MNL). The multinomial logistic regression model allows a discrete outcome variable to have more than two levels, where the normal logit model only deals with binary choices.

The analysis is grounded in choice theory, where rationality is assumed. People are expected to maximize their utility by being able to choose between alternatives. Utility is given by:

$$U_{in} = V_{in} + \varepsilon_{in} \qquad [7]$$

Which states that the latent utility (U_{in}) an individual n gains from choosing alternative i depends on an explainable, or so called systematic component V_{in} and a random component ε_{ij}. The systematic component of the latent utility contains a proportion of utility associated with the attributes of the alternative $V(\beta X_i)$. This refers to the levels of the forest characteristics of the model forest stands. It also contains a component of utility associated with the characteristics of the individual respondent $V(\beta S_n)$. This refers to the individual characteristics, social influences, situational influences, and memory of the respondent. This can be summarized as:

$$V_{in} = V(\beta X_i) + V(\beta S_n) \qquad [8]$$

The error component of the latent utility function explains unpredicted choices through unknown variables. When (1) the error components are extreme-value (Gumbel) distributed, (2) the error components are identically and independently distributed across alternatives, and (3) the error components are identically and independently distributed across observations/individuals' (Koppelman and Bath, 2006, p.26), then one can estimate the probability that an individual chooses alternative i from a set of C_n alternatives through:

$$\Pr(y_{in} = 1|X_n;\beta) = \frac{\exp(\mathrm{V}(\beta \mathrm{x}_{in}))}{\sum_{j\in C_n}^{J} \exp(\mathrm{V}(\beta \mathrm{x}_{jn}))} \quad [9]$$

Where (V_j) is the systematic component of the utility of alternative j. Let's refer to this whole right term as the function [F]. A maximum likelihood estimation will be estimated through the use of the 'mlogit command' in the statistical software program Stata (version 13.0), which is widely used in econometrics. The general concept of maximum likelihood estimation is that one maximizes the likelihood that the parameter values, which are found for a sample, reflect the parameters values of the whole population. This is done by setting up a likelihood function, which reflects the probability that a certain choice is made or not (e.g. $\mathrm{L} = F^{yin}L^{1-yin}$). The derivate of the likelihood function with respect to the betas in the model which is set to zero and solved, gives this maximum probability. The way this is calculated in the case of a multinomial logistic regression model is mathematically complex as the product first needs to be converted to a sum (by taking the log likelihood function). The parameters then need to be found through a simulation as there is no close form solution. This mathematical explanation will, therefore, not be included here (See Croissant (2012) for an in-depth explanation).

The standard errors of the estimation should be robust and clustered to the individual level, in order to get valid results. Statistical analysis, in general, is based on the premise that observations are independently and identically distributed, which results in unbiased estimations. However, in the case of the choice experiment we have recorded multiple observations (choices) for the same respondents. Each person's unobservable characteristics can influence the choices in a similar way, which means that error terms of the observations of each person are related to each other. Using robust clustered standard errors removes this bias and results in more accurate standard errors (Angrist and Pischke, 2008).

3.5.2 Analysis requirements

A few requirements have to be met in order to be able to conduct a maximum likelihood estimation and to come up with a model which reflects how harvest intervention decisions best can be explained. The first step in this procedure is to check for multicollinearity and the independence of irrelevant alternatives (IIA). Additionally, an F-test and goodness of fit indicator are used to check whether the model has predicative power.

Multicollinearity

The variance inflation factor (VIF) test is used to check for multicollinearity between the independent variables. Multicollinearity is the issue of having very high intercorrelations among independent variables. In the case of a high multicollinearity one is not able to distinguish which independent variable is responsible for a correlation with the dependent variable. The VIF-score is calculated through the following formula:

$$VIF = \frac{1}{1-R_i^2} \qquad [10]$$

Where the R_i^2 refers to the normal R^2 of an OLS regression which excludes the variable one is testing. It does not matter that R^2 is taken from an OLS regression instead of the logistic regression as 'the concern is with the relationship among the independent variables in the model, not with the functional form of the model' (Abdulhafedh, 2017, p.286). A VIF of ten or higher is assumed to be problematic (Abdulhafedh, 2017), those variables are therefore dropped from the model. Akaike's (corrected) information criterion (AIC) is also used to determine which variables should be included or excluded. The AIC makes a trade-off between the risk of over-fitting and under-fitting the model. Adding any type of variables to any model almost always increases the goodness of fit, simply by picking up random variation. However, a very large over fitted model is not very useful. It only represents the sample and cannot be used for predictions using other samples. The AIC value is, therefore, used to choose the correct model specification in which bias and precision of a more complex model are traded-off (Jacob et al., 2012). Practically, this means calculating an AIC value for each possible linear model configuration. The model with the lowest AIC is deemed optimal as additional variables increase the AIC-score and additional goodness of fit decreases the AIC-score (Jacob et al., 2012). The Stata package 'vselect' (Lindsey, 2014) is used to automate the selection process using backwards selection. It starts with a full model, and sequently drops the variables with the highest standard deviation, using AIC to determine when to stop dropping variables. Backwards selection is preferred over forwards selection, as backwards selection is not sensitive to the order of the variables which are included (Bradley, 2000). Similar to Bradley (2000), this thesis treats individual dummy variables of categorical variables as separate predictors.

Independence of irrelevant alternatives

The multinomial logistic regression can be conducted after the variables have been through the selection process. A possible hurdle for this regression is the independence of irrelevant alternatives

(IIA) assumption which states that when respondents make a choice between alternatives, their odds of choosing A over B should not depend on whether another alternative C is present or not. The IIA-assumption is a property of the multinomial regression model. This property becomes problematic when there are groups of choices which are more similar than others. This is also known as the red-bus, blue-bus paradox which states than the probability that one takes the train over the bus changes when there is just one train and one bus compared to one train and two different colored busses (Koppelman and Bath, 2006). This is undesired and, therefore, solutions have been found. Nested logit models do not struggle with the IIA-assumption as they group variables which are very similar to each other. The Hausman-McFadden test, which is part of the Stata extension 'mlogtest' from Freese and Long (2000), can be used to test whether a nested logit regression is preferred over a multinomial logistic regression model (Koppelman and Bath, 2006). The Hausman-McFadden test checks whether a full model test gives the same estimates as a reduced model, where for example, a full model takes into account all thinning and harvesting options where a reduced model leaves out thinning from below. If both models give the same estimates (which are reflected by non-significant or negative Hausman-McFadden test results) than the IIA-assumption holds and the multinomial regression model can be used.

Predictive power

After checking the IIA-assumption, the next step is to check whether all the coefficients of the independent variables are simultaneously equal to zero (Freese and Long, 2000). This Likelihood Ratio (LR) Chi-Square test (which is basically a F-test) shows whether at least one of the variables has predictive power with respect to the dependent variable (the significance has to be lower than $\alpha=0.05$). If that is not the case, then there is no point in further testing. The LR-test can also be used to test whether individual variables are different from zero (whether they individually have an effect on the dependent variable) and whether dependent variable categories can be combined. This is the case if the P-value is lower than $\alpha=0.05$ for each respective test (Freese and Long, 2000). As a measure of goodness of fit, McFadden's pseudo-R^2 is reported which is most widely used in choice experiments (Allison, 2014). The value R^2 is seldom found to be higher than 0.5, even in well-specified models (Dougherty, 2011) and values between 0.2 to 0.4 represent an excellent fit (McFadden, 1978)

4 Results

This chapter presents the results of the experiment. Section 4.1 starts with descriptive statistics, providing more information on the background of the respondents. In section 4.2 the results of the experiment are presented. Finally, an overview of explanations of choices made in the experiment by the respondents is provided in section 4.3. This section deals with the results of the open questions in the questionnaire and final comments of the respondents.

4.1 Background of the respondents

The next section contains the descriptive statistics tables which have been split up into different sections in order to match with the sub-research questions. The individual characteristics of the respondents are discussed first. Variables related to social influences, situational influences, and memory follow in the same order as in Table 12. Finally, the total representativeness of the sample is discussed.

4.1.1 Individual characteristics

Table 13 shows the mean of the individual characteristics of the respondents, as well as the standard deviation in the case of numerical variables. The subsample has a relatively high amount of people working in the east of the Netherlands (45.3%). This could be explained by the fact that the east of the Netherlands contains the most forests area (Compendium voor de Leefomgeving, 2012). This could also explain why not many forest managers from the north participated in the experiment, as there is very little forest in the north of the Netherlands.

Table 13: Descriptive statistics of the respondents' individual characteristics (n=53).

VARIABLES	Mean	St. dev.
Region (north)	9.4%	-
Region (east)	45.3%	-
Region (west)	19.0%	-
Region (south)	26.0%	-
Gender (male)	100%	-
Gender (female)	0%	-
Age respondent	50.1	12.1
Education (less than high school degree)	0%	-
Education (high school degree)	0%	-
Education (secondary vocational education (MBO))	17.0%	-
Education (higher professional education (HBO))	45.3%	-
Education (university bachelor degree (WO))	1.9%	-
Education (university bachelor degree (WO))	32.1%	-
Education (university specialized degree (PHD))	3.8%	-
Forestry degree (yes)	79.3%	-
Forestry degree (no)	20.8%	-
Specialization (ecology)	49.1%	-
Specialization (economics)	18.9%	-

Specialization (timber trade)	11.3%	-
Specialization (recreation/tourism)	7.6%	-
Specialization (stewardship)	9.4%	-
Specialization (none of the above)	24.5%	-
Years active	22.5	13.0
Self-assessed professionalism$^{\alpha}$	7.4	1.6
Occupation (main occupation)	50.9%	-
Occupation (side occupation)	49.1%	-
Forest manager identity$^{\alpha}$	7.8	1.8
Forester identity$^{\alpha}$	6.6	3.0
Nature manager identity$^{\alpha}$	7.4	1.7
Finance importance$^{\alpha}$	7.0	2.4
Nature importance$^{\alpha}$	8.1	1.3
Recreation importance$^{\alpha}$	6.7	1.5
HL-value	7.4	2.3

α: SD-scale question responses have been transformed to a 1-10 scale.

In total, 100% of the respondents were male. As there is zero variation in this variable, it is dropped from the analysis. The amount of males in the sample is higher than expected. Although no exact numbers are known, Trouw (2015) estimated that 20-25% of Dutch forester managers are female. A possible explanation of the high amount of male respondents could be that the forest managers in the sample are relatively old (50.1 years on average). In 1981 there were only two female forest managers, indicating a male-oriented profession (Trouw, 2015).

The sample group contains relatively old forest managers. It is unclear why that is the case. Online experiments usually attract a younger group of respondents (e.g. Mußhoff and Maart-Noelck, 2014). The sample group is relatively high educated compared to the average Dutch person, aged between 17 and 75 (CBS, 2018). Most respondents have finished higher professional education (45.3%) or a university master degree (32.1%). The fact that this experiment was online based could explain why the subsample was relatively high educated as highly educated people tend to participate more in online experiments (Sauter et al., 2016). Another explanation for the relatively high education of the respondents could be the network of forest managers used in the data gathering process, which is based around highly educated experts.

Almost 80% of the respondents hold a degree in forest and nature conservation, which is not necessarily unexpected. Organizations involved in forest management usually require employers to have had an education in forest and nature conservation. The types of degrees which are held by the other 20% are unknown. Almost half of the respondents have specialized in ecology during their studies, while the other specializations (economics, timber trade, recreation/tourism, and stewardship) are less common. This implies that 'ecologists' are largely responsible for timber harvesting in the Netherlands as supposed to 'foresters'. This could be explained by forestry becoming an integral part of nature management (Mohren and Wijdeven, 2016) which is the domain of ecologists.

The average forest manager has spent 22.5 years active in forest management. This corresponds to the relatively high age of the forest managers. The forest managers score themselves a 7.4 out of 10 in terms of professionality. This means that the respondents, on average, did find themselves to be relatively professional. This despite, almost half of the respondents not working in forest management as a main occupation. Forest managers who work in forest management as a side occupation, can be found in each employment category. It is most common for a 'side occupation forest manager' to work for a municipality (60%), university (100%), 'other' organization (100%), or as a private forest owners (100%).

The average respondent does identify themselves as a forest manager, forester and nature manager. It seems that (by looking at the point estimates) they feel most strongly related to the term forest manager (SD-score of 7.8 out of 10), followed by nature manager (SD-score of 7.4 out of 10), and forester (SD-score of 6.6 out of 10). The high standard deviation of 3.0 is striking in case of forester. This matches with reality. The biggest debate in terms of terminology is around this term (see section 5.1).

Table 14: Descriptive statistics of the respondents' social influence characteristics (n=53) confirms that modern forest management in the Netherlands is multifunctional. The forest managers found nature goals (SD-score of 8.1 out of 10), finance goals (SD-score of 7.4), and recreation goals (SD-score of 6.7) important aspects of forest management, indicating that forest managers rank all aspects as high, but natural values over financial values whereas both aspects are considered more important than recreational values.

A total of ten respondents have made inconsistent choices in the HL-task (switching back from option B to option A), which is an indication of non-rational behavior. Similar to Sauter et al. (2016) these responses are still included in the analysis, as for the HL-value is simply determined by the number of safe options chosen. The average HL-value is 7.4. This confirms that most forest managers are risk averse, which is the case with a value of four or higher. It seems that Dutch forest managers are slightly more risk averse than German foresters. Mußhoff and Maart-Noelck (2014), report an average HL-value of 5.9 in their study. This is surprising when compared to Hofstede et al. (2005) which finds that Germans score, in general, higher on an uncertainty avoidance index. This difference could be explained by the fact that this uncertainty index, scores countries on (1) the amount of people with job stress, (2) the amount of people willing to break company rules, and (3) on the willingness of people to stay at a company (Hofstede et al., 2005). This uncertainty index, therefore, might be linked to risk attitude but measures something different. The HL-value differences between Dutch and German forest managers do match which Ferreira (2018), which measured cross-country differences in risk attitudes towards financial investment and which shows that Dutch individuals extremely risk averse.

4.1.2 Social influences

Table 14 shows the descriptive statistics of the variables related to social influences. Most respondents work at a consultancy firm (28.3%). We do not know whether this is due to the fact that there are many consultancy firms in the field of forest management or by the fact that roughly 20% of the personal e-mails were sent to people working in consultancy. The 'Bosgroepen' is also very well represented. Their e-mail addresses were also easy to find. Moreover, members of the 'Bosgroepen' own over 400,000 ha of forest and nature areas (Bosgroepen, 2019). This corresponds to 68% of all forest and nature areas in the Netherlands (based on Compendium voor de Leefomgeving, 2017) which also explains the high number of 'Bosgroepen' respondents. Two additional categories have been added to the employment variable based on the 'other' responses. 7.6% of the respondents could be characterized as private forest owners and 9.4% of the forest managers work at an estate based on their own description of their employment. One category was expanded. The consultancy firm group was originally only for people who owned a consultancy firm themselves. This was changed to people working at any type of consultancy firm to accommodate some of the 'other' responses. It is noteworthy that 'Natuurmonumenten' and the State forest commission are underrepresented in the sample. These organizations employ many forest managers but are difficult to reach.

Table 14: Descriptive statistics of the respondents' social influence characteristics (n=53).

VARIABLES	Mean	St. dev.
Employment (Bosgroepen)	17.0%	-
Employment (consultancy firm)	28.3%	-
Employment (municipality)	9.4%	-
Employment (university of applied sciences)	0%	-
Employment (Landschappen NL)	7.6%	-
Employment (Ministery of Defence)	0%	-
Employment (Ministery of Finance)	0%	-
Employment (Natuurmonumenten)	0%	-
Employment (province)	0%	-
Employment (State forest commission)	5.7%	-
Employment (university)	3.8%	-
Employment (unemployed)	0%	-
Employment (other)	11.3%	-
Employment (private forest owner)	7.6%	-
Employment (estate)	9.4%	
Professional organization$^{\alpha}$	4.2	3.1

α: SD-scale question responses have been transformed to a 1-10 scale.

The average forest manager is not very involved in a professional organization (SD-score of 4.2 out of 10) such as the 'KNBV' (Royal Dutch forestry organization). However, the standard deviation (3.1) of this variable is very high. This means that some forester managers are very active, while others are not active at all.

4.1.3 Situational influences

Table 15 contains the descriptive statistics of the variables related to situational influences. The average forest manager scores the July 2019 wood prices a six out of ten, which means they consider the current wood prices to be slightly higher than average wood prices. The standard deviation is again quite high (2.6). This means that some forest managers consider the wood prices to be (much) higher, while others consider them to be (much) lower. This confirms that even for a seemingly objective value (wood prices) perceptions differ largely.

Table 15: Descriptive statistics of the respondents' situational influence characteristics (n=53).

VARIABLES	Mean	St. dev.
Wood prices$^{\alpha}$	6.0	2.6
Disturbances (yes)	60.4%	-
Disturbances (no)	39.6%	-

α: SD-scale question responses have been transformed to a 1-10 scale.

Almost 60% of the forest managers had experienced a large disturbance in the past five years. This matches with the notion of Hoogstra and Schanz (2009) that forest managers often have to deviate from their management plans due to unforeseen circumstances.

4.1.4 Memory

The variables related to memory are described in Table 16. The average forest manager in the sample manages 1517.3 ha forest. This is a relatively large amount of forest as more than 90% of Dutch forests are smaller (Compendium voor de Leefomgeving, 2014). This number could be explained by the high number of consultancy and 'Bosgroepen' respondents in the sample. These forest managers usually work for many owners which combined gives them a large forest to manage. Small forest owners could also be harder to reach (Schelhaas and Clerkx, 2015) and therefore be underrepresented.

Table 16: Descriptive statistics of the respondents' memory characteristics (n=53).

VARIABLES	Mean	St. dev.
Real forest size	1517.3	2323.7
Real forest type (mainly broadleaf species)	3.8%	-
Real forest type (mainly coniferous forest)	34.0%	-
Real forest type (mainly mixed forest)	62.3%	-
Real forest growing conditions$^{\alpha}$	5.3	1.8

α: SD-scale question responses have been transformed to a 1-10 scale.

However, the standard deviation (2323.7) is really high which means that managers of small forests are included in the sample (as well as managers of really large forests). Table 17 shows that the average real forest size variable is inflated due to a small amount of forest managers who manage really large forests.

Table 17: Division of the real forest size variable (n=53).

PERCENTILES	Real forest size
25%	189
50%	750
75%	1200

The average forest manager in the sample manages a mixed forest (62.3%). 34% manages a mainly coniferous forest, while only 3.8% manages a mainly broadleaf forest. Compared to the 6th forest inventory data, especially the broadleaf forest is underrepresented. Schelhaas et al. (2014) show that roughly 21% of the forest in the Netherlands is broadleaf forest. 27% is coniferous forest. Harvest interventions are more common in coniferous forests (Schelhaas et al., 2014) which might explain why forest managers of those forests were more inclined to participate in the experiment.

The average real life managed forest has average growing conditions (SD-score of 5.3 out of 10). This matches with what theoretically could have been expected if each data point was independently and individually drawn from the population. With a standard deviation of 1.8, some of the managed forests have better growing conditions than others, which reflects the diversity of Dutch forests.

4.1.5 Representativeness of the sample

The external validity of an experiment partly relies on the representativeness of the sample for the total population. The statistical model will correct for many factors, so it not necessary to have a fully representative sample. However, in order for the model to be able to correct for many factors, there is a need for a (large) overlap between sample and population characteristics.

It is clear that the sample of 53 forest managers is relatively small. The sample is also slightly skewed by including a relatively high percentage of male, older, and highly educated forest managers who are mostly located in the east of the Netherlands. Forest managers from ‘Natuurmonumenten’ and the State Forest commission are underrepresented.

However, the forest managers, which are included in the sample manage over 80,000 ha forest. This corresponds to roughly one fifth of the total forest area in the Netherlands (based on the total forest area mentioned in Schelhaas et al. (2017)). This is a good indication that the sample, with its limitations, is relatively representative and why overall no serious issues with representativeness are expected.

4.2 Results of the experiment

4.2.1 Results of the model selection

The model selection consists of two parts. Variables which result in multicollinearity are removed first. Secondly, the AIC is used to come up with the 'best' model. As was explained in section 3.5.2, a linear model needed to be regressed in order to conduct the model selection procedure. A first attempt to run the linear model with the choice variable as dependent variable and all other variables (excluding gender) as independent variables resulted in an automatic omission of tree variables. These variables had such serious multicollinearity issues that they had to be omitted before the model could be constructed and the model selection could continue (Stock and Watson, 2003). The level of crown closure, the level of shrub layer, and type of main species are, therefore, not included in the multinomial logistic regression.

The model was re-estimated using all remaining variables and VIF-scores were calculated (Table 18). Using a step by step approach, the variable with the highest VIF-score was removed and a new estimation was conducted without this variable. The model improves with each estimation and is considered free from problematic multicollinearity when no variable has a VIF-score above ten. The variable 'volume' was removed first, followed by 'region', 'real forest type', 'Shannon index'', and the 'age respondent' (Table 18). The mean VIF-score decreased from 44.35 to 4.78, which is an indicator for how the model has improved by the procedure.

Table 18: Variance Inflation Factor (VIF) test results scores (n=636). Numbers in bold indicate the variable with the highest VIF-score for each respective regression.

VARIABLES	VIF1	VIF2	VIF3	VIF4	VIF5	VIF6
Age stand	13.01	4.98	4.98	4.98	4.89	4.89
Ground area	735.61	2.75	2.75	2.74	2.59	2.59
Volume	**804.73**	-	-	-	-	-
Estimated increment	3.14	2.60	2.59	2.59	1.96	1.96
Volume lying dead wood	9.89	9.78	9.77	9.77	1.73	1.73
Volume standing dead wood	2.55	2.48	2.48	2.48	1.43	1.43
Diameter of the middle tree of the main tree species	7.40	7.36	7.36	7.36	6.52	6.52
Main tree species count	44.19	10.44	10.44	10.44	2.51	2.51
Average distance	14.87	7.17	7.17	7.17	2.93	2.93
Shannon index	17.19	12.78	12.77	**12.77**	-	-
Region (east)	60.11	**60.11**	-	-	-	-
Region (west)	24.76	**24.76**	-	-	-	-
Region (south)	54.28	**54.27**	-	-	-	-
Age respondent	13.74	13.73	11.26	10.62	**10.61**	-
Education (higher professional education (HBO))	17.99	17.99	12.3	8.51	8.51	7.97
Education (university bachelor degree (WO))	2.45	2.45	2.30	2.28	2.27	2.27
Education (university master degree (WO))	12.94	12.94	9.09	8.07	8.07	6.4
Education (university specialized degree (PHD))	7.91	7.91	6.46	6.46	6.45	5.63
Forestry degree (no)	6.77	6.77	5.84	5.10	5.10	5.06
Specialization (ecology)	6.42	6.42	5.44	5.41	5.41	4.36
Specialization (economics)	6.01	6.01	3.85	3.06	3.06	2.69
Specialization (timber trade)	6.11	6.11	5.13	4.55	4.55	3.90

Specialization (recreation/tourism)	5.96	5.96	5.61	3.52	3.52	3.52
Specialization (stewardship)	6.73	6.73	4.26	3.46	3.46	3.34
Years active	12.67	12.67	9.85	8.46	8.46	3.78
Self-assessed professionalism	9.29	9.29	8.24	6.33	6.33	5.63
Occupation (side occupation)	8.99	8.99	6.09	5.16	5.16	5.16
Forest manager identity	7.67	7.67	7.35	7.02	7.02	6.95
Forester identity	10.02	10.02	6.83	5.82	5.82	5.47
Nature manager identity	8.98	8.98	7.18	6.38	6.38	6.16
Finance importance	11.35	11.34	10.54	9.72	9.72	9.48
Nature importance	11.48	11.48	6.53	6.46	6.46	6.35
Recreation importance	7.34	7.34	5.15	5.10	5.10	4.93
HL-value	2.64	2.64	2.55	1.88	1.88	1.88
Employment (consultancy firm)	9.45	9.45	7.25	6.37	6.37	6.16
Employment (municipality)	7.18	7.18	6.38	6.32	6.32	5.43
Employment (Landschappen NL)	9.60	9.60	5.80	5.74	5.74	5.65
Employment (State forest commission)	9.83	9.83	6.26	5.12	5.12	5.09
Employment (university)	14.63	14.63	8.21	7.58	7.58	7.57
Employment (other)	24.44	24.44	10.18	8.87	8.87	8.28
Employment (private forest owner)	7.01	7.01	5.45	4.82	4.82	4.56
Employment (estate)	7.76	7.76	6.91	6.19	6.19	4.93
Professional organization	4.54	4.54	4.37	4.08	4.08	3.61
Wood prices	4.36	4.36	3.64	3.40	3.40	3.36
Disturbances (no)	12.38	12.38	9.70	8.64	8.63	8.51
Real forest size	6.49	6.48	6.09	5.02	5.02	4.80
Real forest type (mainly coniferous forest)	35.16	35.16	**22.66**	-	-	-
Real forest type (mainly mixed forest)	42.74	42.74	**25.91**	-	-	-
Real forest growing conditions	2.59	2.59	2.57	2.56	2.56	2.53
Mean VIF-score	44.35	12.1	7.41	6.01	5.30	4.78

The variables which were not excluded after the VIF-tests (the ones with values in the VIF6 column) formed the input for the next part of the model selection. Using the Vselect extension of Stata (which conducts a backwards selection based on the AIC) this procedure determined a model which balances goodness of fit and complexity. The outcome resulted in a model containing the following variables:

- Ground area
- Volume standing dead wood
- Diameter of the middle tree of the main tree species
- Education (university bachelor degree (WO))
- Education (university specialized degree (PHD))
- Forestry degree
- Specialization (ecology)
- Specialization (economics)
- Specialization (recreation/tourism)
- Specialization (stewardship)
- Self-assessed professionalism
- Forest manager identity
- Finance importance
- Nature importance
- HL-value (risk attitude)
- Employment (Landschappen NL)
- Employment (State forest commission)
- Employment (private forest owner)
- Employment (estate)

These variables are used in the multinomial logistic regression model, the next step of the analysis. This means that the following variables have been excluded from the analysis, as they are found not to (strongly) to the choice variable:

- Age stand
- Estimated increment
- Volume lying dead wood
- Main species count
- Education (higher professional education (HBO))
- Education (university master degree (WO))
- Specialization (timber trade)
- Years active
- Occupation (main vs. side)
- Recreation importance
- Employment (consultancy firm)
- Employment (municipality)
- Employment (university)
- Employment (other)
- Professional organization
- Wood prices
- Disturbances
- Real forest size
- Real forest growing conditions

These variables are no longer corrected for in the model. This is not necessarily a problem, as they do not strongly correlate with the dependent variable and thus will not bias the other variables very much in the case of erogeneity. However, one should be very careful in interpreting these results.

Finally, using the variables which are not dropped from the model, the McFadden-Hausman-test shows that the IIA assumption holds (chi-square of 0 in all cases) for the MLR-model. This means that there is enough variation in the dependent variable categories and that there is no need to use a nested logistic model.

4.2.2 Results of the MLR

Table 19 shows the results of the MLR. The dependent variable is the categorical 'choice' variable. This variable represents the chosen harvest intervention option which was made by each respondent for each model stand (n=636). The dependent variables have been selected in the section above. The LR-Chi-Square shows that at least one beta is not equal to zero (chi-square of 603.88, p-value of 0.00) and that the model has (some) predictive power. The McFadden's pseudo R^2 is equal to 0.27 which indicates that the model has an excellent model fit (McFadden, 1978).

Results are presented as Relative Risk Ratio's (RRR). A RRR is calculated by taking the mathematical constant 'e' to the power of the slope-coefficient (the estimated betas). This transformation gets rid of the log-function on both sides of the equation which makes the interpretation of the coefficients easier. For a one unit increase the odds that a forest manager chooses a certain harvest intervention option, compared to the base category of ‘doing nothing’, increases by a factor equal to the RRR, holding the other variables in the model constant. A RRR below 1 suggests that there is a decreased chance of choosing a certain harvest intervention choice. A RRR above 1 suggests that there is an increased chance of picking a certain harvest intervention choice.

Table 19: MLR results expressed in Relative Risk Ratio’s (RRR) (n=636).

VARIABLES	Doing nothing (base-option)	Low intensity thinning from below	High intensity thinning from below	Low intensity thinning from above	High intensity thinning from above	Low intensity future crop tree thinning	High intensity future crop tree thinning	Regeneration cut
Ground area	-	1.395*** (0.0712)	1.235*** (0.0493)	1.500*** (0.0616)	1.217*** (0.0328)	1.172*** (0.0272)	1.123*** (0.0275)	1.125*** (0.0233)
Volume standing dead wood	-	1.125*** (0.0403)	1.112** (0.0500)	1.153*** (0.0374)	1.113*** (0.0332)	1.001 (0.0155)	1.009 (0.0216)	1.017 (0.0250)
Diameter of the middle tree of the main tree species	-	0.974 (0.0950)	0.981 (0.0388)	1.068** (0.0349)	1.032 (0.0255)	0.959*** (0.0145)	0.975 (0.0200)	1.123*** (0.0315)
Education (university bachelor degree (WO))	-	0*** (0)	1.354e+31*** (5.642e+31)	3.48e-10*** (5.44e-10)	0.126 (0.210)	0.130** (0.107)	0*** (0)	0*** (0)
Education (university specialized degree (PhD))	-	6.94e-10*** (1.33e-09)	1.603e+29*** (7.721e+29)	0.157* (0.160)	0.696 (0.728)	0.552 (0.451)	0.0362*** (0.0305)	0*** (0)
Forestry degree	-	0.0173** (0.0277)	0*** (0)	0.110** (0.107)	0.277 (0.305)	1.051 (0.663)	0.166* (0.153)	0.0864** (0.103)
Specialization (ecology)	-	11.03* (14.52)	6.716e+51*** (3.961e+52)	1.212 (1.052)	0.770 (0.692)	0.795 (0.344)	1.255 (0.662)	0.331* (0.210)
Specialization (economics)	-	6.549 (12.53)	3.145e+50*** (2.186e+51)	0.357 (0.280)	0.714 (0.445)	0.664 (0.209)	0.381** (0.164)	0.295** (0.172)
Specialization (recreation/tourism)	-	42.88*** (62.56)	6.26e-07*** (2.12e-06)	64.55*** (86.36)	72.85*** (88.65)	5.557*** (3.418)	10.53*** (7.906)	4.574 (5.399)
Specialization (stewardship)	-	6.35e-09*** (5.91e-09)	2.956e+08*** (7.341e+08)	0.528 (0.457)	1.992 (1.490)	2.536 (1.473)	2.164 (1.730)	4.326** (2.910)
Self-assessed professionalism	-	0.877 (0.337)	0*** (0)	1.855** (0.525)	1.005 (0.306)	0.939 (0.146)	1.532 (0.518)	2.521*** (0.810)
Forest manager identity	-	1.057 (0.310)	0.0212*** (0.00880)	0.927 (0.184)	0.981 (0.165)	1.098 (0.118)	1.179 (0.211)	0.753** (0.0840)
Finance importance	-	0.668** (0.136)	4,767*** (1,973)	1.052 (0.149)	0.872 (0.208)	0.829* (0.0841)	0.795* (0.0987)	0.791 (0.113)
Nature importance	-	1.058 (0.320)	0.0871*** (0.0450)	0.656* (0.154)	0.848 (0.228)	1.244 (0.208)	0.968 (0.200)	1.299 (0.309)
HL-value	-	0.702 (0.189)	3.97e-09*** (3.70e-09)	1.079 (0.126)	0.959 (0.101)	1.039 (0.0870)	0.969 (0.0951)	0.845 (0.0908)
Employment (Landschappen NL)	-	0*** (0)	1.848e+37*** (6.098e+37)	0.0462** (0.0581)	0.0154*** (0.0217)	0.126*** (0.0702)	0.0271*** (0.0233)	0.0725*** (0.0642)
Employment (State forest commission)	-	1.08e-10*** (2.27e-10)	0*** (0)	0.168* (0.174)	0.156 (0.195)	1.347 (0.492)	0.562 (0.310)	1.757 (1.052)
Employment (private forest owner)	-	1.59e-10*** (3.31e-10)	0*** (0)	1.681 (1.393)	0.357 (0.581)	2.463 (2.103)	2.066 (2.116)	1.486 (0.549)
Employment (estate)	-	1.260 (1.441)	1,159*** (2,360)	0.862 (0.619)	3.888** (2.660)	1.720 (0.946)	1.629 (0.888)	1.497 (1.394)
Constant	-	-5.032 (3.223)	210.1*** (10.14)	-14.58*** (2.595)	-3.984* (2.327)	-3.142** (1.523)	-3.282 (2.084)	-8.197*** (2.147)

Robust clustered standard errors are in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results are discussed in order of appearance, starting with ground area. Ground area is the only variable which is significant at α=0.01 in all cases. An increase in ground area makes it more likely that any type of harvest intervention, other than doing nothing, is applied. For example, a one m^2/ha increase in ground area makes it 50% more likely that low intensity thinning from above is chosen.

The volume of standing dead wood is significant at α=0.01 for low intensity thinning from below, low intensity thinning from above, and high intensity thinning from above. It is significant at α=0.05 for high intensity thinning from below and not significant in the other cases. Thus, an increase in standing dead wood volume makes it more likely that either thinning from below or above is chosen, compared to the base category and keeping other variables constant (by 11% to 15%).

The diameter of the middle tree of the main tree species is significant at α=0.01 for low intensity thinning from above, low intensity future crop tree thinning, and regeneration cut. The strongest relationship between diameter middle tree and a harvest intervention option is with the regeneration cut option. Having the diameter of the middle tree increase by one cm increases the chances of choosing the regeneration cut option by 12%. There is also a positive relation with thinning from above.

Having a bachelor degree or PhD compared to any other type of highest level of finished education increases the chance that high intensity thinning from below is chosen by an extremely large factor compared to the other harvest intervention options.

Having a degree in forestry decreases the chance that almost any harvest intervention option is chosen compared to doing nothing, keeping the other variables constant. This mean that between two forest managers with similar ideas about the importance of financial and natural aspects of forest management, the one with the forestry degree has a 91% decreased chance to pick a regeneration cut (α=0.05). Thinning from below is extremely likely not to be chosen by degree holders. Only the chance of a forest manager picking low intensity future crop tree thinning is not significantly different from doing nothing.

Those who specialized in ecology or economics are less likely to pick a regeneration cut, compared to doing nothing. Specializing in ecology decreases the chance by 69% (α=0.10), while specializing in economics decreases the chance by 71% (α=0.05). While it seems that those who specialized in stewardship are more likely to pick a regeneration cut. A stewardship specialization increases the chance of a regeneration cut, compared to doing nothing by 333% (α=0.05). Forest managers which are specialized in recreation/tourism are very likely to pick thinning options over doing nothing.

For every one point increase in the SQ-scale of self-assessed professionalism there is a 152% higher chance that a regeneration cut is applied than that doing nothing is chosen (α=0.01). Low intensity thinning from above is also popular among those who consider themselves more professional. Thinning from below is less popular.

For every one point increase in the SQ-scale of identifying yourself as a forest manager there is a 98% lower chance of using high intensity thinning from below (α=0.01) and a 25% lower chance of using an regeneration cut (α=0.05).

Forest managers who find financial aspects of forest management important are less likely to make use of future crop thinning or low intensity thinning from below, compared to doing nothing (α=0.10). Their extremely high appreciation of high intensity thinning from below is strange, and most likely a result of a methodological issue, see the next section. Forest managers who find ecological aspects of forest management very important will not likely choose high intensity thinning from below (α=0.01). In general is it striking that both finance importance as nature importance are not really significant predictors.

The HL-value is also not a very significant predictor for the choice behavior. Only high intensity thinning from below is extremely well predicted.

Finally, there are the employment dummy variables to be discussed. Some extremely high and low RRRs are found for thinning from below. Otherwise, what is most striking is the lack of significant results in these variables. The only variable which is a successful predictor of all harvest intervention choices is employment for Landschappen NL. Forest managers working for Landschappen NL are especially likely to do nothing.

4.2.3 Methodological issues

Some strange findings were the result of the multinomial logistic regression. Some relative risk ratios were found to be extremely high or low. These seemingly strange results can be explained through the concept of (quasi)-complete separation (UCLA, 2008). This phenomenon occurs when the dependent variable (almost) completely separates a predictor value. This happens when the independent variables are extremely correlated with a certain choice option. In the context of this report it is clear that this methodological issue stems from the relatively low response rate. Figure 11 shows the low amount of times some particular outcome levels were chosen while the descriptive statistics shows how low some of the variation in predictor variables is. Especially, low and high intensity thinning from below were very unpopular choices. The few people that did choose those options steer the results very heavily in their direction. Especially in the case of the dummy variables there is little variation. For example, one person in the sample has a bachelor degree as highest level of completed education. If this person very often chose high intensity thinning from below, where almost none of the other respondents did so, then it makes sense that having a bachelor degree is an almost perfect predictor for choosing this type of harvest intervention choice.

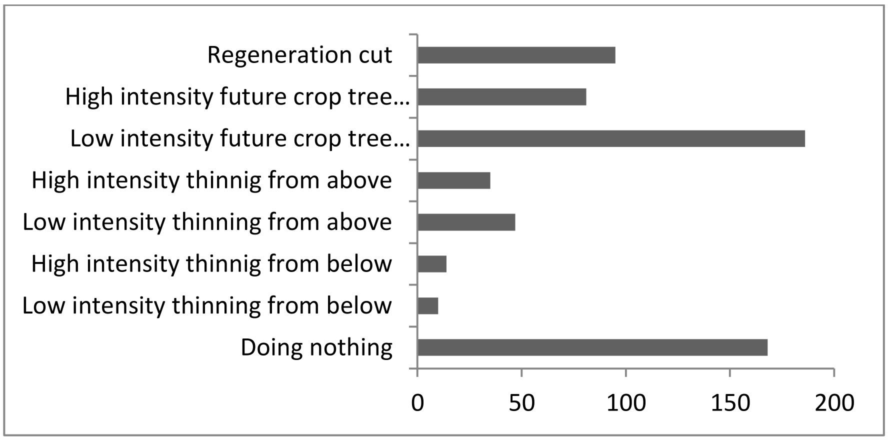


Figure 11: Frequency table on the amount of times a certain harvest intervention choice was made (n=636).

(Quasi-)complete separation is not necessarily an analytical problem (UCLA, 2008). It is more problematic for the generalization of the model. Affected variables have a very poor external validity. This is most likely the case for any choices related to thinning from below, the employment variables, and the education variables. The other variables in the model seem to be unaffected. Taking out the affected variables, however, would bias the variables which are not affected and left in the model (UCLA, 2008). Combining some of the choice categories could solve the issue of having not enough data for each category. However, that would also introduce statistical noise. There are differences between predictor values for low and high intensity thinning options. This predictive power would be lost if the choice categories are collapsed. Therefore, it was decided not to interfere. Quasi-complete separation could lead to a goodness of fit statistic not being reliable (UCLA, 2008). Taking out all possible problematic variables reduces McFadden's R^2 to 0.15, which indicates a worse goodness of fit. Although this most likely is an underestimation as many variables are only problematic in one or two choice options (thinning from below, and in particular high intensity thinning from below) and perfectly fine predicting the other choice options.

4.3 Other results of the questionnaire

While the main part of the choice experiment consisted of discrete choice options, there were two instances in which respondents could use text answers to clarify their choices. First of all, they could specify which type of regeneration cut they would like to implement when they previously selected the discrete option of applying a regeneration cut. Secondly, at the end of the choice experiment they could provide the most important reasons for the decisions which were made during the experiment. These answers have been analyzed using emergent coding (see Stuckey, 2015), which means that similar answers were grouped and given a label based on their shared meaning.

4.3.1 The type of regeneration cut

Figure 12 shows the specific types of regeneration cut options, which forest managers would like to have applied for the experimental stands. It is clear that group cut and seed tree cut are the most popular regeneration cut options. They together explain more than 50% of the choices, while no other type of regeneration cut reached more than 5%. Nature oriented forest transformation does explain 15% of the choices, but that is not really a regeneration cut option, but more a general description of how respondents would like to alter the goal of the forest.

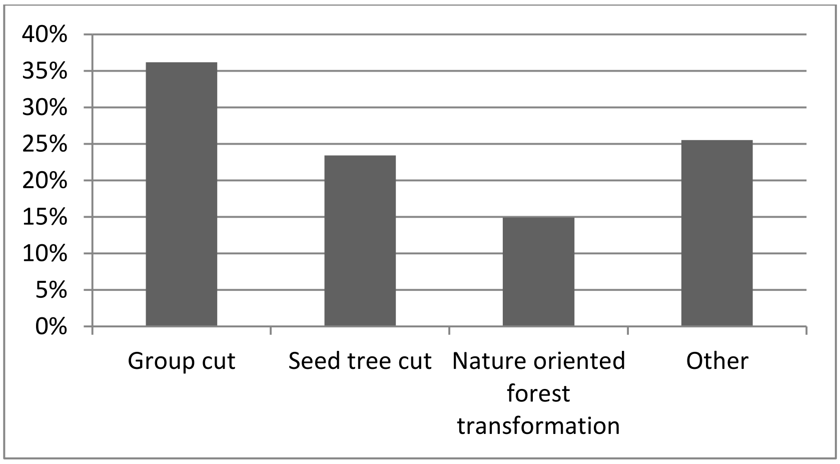


Figure 12: Most common specifications of the rejuvenation cut option. Only those regeneration cut options are mentioned in a separate category which make up at least 5% of the answers (n=94).

4.3.2 The most important decision factor

Respondents in the experiment could each mention the three main factors which they took into consideration when making their choices in the experiment. The most important factors are described in Figure 13. It is clear that species composition and age are the most important factors which forest managers take into account when making harvest intervention decisions, they are both mentioned more than 20 times. Ground area, ensuring rejuvenation, and creating diversity are mentioned almost half so many times. Crown closure, limited intervention, increment and high quality of wood also made up more than 5% of the answers.

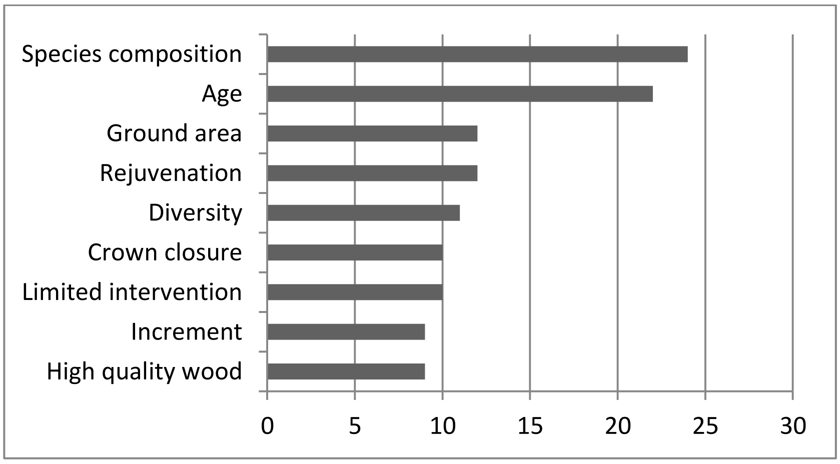


Figure 13: Most important factor count of the factors which were taken into consideration by the respondents when they made their decisions. Only those factors are mentioned which make up at least 5% of the answers (n=159).

4.3.3 Respondents reflection on the experiment

The last part of the questionnaire included the possibility to reflect on the general questionnaire, and the experiment in particular. It seems that the respondents enjoyed taking part in the experiment. 92% of the respondents have expressed that they would like to receive a summary of the most important results of the study, which indicates the relevance of the topic and the interest of forest managers in insights about forest management decision-making. 72% of the respondents are willing to provide an explanation for the choices they made in the experiment in some kind of follow-up study. These forest managers have clearly taken the experiment seriously as they would be able to explain their choices. A small amount of the respondents noted how they hit some obstacles during the experiment. The time of the experiment was one factor, while unclarity about the Holt and Laury task was another factor. Table 20 shows how the duration of the experiment is not significantly correlated to most of the choices and that the size of the effect is very small in the cases where there is a significant relation.

Table 20: MLR of duration on the choice variable, expressed in Relative Risk Ratio's (RRR) (n=636).

VARIABLES	Doing nothing (base-option)	Low intensity thinning from below	High intensity thinning from below	Low intensity thinning from above	High intensity thinning from above	Low intensity future crop tree thinning	High intensity future crop tree thinning	Regeneration cut
Duration	-	0.100 (0.000274)	0.998 (.00177)	1.00*** (6.17e-07)	1.00* (4.60e-06)	1.00*** (4.39e-07)	1.00 (7.04e-07)	1.00 (6.85e-07)
Constant	-	0.0947*** (0.0618)	0.901 (1.976)	0.276*** (0.0585)	0.215*** (0.0482)	1.078 (0.164)	0.482 (0.110)	0.558 (0.134)

Robust clustered standard errors are in parentheses
*** p<0.01, ** p<0.05, * p<0.1

It is expected that not all respondents feel the need to express their opinions on the experiment. Therefore, it is striking that 23% of the final comments were about the experiment being too much a simplification of reality. Anonymous respondent nr.11 wrote: "*The harvest intervention options are too limited and in some cases not completely fitting*." ["De beheermaatregelen zijn te beperkt en in sommige gevallen geheel niet passend."] In various ways, the respondents express how forest management as a work field is complicated and that in order to make decisions about the stands, one should go out into the forest or at least have a picture of the forest. Anonymous respondent nr. 24, for example, wrote: "*For forest mangement, we usually look at the trees to figure out where it should go to ('ask the trees')*." ["Bij het bosbeheer kijk ik doorgaans naar de bomen om te weten te komen waar het heen moet ('vraagt het de bomen')."]. Wood quality is one of the values which can only be assessed by looking at the forest according to the respondents. Moreover, comments expressed how context information was lacking and how various mixed methods and individual forest management techniques were not possible in the context of the experiment. Harvest intervention options related to QD-forestry[3], which is becoming more popular in Dutch forestry were, for example, not possible in the context of the experiment. Some respondents would have liked to intervene in the undergrowth or would have liked to take out exotic species.Anonymous respondent nr. 32, therefore, stated: "*We usually look in the forest to decide if and how we would like to intervene and consider this theoretical approach as just a fun exercise*." ["Wij kijken doorgaans in het bos om te bepalen of en wat we doen en zien deze theoretisch benadering slechts als een leuke vingeroefening maar niet richtinggevend."].

[3] Qualifizieren-Dimensionieren (QD) forest mangement orienated in Germany and is based on the realization of a small amount of future crop trees which should produce (extremely) high quality wood (Olsthoorn, 2014).

5 Discussion & recommendations

The discussion consists of four parts. Section 5.1 reflects on the various results. It tries to explain why certain results have been found and how these results compare to previous research. Section 5.2 reflects on the methodology. It puts the results in perspective and explains the difficulties which have been faced in the setting up and analyzing the experiment. Section 5.3 reflects on the theory. It explains how the temporal setting, and reflects on the rationality assumption. Finally, section 5.4 provides recommendations for science and policy.

5.1 Reflection on the results

5.1.1 Harvest interventions

This study shows that Dutch forest managers use various harvest interventions in the management of multifunctional forests (with forest characteristics as described in section 3.2.2). Future crop tree thinning is most commonly used, while doing nothing is also perfectly acceptable management approach. Relatively low impact rejuvenation cut options (e.g. small group cuts) are preferred over high impact regeneration cut options (e.g. clear cutting). The results are in line with current thoughts about forest management and the economic situation of forest managers. Low intervention forest management with much attention for natural processes is becoming the leading paradigm in (Dutch) forest management (Schelhaas et al., 2005; Franklin et al., 2018). Additionally, as nature subsidies have decreased, it has become more important for forest managers to decrease costs (Nabuurs et al., 2016). Low intervention management and future crop tree thinning, in specific, are useful tools in increasing (cost) efficiency. Future crop tree thinning requires relatively little labor as trees only have to be selected once (Cornelis et al., 2018). Moreover, only areas around future crop trees have to be managed while the rests of the forest can develop naturally.

5.1.2 Factors explaining harvest interventions

Besides looking into the of harvest interventions choices, the goal of this study was also to explain why these choices are made. Table 21 and 22 provide a general overview of the variables which can significantly be correlated to either low intervention management (doing nothing), or high intervention management (using (heavy) thinning and regeneration cuts). It is clear that the significant predictors of either low or high intervention choices are mainly individual characteristics (e.g. education) and stand characteristics (e.g. ground area). The other factors in the EKB-model (social influences, situational influences, and memory) seem not to be of relevance in making harvesting decisions.

Table 21 and Table 22: Overview of variables that successfully explain low or high intervention management.

Significant for low intervention management
Individual characteristics:
Education (university bachelor degree (WO))
Education (university specialized degree (PHD))
Forestry degree
Specialization (ecology)
Specialization (economics)
Forest manager identity
Social Influences:
Employment (Landschappen NL)

Significant for high intervention management
Stand characteristics:
Ground area
Volume standing dead wood
Diameter of the middle tree of the main tree species
Individual characteristics:
Specialization (recreation/tourism)
Specialization (stewardship)
Self-assessed professionalism

5.1.2.1 Low intervention management as paradigm in forestry education

Table 21 illustrates that forest managers who hold a degree in forest and nature conservation (which means that they have successfully finished forest and nature conservation education at MBO, HBO or WO level) are more likely to apply low intervention forest management, especially if they specialized in ecology or economics during their studies. This can be explained by the broad focus of modern forest and nature conservation education which has diverted from a focus on production forestry. Up to the 1980s, forest education was focused on wood production, forest exploitation, forest economics, and stewardship (Mohren and Wijdeven, 2016). Forest management became a more open discipline under the influence of a more prosperous society in which recreation became increasingly important (Hirt, 1996), public concern for the environment (Brown, 2003), and low wood prices combined with increased subsidies for recreation and conservation (Verbij, 2008). Nature became the dominant theme in research and education and forests became a part of nature (Mohren and Wijdeven, 2016).

Another strong predictor for low intervention forest management is the variable which reflects 'being a forest manger'. It is difficult to assess why this is the case. The term 'forest manager' is perhaps the best fitting term for someone believes in the ideas of multifunctional forest management, especially compared to the term 'forester' or 'nature manager', which were mentioned in the same block of questions in the survey. More research is necessary to correctly identify the role of culture and identity to confirm this thesis. It is also not yet clear why working for Landschappen NL is a good predictor for low intervention management while many other employment variables are not-significant predictors of choice behavior.

5.1.2.2 Explaining significant predictors of high intervention management

There are two types of factors which explain why forest managers make use of high intervention forest management. First of all, there are stand characteristics which explain in which situation high intervention management is applied. Table 21 shows that ground area, volume of standing dead wood, and the diameter of the middle tree explain these choices. In the case of ground area and diameter of the middle three is makes sense that an increase in the amount of wide trees would increase the probability of a harvest intervention decision. It is unknown how standing dead wood influences this decision. Most likely, this variable is correlated to endogenous variables.

Secondly, there are personal characteristics which explain high intervention management. Having specialized in stewardship or recreation/tourism during your education proves to be a successful predictor. These specializations are more commercially orientated than other specializations, which could explain their effect. Another explanation is that estate forests are historically differently managed. Thinning is used in these forests to remove clutter in understory layers in order to create an estate forest with tall trees and a clean look (Den Ouden et al., 2010). It is surprising that self-assessed professionalism has such a strong positive relationship with the regeneration cut option, while keeping other variables constant. A possible explanation could be a physiological phenomenon in which 'real' foresters are assumed not to be afraid to harvest and while more amateurish forest managers are not as decisive. Again, more research is necessary to correctly identify the effect of culture and personal identity on harvest intervention decisions.

5.1.3 Factors not explaining harvest interventions

Despite that several stand characteristics influence decision-making, it is interesting to note that several stand characteristics - in contrast to expectations - do not seem to be significant. Especially the age of the stand would logically have been expected to show a strong correlation with the choice variable, as becomes clear from the text answers the respondents provided (see Figure 13). The main explanation of the lack of significant results in respect of these variables is a lack of variation in the choice stands. Only twelve stands are part of the set-up of the experiment which means that there are only twelve data points for each stand characteristic. This proved not to be enough to clearly distinguish which factor was steering a decision process, which also (partly) explains (extreme) multicollinearity in the stand characteristics.

Similar to Sauter et al. (2015), the experiment has shown that many individual characteristics and social influences are not significant predictors of choice behavior. Duerr and Duerr (1975) provide a possible explanation for the small differences between choices made by various forest managers. Duerr and Duerr (1975), namely, consider forest managers to be their own sub-culture, with their own doctrines (such as the doctrine of sustained yield). Shared professional culture can, therefore, explain why forest management is not as diverse between various groups of forest managers.

Variables related to risk are also found not to be significant. Similar to what Mußhoff and Maart-Noelck (2014) found, there is no effect of the HL-value. It also does not seem to matter how changes in wood prices are perceived and if past disturbances had been experienced. Blennow (2008) provides three explanations for risk related variables not to be significant. The first is the defeatist approach. Blennow (2008) states that forest managers accept external disturbances as natural occurrences. Natural hazards, other than technological risks, are part of life and do not have to be modulated. A second explanation would be that the stakes are simply not high enough. De Bruin et al. (2015), shows that uncertain factors are rarely considered important factors in forest management. Natural disasters, for example, do result in damage but mitigating this damage might be more expensive or troublesome than just accepting the risk. The third explanation suggested by Blennow (2008) is that forestry is an enterprise free of valuation. Putting a prize on potential risks is uncommon practice because putting a price on any part of forestry is uncommon. Additionally to Blennow (2008), a fourth explanation could be that the experiment's stands were already diverse which meant that management interventions would not result in a highly reduced risk of external damages.

The fact that the 'perceptions of wood prices' is not significant proves that forest managers are not rational profit maximizers. The doctrine of the long run could potentially explain the lack of a significant result. Long term investment is a common approach to deal with volatility in stock prices when investors in the financial market are faced with uncertainty (e.g. Rajublu, 2011). As there is no indication it is easy to predict changes in the wood market one can use a similar strategy as long term investors. If forest managers do not try to time the market, but always sell wood in similar intervals, then they would sometimes get good prices while other times they would get bad prices. Overall, if the principles of long term investment hold, forest managers would receive an average price over the years without too much trouble. This could be a satisfactory result for many forest managers.

This study does not always match with previous results. Binkley (1981), Dennis (1998), Joshi and Arno (2009), Garcia et al. (2014), Petucco et al. (2015), and Mußhoff and Maart-Noelck (2014) show that many other individual characteristics and social variables do significantly relate to harvest choices (see section 2.5.2). Another potential explanation of non-significant results is simply a lack of variation in the respondent's characteristics, which is especially low in the case of dummy variables. Specifically, in the case of risk attitude there is also the possibility that risk should be measured differently, as suggested by Mußhoff and Maart-Noelck (2014).

5.2 Reflection on the method

5.2.1 Putting the results in a temporal perspective

Time is always a factor in experimental research as there are always developments which influence the way decisions are made. The results of this research report were collected in the summer of 2019. This timeframe can be characterized by a big public debate about harvesting wood in the Netherlands (e.g. Spijkers, 2019). As this mainly was a public debate, it can be expected that forest professionals were not affected too much in their decision making. This time frame can also be characterized by concerns about the rapid spread of exotic species such as the oak processionary caterpillar (Thaumetopoea processionea) (Spijker et al., 2019) and plant diseases such as the ash dieback epidemic (Kopinga and De vries, 2015). These phenomena result in calls for more diverse forest (Staatsbosbeheer, 2015), which might have influenced the results. Panel data and repeated experiments would be necessary to extract the influence of a certain timeframe on harvest intervention choices.

5.2.2 The issue of a small sample size

The sample size (n=53) was too small, as described in section 3.4, to make reliable inferences about all variables in the study. However, the response rate of the personal e-mails (31-40%) was considerably higher than the response rate of similar studies. Sauter et al. (2016) had a response rate of 7%, while Mußhoff and Maart-Noelck (2014) had a 19% response rate. This suggests that the main issue of not reaching a larger sample size was a lack of a larger contact list.

The small sample is, combined with the low variation in the choice stands, responsible for the issue of (quasi-)complete separation (see section 4.2). As explained in section 4.2, (quasi-)complete separation does not bias the results but does result in an overestimation of the goodness of fit statistic. The results show that a pseudo R^2 of 0.15 can be reached in a model estimation without any problematic variables. This indicates that the full model is still reasonably capable of explaining choice behavior. Although it cannot be tested, it is likely that the explanatory power of the non-problematic part of partly problematic variables will take the pseudo R^2 over the threshold of 0.2, which indicates an excellent goodness of fit according to McFadden (1974).

It is important to realize that the main problem of small size datasets in maximum likelihood estimations is a type II error and not a type I error according to Hart and Clark (1999). A type I error would be more problematic as one would find significant relationships between variables which are not there in practice (false positive). In the case of type II errors one cannot find significant relationships between variables while in reality these relationships do exist (false negative). It is not ideal that these results might be overlooked. However, if there is a really strong relationship between two variables then it should also be presents in a small sample data set.

There are some solutions to the issue of the small sample size in these types of experiments. New choice experiment studies could add more variation in choice alternatives by a random selection of choice alternatives for each respondent. The introduction of more effective data collection methods could also increase the amount of individual data. The Dutch forest inventory could, for example, start collecting socio-economic data about forest managers with their usual data collection. In terms of analysis, future studies could make use of an exact logistic regression to deal the issues of small data sets. However, this type of analysis can only be used with a binary dependable variable and does not work with (quasi-)complete separation, which was the reason why it was not used in this report.

5.3 Reflection on the theory

5.3.1 Complexity and hypothetical bias

Respondents took on average 36 minutes to complete the experiment, which was much higher than the anticipated 15 minutes. It seems that this did not bias the results. Respondents seemed very serious in answering the (open) questions, even in the later stage the questionnaire. There is also no strong significant relation between the duration of the experiment and the choice variable in a simple MLR regression (Table 20). The duration of the experiment could, however, explain why some respondents did not finish the questionnaire. There are two possible options why it took respondents a long time the finish. Either, there were too many choice options or the questionnaire in its completeness was still too complex. A further reduction of the choice situations is also not possible. There is already not enough variation in the choice stands for each forest characteristics to individually be able to explain a choice trend. Reducing complexity will also be difficult. Some respondents already noted how choice options, forest characteristics, and context information was missing in the current set-up. Simplifying the experiment would introduce too much hypothetical bias. This raises questions about the feasibility of choice experiments in forestry science which are able to balance complexity and hypothetical bias. A very careful design procedure would be required to improve these experiments in the future.

5.3.2 Reflection on assumed rationality

Discrete choice theory, even when used in sophisticated experiments with sophisticated statistics, still assumes (thin) rational choice. This might be problematic, as some of the results cast doubts on the rationality of forest managers. First of all, there is no significant relationship between expected wood prices and the choice variable. This does not match which rational thought, which assumes that people are profit maximizers. Secondly, there have been inconsistencies in the results of the Holt and Laury task. This shows that expected choice theory is not always able to properly predict choices, even when probabilities are 100% known. Finally, there are respondents who express the need to go into the forest. This could partly be explained by a lack of information in the choice stands. By going into the forest one might, for example, get a better overview of the wood quality. However, this could also be explained by the notion that forest management is not an exact science. More often than not, Dutch forest managers use their intuition when deciding the use of thinning and regeneration measurements according to Van Blitterswijk et al. (2001).

5.4 Recommendations for policy and science

5.4.1 Policy recommendations

The small sample size combined with a lack of variation in choice stands make it very difficult to come up with concrete policy recommendations as many variables have been excluded in the model selection procedure. Of the variables which were in the final model, many are difficult to explain. It is yet unknown how identity influences decision making and to what extent identity of forest managers can be altered. Additionally, there are concerns about hypothetical bias and the rationality assumption which might bias the final results.

However, with the limitations of the study in mind, it is clear that forest and nature conservation education is a place where policy makers can potentially influence harvest intervention choices. It seems that production forestry has become a very small part of the curriculum. More courses which are focused on (sustainable) production forestry and the importance of wood production in a circular economy could result in new generation of forest managers which will make more commonly use of harvest interventions. It will not, necessarily, be easy to change forest and nature conservation education, as (forestry) education often follows changes in society (Brown, 2003). In the current situation where cutting down forests has become increasingly scrutinized in the public debate, this would require a change of the public mindset. However, political commitment for furthering the bio-economy, such as the European Union’s 2015 Circular Economy Strategy and for stopping climate, such as in the Paris Agreement can foster discussions about the future role of wood in our economy (Nabuurs and Van den Briel, 2017).

5.4.2 Science recommendations

The issue of a small sample size or lack of variation in the choice stands can be solved in future studies. More problematic is hypothetical bias. The experiment is stated by (some) respondents to be too simple, but it also takes respondents a very long time to finish. It seems that there is no way of improving the realism of the experiment without increasing the complexity and the duration. As long as this issue is not solved, it does not make sense to use choice experiments by other researchers to investigate harvest intervention decisions. One might as well spend the time of building a very complex choice experiment, on collecting field data (e.g. Petucco et al., 2015) or other types of research. Field data can have a very high external and internal validity if enough data is collected. Novel studies, using computer simulated forests, can balance the benefits of field data and choice experiment, by building a controlling setting which respondents have much freedom to apply harvest intervention decisions (Muys et al., 2010).

Additionally, there is a problem with the rationality assumption. We do not know how this assumption in the analysis skews the results of the choice experiment. It is recommended that researchers use criterion validity tests to check how the results of forest management choice experiments hold up compared to other methods, when one wants to continue with choice experiment in the field of forestry science. Criterion validity tests compare if different research methods get similar results. Future research can investigate the effect of a fixed set of explanatory factors on harvest intervention decisions in an actual forest, a simulated forest, and a choice experiment.

6 Conclusion

Despite the small sample size, lack of variation in choice stands, hypothetical bias, and doubts about the rationality assumption, this research provides new insights in forest management decision making and the use of choice experiments in forestry science. It shows how low intervention forest management is being applied in both thinning and regeneration practices. It has also become clear that individual characteristics such as education and identity, in combination with forest characteristics, such as, ground area, volume of standing dead wood, and the diameter of the middle tree, determine these harvest intervention decisions of Dutch forest managers. Other factors that were included in the research, i.e. social influences, situational influences, and memory, were not of importance. However, considering the explorative nature of the experiment and the challenges experienced, future research should explore potential issues of the choice experiment using criterion validity tests. Until it is clear that the simplified setting of choice experiments, in forestry science, do not bias the results and a solution has been found which makes choice experiments more realistic without adding complexity, it is recommended to use computer simulations and field data to investigate harvest intervention decision making.

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Appendix A: Mathematics

Basic logit models

The basic concept of logit models is based around the premise that 'normal' regression models could predicts odds that are larger than one or smaller than zero when used to estimate the chances that certain events will happen or certain choices will be made. This would violate the normality and homoscedasticity assumption (Sieben, and Linssen, 2009). Log odds (logit) models, as an alternative, predict the natural logarithm of an odds function which results in an odds ratio which is always in between zero and one. If we assume a binary situation where either choice option 1 is chosen or not chosen, then we can mathematically express this as:

$$ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 X_1 + \cdots \qquad [A1]$$

Where: p = the probability that option 1 is chosen;

$\beta_0 + \beta_1 X_1 + \cdots$ = a basic regression model with X's as explanatory variables.

If p>0.5, then this expression (A1) can be rewritten to a function which isolates [p]. In order to get rid of the [ln] function both sides are multiplied with the mathematical constant [e] which gives:

$$\left(\frac{p}{1-p}\right) = exp(\beta_0 + \beta_1 X_1 + \cdots)$$

Both sides are multiplied by (1-p) to get:

$$p = (1-p)exp(\beta_0 + \beta_1 X_1 + \cdots)$$

Solving the brackets gives:

$$p = exp(\beta_0 + \beta_1 X_1 + \cdots) - p(\exp(\beta_0 + \beta_1 X_1 + \cdots))$$

Now we can add $p(\exp(\beta_0 + \beta_1 X_1 + \cdots))$ to both sides to get:

$$p + p(\exp(\beta_0 + \beta_1 X_1 + \cdots)) = exp(\beta_0 + \beta_1 X_1 + \cdots)$$

Taking p out of the brackets:

$$p(1 + \exp(\beta_0 + \beta_1 X_1 + \cdots)) = exp(\beta_0 + \beta_1 X_1 + \cdots)$$

To finally arrive at:

$$p = \frac{exp(\beta_0 + \beta_1 X_1 + \cdots)}{(1 + \exp(\beta_0 + \beta_1 X_1 + \cdots))} \quad [A2]$$

Function (A2) shows the common way in which logit models are expressed. After conducting a maximum likelihood estimation one could replace the beta's with the estimates. Function (A2) could then be used to estimate the likelihood of any person with specific 'X' characteristics choosing option 1.

Multinomial logit models

The multinomial logit model is not so different from a basic logit model. The only difference is that instead of a binary choice alternative there are multiple choice alternatives. For example, there is a person who has to choose between option A, B and C. With mathematics it can be shown that even in this case it is possible to express the probability of choosing one of these alternatives in one single formula (Malakar, 2017). In this example it is assumed that option C is the reference category. The probability that one chooses option A compared to C can then be expressed as:

$$ln\left(\frac{p(A)}{p(C)}\right) = \beta_{0A} + \beta_{1A}X_{1A} + \cdots \quad [A3]$$

Where: p(A) = the probability that option A is chosen;

p(C) = the probability that option C is chosen;

$\beta_{0A} + \beta_{1A}X_{1A} + \cdots$ = a basic regression model with X_A's as explanatory variables.

Getting rid of the [ln] function and by rearranging we get:

$$p(A) = P(C)\exp(\beta_{0A} + \beta_{1A}X_{1A} + \cdots) \quad [A4]$$

Similarly it is possible to express the probability that one chooses option B compared to the reference category C. If the same steps are taken we get:

$$p(B) = P(C)\exp(\beta_{0B} + \beta_{1B}X_{1B} + \cdots) \quad [A5]$$

Now it is important to realize that the odds of choosing either A, B or C should add up to one if these are the only choice options available and everyone made a choice. So:

$$p(A) + p(B) + p(C) = 1 \quad [A6]$$

Next it is possible to plug in expression (A4) and (A5) into expression (A6) which gives:

$$p(C)\exp(\beta_{0A} + \beta_{1A}X_{1A} + \cdots) + p(C)\exp(\beta_{0B} + \beta_{1B}X_{1B} + \cdots) + p(C) = 1$$

Placing $p(C)$ in front of the brackets:

$$p(C)(1 + \exp(\beta_{0A} + \beta_{1A}X_{1A} + \cdots) + \exp(\beta_{0B} + \beta_{1B}X_{1B} + \cdots)) = 1$$

So $p(C)$ is equal to:

$$p(C) = \frac{1}{(1+\exp(\beta_{0A}+\beta_{1A}X_{1A}+\cdots)+\exp(\beta_{0B}+\beta_{1B}X_{1B}+\cdots))} \quad [A7]$$

This function (A7) shows that it possible to express the probability that alternative C is chosen can be expressed in a single formula with beta's that can be estimated and X's which are known explanatory variables. To get the same type of expression for alternative A or B one needs to plug expression [A7] into expression [A4] or into expression [A5]:

$$p(A) = \frac{\exp(\beta_{0A}+\beta_{1A}X_{1A}+\cdots)}{(1+\exp(\beta_{0A}+\beta_{1A}X_{1A}+\cdots)+\exp(\beta_{0B}+\beta_{1B}X_{1B}+\cdots))} \quad [A8]$$

$$p(B) = \frac{\exp(\beta_{0B}+\beta_{1B}X_{1B}+\cdots)}{(1+\exp(\beta_{0A}+\beta_{1A}X_{1A}+\cdots)+\exp(\beta_{0B}+\beta_{1B}X_{1B}+\cdots))} \quad [A9]$$

These expressions show that it also possible to express the probability that alternative A or alternative B is chosen in a single formula. Again, the beta's can be estimated and X's which are known explanatory variables. A general form of the expressions [A7-A9] is used in section 2.4.1 and 3.5. In this general form the number of choice alternatives can be any positive integer (K).

Forest characteristics

Shannon-index

The Shannon-index (Shannon-Weaver Index, Shannon-Weaver index, or 'H') is a common measure used to express species diversity (Spellerberg and Fedor, 2003). It incorporates the number of species as well as the number of individuals of each species present. Its mathematical formula can be expressed as:

$$H = -\sum_{i=1}^{n} \rho_i \ln(\rho_i)$$

[A10]

Where: H = the Shannon-index

ρ_i= the relative probability of a species presence expressed as the number of individuals of species i compared to the total number of individuals N: $\frac{n_i}{N}$.

The Shannon-index can range between 0 and ∞. The higher the index becomes, the more diverse the situation is. As the Shannon-index is a relative measure it does, in principle, not matter whether it is used with the data gathered from the circular plots from the forest inventory or with the data of the upscaled forest stands in the experiment.

Average tree distance

There are various ways in which the clustering of trees on a spatial plane could be expressed. This thesis makes use of the average tree distance. This variable is measured by taking the Euclidian distance of each tree in the circular plot from the forest inventory to all other trees. These distances could be calculated as X-coordinates, Y-coordinates and angels of the location of each tree to the center were collected in the forest inventory using standard geometric calculations. Of all these distances the average was taken to express tree clustering in one single number.

Diameter middle tree

The diameter of the middle tree could be used as a measure for the thickness of the main tree species which is used by (some) forest managers to decide when to do a regeneration cut (Den Ouden et al., 2010). The middle tree is a hypothetical tree with an average ground area measured at 1.30 m. For the main tree species this average ground area is calculated. Using the following formula this can be brought back to a diameter of the hypothetical middle tree:

$$DBH = 2 * \sqrt{\frac{A}{\pi}}$$

[A11]

Where: DBH = diameter breast height (at 1.30 m);

A = ground area middle tree.

Appendix B: Original script

Page 1

Hartelijk dank dat u mee wilt doen met dit onderzoek van de leerstoelgroep Bos- en Natuurbeleid van de Wageningen Universiteit. Het doel van dit onderzoek is inzicht te krijgen in besluitvormingsprocessen rond bosbeheeringrepen van verschillende soorten bosbeheerders in Nederland. In dit onderzoek krijgt u de kans om uw bosbeheerervaringen met ons te delen door middel van een model-oefening. Na deze oefening volgt een loterij-oefening en een aantal algemene vragen. Gemiddeld neemt dit onderzoek 15 minuten in beslag. Uw antwoorden worden uiteraard vertrouwelijk behandeld en anoniem geanalyseerd. Onder de deelnemers van dit experiment wordt 3 keer het boek 'Heibel in de polder' verloot.

Voor vragen of opmerkingen kunt u contact opnemen met drs. M.M.F. Schuurbiers [merlijn.schuurbiers@wur.nl].

Wat voor type bosbeheerder bent u? [B1]

A: Particuliere boseigenaar

B1: Bosbeheerder werkzaam bij een publiekrechtelijke organisatie

B2: Bosbeheerder werkzaam bij een natuurbeschermingsorganisatie

C: Bosbeheerder werkzaam bij een adviesbureau/consultancy bureau

B3: Bosbeheerder werkzaam bij een ander type organisatie

Page 2A

Dit eerste deel van het onderzoek bestaat uit een model-oefening. Stelt u zich voor dat u recent eigenaar geworden bent van een nieuw bosgebied van 60 ha. Uw gehele nieuwe aanwinst ligt, zoals de meeste bossen in Nederland, op een arme zandgrond. De grondwaterstand is diep en het bos is regenwater gevoed. De graasdruk is gering en de hoofdboomsoorten zijn grove den en inlandse eik.

De vorige eigenaar beschrijft in zijn laatste managementplan dat hij een simpele zonering gebruikte op basis van het SNL subsidiestelsel. Het bos bestaat deels uit natuurgericht bos (N15.02 Dennen-, eiken-, en beukenbos) en deels uit multifunctioneel bos (N16.03 Droog bos met productie). In deze oefening richten we ons op het multifunctionele bos. Onderstaand kaartje geeft de situatie voor dat deel van het bos weer.

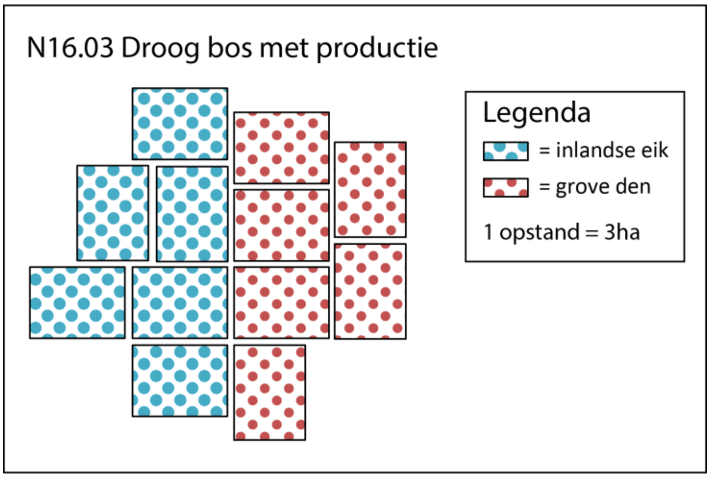

Figure B1: Map of the study site which is made up of twelve stands multifunctional forest. The main tree species, common oak and scots pine are equally present.

Page 3A

Specifiek richt dit onderzoek zich op de 12 opstanden in het multifunctionele bosgebied van elk 3 hectare. Als nieuwe eigenaar van dit gebied is het aan u de keuze welke bosbeheeringrepen u zou willen toepassen op elke opstand. U kunt straks kiezen uit:

- Niets doen
- Laagdunning waarbij u het grondvlak terug dunt tot 24 m2/ha
- Laagdunning waarbij u het grondvlak terug dunt tot 18 m2/ha
- Vrije hoogdunning waarbij u het grondvlak terug dunt tot 24 m2/ha
- Vrije hoogdunning waarbij u het grondvlak terug dunt tot 18 m2/ha
- Toekomstbomen dunning waarbij u 30% (voor eiken) of 50% (voor grove den) van de kroonruimte vrijstelt voor 40 (voor eiken) of 90 (voor grove den) toekomstbomen per hectare
- Toekomstbomen dunning waarbij u 100% van de kroonruimte vrijstelt voor 40 (voor eiken) of 90 (voor grove den) toekomstbomen per hectare
- Een nader door u te specificeren verjongingskap

Als het grondvlak van de keuzeopstand onder de 18 m2/ha zit is een dunning tot 18 m2 fysiek niet mogelijk. Als het grondvlak van de keuzeopstand onder de 24 m2/ha zit is een dunning tot 24 /ha fysiek niet mogelijk. Deze opties worden in dat geval dan ook niet aangeboden.

Om u te helpen met deze keuzes heeft u een bosinventarisatie laten uitvoeren, zodat u voor elke opstand een schatting heeft van een aantal eigenschappen van de bosopstand welke u straks gepresenteerd krijgt. Onderstaande afbeelding geeft een voorbeeld opstand weer.

- In de tabel genaamd '**opstand informatie**' staat alle informatie die uit de bosinventarisatie kwam met betrekking tot leeftijd, houtvoorraad, groeiplaatskwaliteit en omgevingsfactoren.
- In de tabel genaamd '**algemene bosinformatie**' staat nogmaals samengevat hoe het gehele bos er uit ziet waar deze keuzeopstand deel vanuit maakt.
- De figuur geeft grafisch de **steekproefcirkelmeting** weer om een beeld te krijgen van de soortensamenstelling en het plantverband. Ieder punt in deze cirkel staat voor een boom met een DBH van ≥ 5 cm. De straal van de steekproefcirkel is zo groot gekozen dat, in principe, minimaal 20 bomen met een diameter ≥ 5 cm binnen de proefvlakte vallen.
- U kunt er vanuit gaan dat waarden van alle externe factoren waar u geen informatie over krijgt gelijk zijn aan **praktijkwaarden**.

Voorbeeld opstand:

Plot informatie	
Opstand grootte	3 ha
Leeftijd	36 jaar
Grondvlak	14 m^2/ha
Volume	118 m^3
Geschatte bijgroei	6 m^3
Kroonsluiting	10-25%
Bedekkingsgraad struiklaag	0.01-01%
Volume liggend dood hout	19 m^3
Volume staand dood hout	0 m^3
Hoofdboomsoort	Grove den
Diameter middenboom Hoofboomsoort	15 cm
Stamtal hoofdboomsoort	1100 ha^{-1}

Algemene bosinformatie	
SNL-classificering	Droog bos met productie
Bodemtype	Arme zandgrond
Waterhuishouding	Diepe grondwaterstand; Regenwater gevoed
Graasdruk	Gering

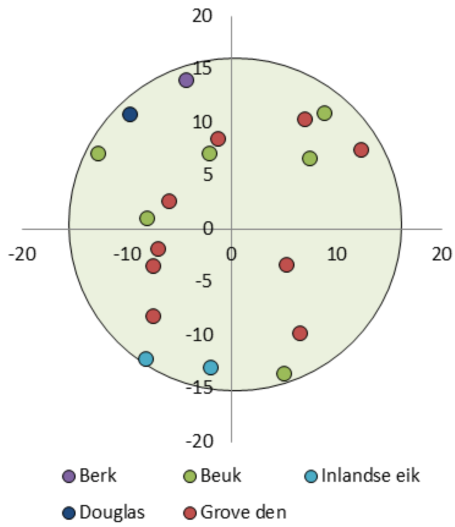

Figure B2: Example of the stand information presented to the respondents which is split into general forest information, specific stand information and a figure showing the species diversity and planting layout. This example is used here to explain how the actual choice stands will look like.

Uit ervaring met vergelijkbare experimenten blijkt dat de antwoorden die gegeven worden in dit soort experimenten niet altijd overeenkomen met gedrag in de praktijk. Het doel van dit onderzoek is echter met deze simulatie de praktijk zo veel mogelijk na te bootsen. Ons verzoek is dan ook de keuzes die u maakt op dezelfde manier te maken als dat u dat in uw dagelijkse beheerpraktijk zou doen.

Hoewel deze oefening gebruik maakt van een fictief bos berusten de waarden, die u straks gepresenteerd krijgt, op werkelijke waarden uit de 6e Nederlandse bosinventarisatie.

Page 2B

Dit eerste deel van het onderzoek bestaat uit een model-oefening. Stelt u zich voor dat organisatie waar u werkzaam bent recent eigenaar is geworden van een nieuw bosgebied van 60 hectare. U bent aangewezen als nieuwe bosbeheerder van dit gebied. De gehele nieuwe aanwinst ligt, zoals de meeste bossen in Nederland, op een arme zandgrond. De grondwaterstand is diep en het bos is regenwater gevoed. De graasdruk is gering en de hoofdboomsoorten zijn grove den en inlandse eik.

De vorige eigenaar beschrijft in zijn laatste managementplan dat hij een simpele zonering gebruikte op basis van het SNL subsidiestelsel. Het bos bestaat deels uit natuurgericht bos (N15.02 Dennen-, eiken-, en beukenbos) en deels uit multifunctioneel bos (N16.03 Droog bos met productie). In deze oefening richten we ons op het multifunctionele bos. Onderstaand kaartje geeft de situatie voor dat deel van het bos weer.

-figure B1-

Page 3B

Specifiek richt dit onderzoek zich op de 12 opstanden in het multifunctionele bosgebied van elk 3 hectare. Als de nieuwe bosbeheerder van dit gebied is het aan u de keuze welke bosbeheeringrepen u zou willen toepassen op elke opstand. U kunt straks kiezen uit:

- Niets doen
- Laagdunning waarbij u het grondvlak terug dunt tot 24 m2/ha
- Laagdunning waarbij u het grondvlak terug dunt tot 18 m2/ha
- Vrije hoogdunning waarbij u het grondvlak terug dunt tot 24 m2/ha
- Vrije hoogdunning waarbij u het grondvlak terug dunt tot 18 m2/ha
- Toekomstbomen dunning waarbij u 30% (voor eiken) of 50% (voor grove den) van de kroonruimte vrijstelt voor 40 (voor eiken) of 90 (voor grove den) toekomstbomen per hectare
- Toekomstbomen dunning waarbij u 100% van de kroonruimte vrijstelt voor 40 (voor eiken) of 90 (voor grove den) toekomstbomen per hectare
- Een nader door u te specificeren verjongingskap

Als het grondvlak van de keuzeopstand onder de 18 m2/ha zit is een dunning tot 18 m2 fysiek niet mogelijk. Als het grondvlak van de keuzeopstand onder de 24 m2/ha zit is een dunning tot 24 /ha fysiek niet mogelijk. Deze opties worden in dat geval dan ook niet aangeboden.

Om u te helpen met deze keuzes heeft u een bosinventarisatie laten uitvoeren, zodat u voor elke opstand een schatting heeft van een aantal eigenschappen van de bosopstand welke u straks gepresenteerd krijgt. Onderstaande afbeelding geeft een voorbeeld opstand weer.

- In de tabel genaamd '**opstand informatie**' staat alle informatie die uit de bosinventarisatie kwam met betrekking tot leeftijd, houtvoorraad, groeiplaatskwaliteit en omgevingsfactoren.
- In de tabel genaamd '**algemene bosinformatie**' staat nogmaals samengevat hoe het gehele bos er uit ziet waar deze keuzeopstand deel vanuit maakt.
- De figuur geeft grafisch de **steekproefcirkelmeting** weer om een beeld te krijgen van de soortensamenstelling en het plantverband. Ieder punt in deze cirkel staat voor een boom met een DBH van ≥ 5 cm. De straal van de steekproefcirkel is zo groot gekozen dat, in principe, minimaal 20 bomen met een diameter ≥ 5 cm binnen de proefvlakte vallen.
- U kunt er vanuit gaan dat waarden van alle externe factoren waar u geen informatie over krijgt gelijk zijn aan **praktijkwaarden**.

Voorbeeld opstand:

-figure B2-

Uit ervaring met vergelijkbare experimenten blijkt dat de antwoorden die gegeven worden in dit soort experimenten niet altijd overeenkomen met gedrag in de praktijk. Het doel van dit onderzoek is echter met deze simulatie de praktijk zo veel mogelijk na te bootsen. Ons verzoek is dan ook de keuzes die u maakt op dezelfde manier te maken als dat u dat in uw dagelijkse beheerpraktijk zou doen.

Hoewel deze oefening gebruik maakt van een fictief bos berusten de waarden, die u straks gepresenteerd krijgt, op werkelijke waarden uit de 6e Nederlandse bosinventarisatie.

Page 2C

Dit eerste deel van het onderzoek bestaat uit een model-oefening. Stelt u zich voor dat u recent gevraagd bent door de organisatie waar u werkzaam bent om beheeradvies te geven aan de nieuwe eigenaar van een 60 hectare groot bosgebied. Dit bos, zoals de meeste bossen in Nederland, ligt op een arme zandgrond. De grondwaterstand is diep en het bos is regenwater gevoed. De graasdruk is gering en de hoofdboomsoorten zijn grove den en inlandse eik.

De vorige eigenaar beschrijft in zijn laatste managementplan dat hij een simpele zonering gebruikte op basis van het SNL subsidiestelsel. Het bos bestaat deels uit natuurgericht bos (N15.02 Dennen-, eiken-, en beukenbos) en deels uit multifunctioneel bos (N16.03 Droog bos met productie). In deze oefening richten we ons op het multifunctionele bos. Onderstaand kaartje geeft de situatie voor dat deel van het bos weer.

-figure B1-

Page 3C

Specifiek richt dit onderzoek zich op de 12 opstanden in het multifunctionele bosgebied van elk 3 hectare. Als adviseur is het aan u de keuze welke bosbeheeringrepen u zou willen toepassen op elke opstand. U kunt straks kiezen uit:

- Niets doen
- Laagdunning waarbij u het grondvlak terug dunt tot 24 m2/ha
- Laagdunning waarbij u het grondvlak terug dunt tot 18 m2/ha
- Vrije hoogdunning waarbij u het grondvlak terug dunt tot 24 m2/ha
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- Toekomstbomen dunning waarbij u 30% (voor eiken) of 50% (voor grove den) van de kroonruimte vrijstelt voor 40 (voor eiken) of 90 (voor grove den) toekomstbomen per hectare
- Toekomstbomen dunning waarbij u 100% van de kroonruimte vrijstelt voor 40 (voor eiken) of 90 (voor grove den) toekomstbomen per hectare
- Een nader door u te specificeren verjongingskap

Als het grondvlak van de keuzeopstand onder de 18 m2/ha zit is een dunning tot 18 m2 fysiek niet mogelijk. Als het grondvlak van de keuzeopstand onder de 24 m2/ha zit is een dunning tot 24 /ha fysiek niet mogelijk. Deze opties worden in dat geval dan ook niet aangeboden.

Om u te helpen met deze keuzes heeft u een bosinventarisatie laten uitvoeren, zodat u voor elke opstand een schatting heeft van een aantal eigenschappen van de bosopstand welke u straks gepresenteerd krijgt. Onderstaande afbeelding geeft een voorbeeld opstand weer.

- In de tabel genaamd ‘**opstand informatie**’ staat alle informatie die uit de bosinventarisatie kwam met betrekking tot leeftijd, houtvoorraad, groeiplaatskwaliteit en omgevingsfactoren.
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- De figuur geeft grafisch de **steekproefcirkelmeting** weer om een beeld te krijgen van de soortensamenstelling en het plantverband. Ieder punt in deze cirkel staat voor een boom

met een DBH van ≥ 5 cm. De straal van de steekproefcirkel is zo groot gekozen dat, in principe, minimaal 20 bomen met een diameter ≥ 5 cm binnen de proefvlakte vallen.

- U kunt er vanuit gaan dat waarden van alle externe factoren waar u geen informatie over krijgt gelijk zijn aan **praktijkwaarden**.

Voorbeeld opstand:

-figure B2-

Uit ervaring met vergelijkbare experimenten blijkt dat de antwoorden die gegeven worden in dit soort experimenten niet altijd overeenkomen met gedrag in de praktijk. Het doel van dit onderzoek is echter met deze simulatie de praktijk zo veel mogelijk na te bootsen. Ons verzoek is dan ook de keuzes die u maakt op dezelfde manier te maken als dat u dat in uw dagelijkse beheerpraktijk zou doen.

Hoewel deze oefening gebruik maakt van een fictief bos berusten de waarden, die u straks gepresenteerd krijgt, op werkelijke waarden uit de 6e Nederlandse bosinventarisatie.

Page 4-23

In de onderstaande tabellen en figuur wordt de informatie uit de uitgevoerde bosinventarisatie gepresenteerd.

In de tabel genaamd 'opstand informatie' staat alle informatie die uit de bosinventarisatie kwam met betrekking tot leeftijd, houtvoorraad, groeiplaatskwaliteit en omgevingsfactoren.

In de tabel genaamd 'algemene bosinformatie' staat nogmaals samengevat hoe het gehele bos er uit ziet waar deze keuzeopstand deel vanuit maakt.

De figuur geeft grafisch de steekproefcirkel meting weer om een beeld te krijgen van de soortensamenstelling en het plantverband. Ieder punt in deze cirkel staat voor een boom met een DBH van ≥ 5 cm. De straal van de steekproefcirkel is zo groot gekozen dat, in principe, minimaal 20 bomen met een diameter ≥ 5 cm binnen de proefvlakte vallen.

Plot informatie	
Opstand grootte	3 ha
Leeftijd	36 jaar
Grondvlak	14 m^2/ha
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Geschatte bijgroei	6 m^3
Kroonsluiting	10-25%
Bedekkingsgraad struiklaag	0.01-01%
Volume liggend dood hout	19 m^3
Volume staand dood hout	0 m^3
Hoofdboomsoort	Grove den
Diameter middenboom Hoofboomsoort	15 cm
Stamtal hoofdboomsoort	1100 ha^{-1}

Algemene bosinformatie	
SNL-classificering	Droog bos met productie
Bodemtype	Arme zandgrond
Waterhuishouding	Diepe grondwaterstand; Regenwater gevoed
Graasdruk	Gering

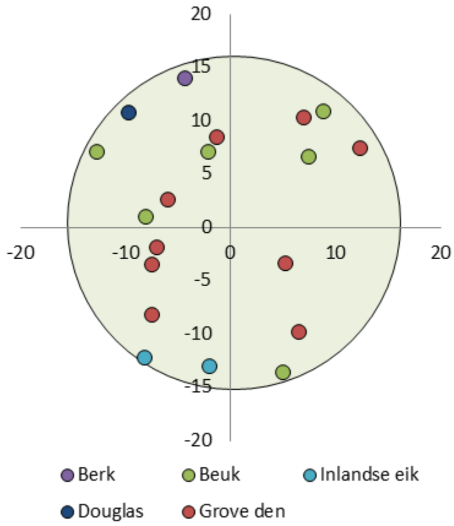

Figure B3: Example of the stand information presented to the respondents which is split into general forest information, specific stand information and a figure showing the species diversity and planting layout. There are twelve different stand information pictures corresponding to each choice object (see Appendix D: Choice objects).

Wat voor bosbeheeringreep wilt u toepassen op deze opstand? [B2-B24]

A: Niets doen

B: Laagdunning: grondvlak terug dunnen tot 24 m2/ha

C: Laagdunning: grondvlak terug dunnen tot 18 m2/ha

D: Vrije hoogdunning: grondvlak terug dunnen tot 24 m2/ha

E: Vrije hoogdunning grondvlak terug dunnen tot 18 m2/ha

F: Toekomstbomendunning: dunnen tot 30%/50% van de kroonruimte vrij is voor de 40/90 toekomstbomen per ha

G: Toekomstbomendunning: dunnen tot 100% van de kroonruimte vrij is voor de 40/90 toekomstbomen per ha

H: Verjongingskap

U heeft gekozen voor het inzetten van een verjongingskap. U kunt hier toelichten van welk type verjongingskap u gebruik wilt maken. U hoeft alleen het type kap aan te geven en hoeft niet in te gaan op herplantingstrategieën. Van welk type verjongingskap wilt u gebruik maken? [B3-B25]

[Open veld]

Page 24

Wat waren de drie belangrijkste overwegingen bij de keuzes die u zojuist voor dit bos gemaakt heeft?

[B26]

[Open veld 1]

[Open veld 2]

[Open veld 3]

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Waar u zojuist bosbeheer keuzes heeft gemaakt gaan we nu over naar ander soort vraag. In dit deel van het onderzoek kijken we naar een loterij.

Onder deze tekst staan 10 keuzemogelijkheden. In deze loterij kunt u voor iedere keuzemogelijkheid kiezen tussen twee verschillende opties. Gekoppeld aan iedere optie hangt een relatieve kans om een bepaald geldbedrag te winnen. U bent vrij om in sommige keuzerijen de eerste optie te kiezen en in andere de tweede optie, om keuzes te herzien en om de keuzes in willekeurige volgorde te maken.

Net als bij het eerste deel van dit experiment, gaat het hier om een hypothetische situatie. Geldbedragen worden dus niet uitgekeerd. We zijn geïnteresseerd in de keuzes die u zou maken als deze geldbedragen wel zouden worden uitgekeerd.

Geeft u alstublieft aan wat uw voorkeuren zijn bij elk van de loterij paren [B27-B36]

Keuze nummer	Optie A	Optie B
1	10% kans op €200; 90% kans op €160	10% kans op €385; 90% kans op €10
2	20% kans op €200; 80% kans op €160	20% kans op €385; 80% kans op €10
3	30% kans op €200; 70% kans op €160	30% kans op €385; 70% kans op €10
4	40% kans op €200; 60% kans op €160	40% kans op €385; 60% kans op €10
5	50% kans op €200; 50% kans op €160	50% kans op €385; 50% kans op €10
6	60% kans op €200; 40% kans op €160	60% kans op €385; 40% kans op €10
7	70% kans op €200; 30% kans op €160	70% kans op €385; 30% kans op €10
8	80% kans op €200; 20% kans op €160	80% kans op €385; 20% kans op €10
9	90% kans op €200; 10% kans op €160	90% kans op €385; 10% kans op €10
10	100% kans op €200; 0% kans op €160	100% kans op €385; 0% kans op €10

Page 26

In dit laatste deel van het experiment willen we u enkele achtergrondvragen stellen. Net bij de andere onderdelen van dit experiment worden ook deze antwoorden vertrouwelijk behandeld en anoniem geanalyseerd.

In welke regio van Nederland houdt u zich overwegend bezig met bosbeheer (zie onderstaande afbeelding)? [B37]

A: Noord

B: Oost

C: West

D: Zuid

Figure B4: NUTS1 regions in the Netherlands (Piccolo Modificatore Laborioso, 2008).

Wat is uw geslacht? [B38]

A: Man

B: Vrouw

C: Anders (toelichting)

Wat is uw leeftijd? [B39]

[Open veld]

Wat is uw hoogst genoten afgeronde opleiding? [B40]

A: Lager dan middelbare school

B: Middelbare school

C: MBO opleiding

D: HBO opleiding

E: WO bachelor

F: WO master

G: Phd

Heeft u een diploma in de richting van Bos- en Natuurbeheer (op MBO, HBO of WO niveau)? [B41]

A: Ja

B: Nee

Waar heeft u naast bosbeheer extra nadruk op gelegd binnen u studie? (meerdere antwoorden zijn mogelijk) [B42]

A: Ecologie

B: Economie

C: Houthandel

D: Recreatie/toerisme

E: Rentmeesterij

F: Anders (specificeer)

Hoeveel jaar bent u al actief in bosbeheer? [B43]

[Open vraag]

Page 28

Waar werkt u? [B44]

A: Bosgroepen

B: Eigen advies bureau

C: Gemeente

D: Hoge school

E: Landschappen NL

F: Ministerie van Defensie

G: Ministerie van Financiën

H: Natuurmonumenten

I: Provincie

J: Staatsbosbeheer

K: Universiteit

L: Werkeloos

M: Anders (specifieer)

Is bosbeheer uw hoofd of nevenfunctie? [B45]

A: Hoofdfunctie

B: Nevenfunctie

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Bij de volgende vragen kunt u met behulp van een slider antwoord geven.

Hoe actief bent u bij een beroepsvereniging (KNBV, NVR, etc.)? [B46]

0: Totaal niet actief

1000: Zeer actief

Hoe professioneel vindt u zichzelf in de rol van bosbeheerder? [B47]

0: Amateur

1000: Professional

In hoeverre identificeert u zich met de term bosbouwer? [B48]

0: Totaal niet

1000: Volledig

In hoeverre identificeert u zich met de term bosbeheerder? [B49]

0: Totaal niet

1000: Volledig

In hoeverre identificeert u zich met de term natuurbeheerder? *[B50]*

0: Totaal niet

1000: Volledig

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Bij de volgende vragen kunt u met behulp van een slider antwoord geven.

Hoe belangrijk zijn financiële aspecten in bosbeheer voor u? [B51]

0: Totaal niet belangrijk

1000: Erg belangrijk

Hoe belangrijk zijn natuurwaarden voor bosbeheer voor u? [B52]

0: Totaal niet belangrijk

1000: Erg belangrijk

Hoe belangrijk zijn recreatiewaarde voor bosbeheer voor u? [B53]

0: Totaal niet belangrijk

1000: Erg belangrijk

Wat vindt u van de huidige (juli 2019) houtprijzen? [B54]

0: De houtprijs is erg laag

1000: De houtprijs is erg hoog

Page 29

Hoe groot is het bos wat u in beheer heeft (in hectares)? [B55]

[open vraag]

Wat voor type bos heeft u in beheer? [B56]

A: Overwegend loofbos

B: Overwegend naaldbos

C: Overwegend gemengd bos

Hoe is de groeiplaatskwaliteit van het bos wat u beheert? [B57]

0: Erg slecht

1000: Erg goed

Heeft u de afgelopen 5 jaar grote verstoringen meegemaakt van het bos dat u beheert zoals windworp of een bosbrand? [B58]

A: Ja

B: Nee

Page 30

Hiermee bent u aan het einde van de vragenlijst gekomen. Onze hartelijke dank voor uw deelname. U kunt hieronder uw e-mailadres achterlaten om kans te maken op het boek 'Heibel in de polder'. Ook kunt u aangeven of we eventueel contact met u zouden mogen opnemen voor een eventuele toelichting van uw gegeven antwoorden en of u een terugkoppeling van de resultaten wilt ontvangen.

Vul hier uw e-mailadres in om mee te loten [B59]

[Open vraag]

Ik ben bereid om toelichting te geven bij mijn antwoorden, mocht dat nodig zijn. [B60]

A: Ja

B: Nee

Ik ontvang graag een terugkoppeling van de resultaten van dit onderzoek. [B61]

A: Ja

B: Nee

Page 31

Nogmaals bedankt voor uw deelname. U kunt dit venster nu sluiten.

Appendix C: Translated script

Page 1

Thank you very much for participating in this research from the Forest and Nature Policy chair group of the Wageningen University. The goal of this research is to get an understanding of the decision-making processes of different types of forest managers in the Netherlands. In this research you will be given to opportunity to share your experiences with forest management through a model exercise. After this exercise a lottery will follow as well as a number of general questions. On average this research takes up 15 minutes of your time. Your answers will, of course, be treated confidentially and will be analyzed anonymously. The book 'Heibel in the polder' will be raffled 3 times among the respondents of this experiment.

For questions or comments you can contact drs. M.M.F. Schuurbiers [merlijn.schuurbiers@wur.nl].

What type of forest manager do you consider yourself to be? [C1]

A: Private forest owner

B1: Forest manager working for a public sector body

B2: Forest manager working for a nature organization

C: Forest manager working for a consultancy firm

B3: Forest manager working for a different type of organization

Page 2A

This first part of the research consists of a model exercise. Image, you have recently become the owner of a new forest area of 60 ha. Your entire new property is located, like most forests in the Netherlands, on a poor sandy soil type. The groundwater level is deep and the forest is fed by rainwater. The grazing pressure is low and the main tree species are scots pine and common oak.

The previous owner describes in the latest management plan that they used a simple zoning based on the SNL subsidy scheme. The forest is partly made up of nature orientated forest (N15.02 pines, oaks, and beech forest) and partly made up of multifunctional forest (N16.03 Dry forest with production). In this expertise we will focus on the multifunctional forest. The picture below shows the situation for that part of the forest.

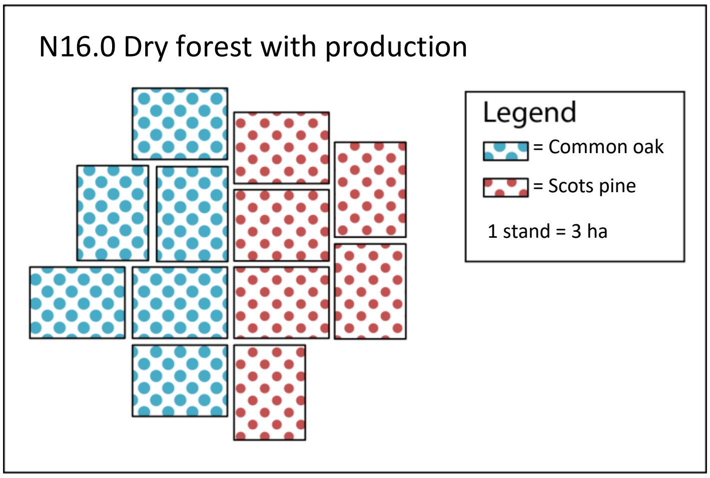

Figure C1: Map of the study site which is made up of twelve stands multifunctional forest. The main tree species, common oak and scots pine are equally present.

Page 3A

Specifically, this research focuses on the 12 stands in the multifunctional forest which each have a size of 3 ha. As the new owner of this area it is up to you to decide which harvest interventions you would like to apply to each stand. You will be able to choose between:

- Doing nothing
- Thinning from below which reduces the ground area to 24 m2/ha
- Thinning from below which reduces the ground area to 18 m2/ha
- Free thinning from above which reduces the ground area to 24 m2/ha
- Free thinning from above which reduces the ground area to 18 m2/ha
- Future crop tree thinning which frees up the crown space of 40 (for oak) and 90 (for scots pine) future crop trees by 30% (for oak) or 50% (for scots pine)
- Future crop tree thinning which frees up the crown space of 40 (for oak) and 90 (for scots pine) future crop trees by 100%
- A further to be specified form of a regeneration cut

If the ground area of the choice stand falls below 18 m2/ha then it is no longer physically possible to thin to 18 m2. If the ground area of the choice stand falls below 24 m2/ha then it is no longer physically possible to thin to 24 m2. These options will not presented in those cases.

You commissioned a forest inventory in order to help yourself with the choices such that for each stand you have an estimate of a number of factors which you will get presented later. The image below shows an example stand

- In the table called '**stand information**' there is information for the forest inventory which is related to age, wood volumes, growing conditions and environmental factors.
- In the table called '**general forest information**' there is a summary of the way the forest as a whole looks like which the choice stand is a part of.
- The figure gives a graphical representation of a **circle plot** measurement in order to get an idea of the species composition and the planting lay-out. Each point in this circle represents a tree with a DBH of ≥ 5 cm. The radius of the circle plot is chosen such that, in principle, at least 20 trees with a DBH of ≥ 5 cm are included.
- You can assume that all external factors for which no information is provided are equal to **real life values**.

Example stand:

Plot information	
Stand size	3 ha
Age	36 year
Ground area	14 m^2/ha
Volume	118 m^3
Estimated increment	6 m^3
Crown closure	10-25%
Shrub layer cover	0.01-01%
Volume lying dead wood	19 m^3
Volume standing dead wood	0 m^3
Main tree species	Grove den
Diameter of the middle tree of the main tree species	15 cm
Main tree species count	1100 ha^{-1}

General forest information	
SNL-classification	Dry forest with production
Soil type	Poor sandy soil
Hydrological environment	Deep groundwater level; Fed by rainwater
Grazing pressure	Low

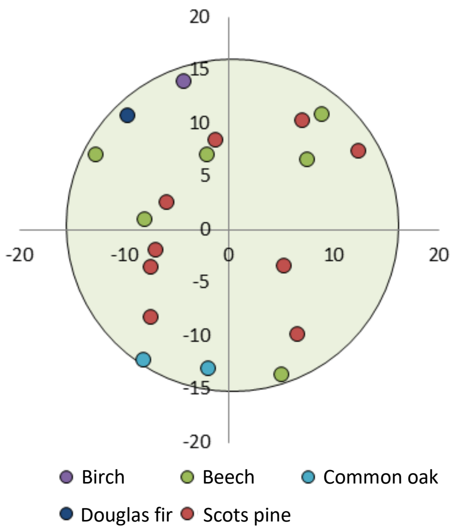

Figure C2: Example of the stand information presented to the respondents which is split into general forest information, specific stand information and a figure showing the species diversity and planting layout. This example is used here to explain how the actual choice stands will look like.

From experience with previous experiments we know that answers given in these types of experiments are not always in compliance with behavior in practice. The goal of this research is, however, to mimic a real life situation through a simulation as good as possible. Our request is that you would make decision in a similar fashion as you would do so in your daily management practice.

This exercise makes use of a fictive forest. However, the values which you will get presented later are based on real life values from the 6th Dutch forest inventory.

Page 2B

This first part of the research consists of a model exercise. Image, the organization for which you work has recently become the owner of a new forest area of 60 ha. You have been chosen as the new forest manager of this area. The entire new property is located, like most forests in the Netherlands, on a poor sandy soil type. The groundwater level is deep and the forest is fed by rainwater. The grazing pressure is low and the main tree species are scots pine and common oak.

The previous owner describes in the latest management plan that they used a simple zoning based on the SNL subsidy scheme. The forest is partly made up of nature orientated forest (N15.02 pines, oaks, and beech forest) and partly made up of multifunctional forest (N16.03 Dry forest with production). In this expertise we will focus on the multifunctional forest. The picture below shows the situation for that part of the forest.

-figure C1-

Page 3B

Specifically, this research focuses on the 12 stands in the multifunctional forest which each have a size of 3 ha. As the new manager of this area it is up to you to decide which harvest interventions you would like to apply to each stand. You will be able to choose between:

- Doing nothing
- Thinning from below which reduces the ground area to 24 m2/ha
- Thinning from below which reduces the ground area to 18 m2/ha
- Free thinning from above which reduces the ground area to 24 m2/ha
- Free thinning from above which reduces the ground area to 18 m2/ha
- Future crop tree thinning which frees up the crown space of 40 (for oak) and 90 (for scots pine) future crop trees by 30% (for oak) or 50% (for scots pine)
- Future crop tree thinning which frees up the crown space of 40 (for oak) and 90 (for scots pine) future crop trees by 100%
- A further to be specified form of a regeneration cut

If the ground area of the choice stand falls below 18 m2/ha then it is no longer physically possible to thin to 18 m2. If the ground area of the choice stand falls below 24 m2/ha then it is no longer physically possible to thin to 24 m2. These options will not presented in those cases.

You commissioned a forest inventory in order to help yourself with the choices such that for each stand you have an estimate of a number of factors which you will get presented later. The image below shows an example stand

- In the table called '**stand information**' there is information for the forest inventory which is related to age, wood volumes, growing conditions and environmental factors.
- In the table called '**general forest information**' there is a summary of the way the forest as a whole looks like which the choice stand is a part of.
- The figure gives a graphical representation of a **circle plot** measurement in order to get an idea of the species composition and the planting lay-out. Each point in this circle represents a tree with a DBH of ≥ 5 cm. The radius of the circle plot is chosen such that, in principle, at least 20 trees with a DBH of ≥ 5 cm are included.
- You can assume that all external factors for which no information is provided are equal to **real life values**.

Example stand:

-figure C2-

From experience with previous experiments we know that answers given in these types of experiments are not always in compliance with behavior in practice. The goal of this research is, however, to mimic a real life situation through a simulation as good as possible. Our request is that you would make decision in a similar fashion as you would do so in your daily management practice.

This exercise makes use of a fictive forest. However, the values which you will get presented later are based on real life values from the sixth Dutch forest inventory.

Page 2C

This first part of the research consists of a model exercise. Image, the organization for which you work has recently requested of you to give advice to the new owner of a forest area of 60 ha. The forest, like most forests in the Netherlands, on a poor sandy soil type. The groundwater level is deep and the forest is fed by rainwater. The grazing pressure is low and the main tree species are scots pine and common oak.

The previous owner describes in the latest management plan that they used a simple zoning based on the SNL subsidy scheme. The forest is partly made up of nature orientated forest (N15.02 pines, oaks, and beech forest) and partly made up of multifunctional forest (N16.03 Dry forest with production). In this expertise we will focus on the multifunctional forest. The picture below shows the situation for that part of the forest.

-figure C1-

Page 3C

Specifically, this research focuses on the 12 stands in the multifunctional forest which each have a size of 3 ha. As consultant it is up to you to decide which harvest interventions you would like to apply to each stand. You will be able to choose between:

- Doing nothing
- Thinning from below which reduces the ground area to 24 m2/ha
- Thinning from below which reduces the ground area to 18 m2/ha
- Free thinning from above which reduces the ground area to 24 m2/ha
- Free thinning from above which reduces the ground area to 18 m2/ha
- Future crop tree thinning which frees up the crown space of 40 (for oak) and 90 (for scots pine) future crop trees by 30% (for oak) or 50% (for scots pine)
- Future crop tree thinning which frees up the crown space of 40 (for oak) and 90 (for scots pine) future crop trees by 100%
- A further to be specified form of a regeneration cut

If the ground area of the choice stand falls below 18 m2/ha then it is no longer physically possible to thin to 18 m2. If the ground area of the choice stand falls below 24 m2/ha then it is no longer physically possible to thin to 24 m2. These options will not presented in those cases.

You commissioned a forest inventory in order to help yourself with the choices such that for each stand you have an estimate of a number of factors which you will get presented later. The image below shows an example stand

- In the table called '**stand information**' there is information for the forest inventory which is related to age, wood volumes, growing conditions and environmental factors.
- In the table called '**general forest information**' there is a summary of the way the forest as a whole looks like which the choice stand is a part of.
- The figure gives a graphical representation of a **circle plot** measurement in order to get an idea of the species composition and the planting lay-out. Each point in this circle represents a tree with a DBH of ≥ 5 cm. The radius of the circle plot is chosen such that, in principle, at least 20 trees with a DBH of ≥ 5 cm are included.

- You can assume that all external factors for which no information is provided are equal to **real life values**.

Example stand:

-figure C2-

From experience with previous experiments we know that answers given in these types of experiments are not always in compliance with behavior in practice. The goal of this research is, however, to mimic a real life situation through a simulation as good as possible. Our request is that you would make decision in a similar fashion as you would do so in your daily management practice.

This exercise makes use of a fictive forest. However, the values which you will get presented later are based on real life values from the 6th Dutch forest inventory.

Page 4-23

Information from the conducted forest inventory is presented in the tables and figure below.

In the table called '**stand information**' there is information for the forest inventory which is related to age, wood volumes, growing conditions and environmental factors.

In the table called '**general forest information**' there is a summary of the way the forest as a whole looks like which the choice stand is a part of.

The figure gives a graphical representation of a **circle plot** measurement in order to get an idea of the species composition and the planting lay-out. Each point in this circle represents a tree with a DBH of ≥ 5 cm. The radius of the circle plot is chosen such that, in principle, at least 20 trees with a DBH of ≥ 5 cm are included.

Plot information	
Stand size	3 ha
Age	36 year
Ground area	14 m^2/ha
Volume	118 m^3
Estimated increment	6 m^3
Crown closure	10-25%
Shrub layer cover	0.01-01%
Volume lying dead wood	19 m^3
Volume standing dead wood	0 m^3
Main tree species	Grove den
Diameter of the middle tree of the main tree species	15 cm
Main tree species count	1100 ha^{-1}

General forest information	
SNL-classification	Dry forest with production
Soil type	Poor sandy soil
Hydrological environment	Deep groundwater level; Fed by rainwater
Grazing pressure	Low

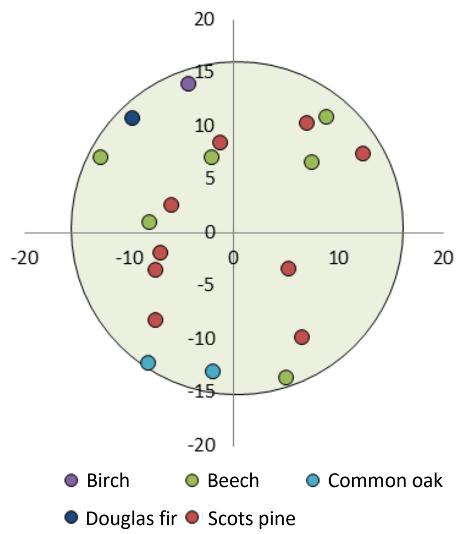

Figure C3: Example of the stand information presented to the respondents which is split into general forest information, specific stand information and a figure showing the species diversity and planting layout. There are twelve different stand information pictures corresponding to each choice object (see Appendix D: Choice objects).

What type of harvest intervention would you like to apply to this stand? [C2-C24]

A: Do nothing

B: Thinning from below: thin the ground area to 24 m2/ha

C: Thinning from below: thin the ground area to 18 m2/ha

D: Free thinning from above: thin the ground area to 24 m2/ha

E: Free thinning from above: thin the ground area to 18 m2/ha

F: Future crop tree thinning: thin 30%/50% of the crown area of 40/90 future crop trees per ha

G: Future crop tree thinning: thin 100% of the crown area of 40/90 future crop trees per ha

H: Regeneration cut

You have chosen to make use of a regeneration cut. You only have to decide which type of cut you would like to use and you do not have to specify replanting strategies. From which type of regeneration cut would you like to make use? [C3-C25]

[Open field]

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What were the tree most important factors related to the decisions you just made fort his forest? [C26]

[Open field 1]

[Open field 2]

[Open field 3]

Page 25

Where you just made forest management choices, we will now switch to a different kind of question. In this part of the research we will look at a lottery.

Below this text there are 10 choice pairs. In this lottery you are able, for every choice pair, to choose between two different options. Each option is coupled to a relative chance to win a certain amount of money. You are free to choose the first option in some rows and the second option in other rows, to change your answers and to make your choices in a random order.

Similar to the first part of this experiment, a hypothetical situation is presented. The different amounts of money will therefore not be cashed out. We are interested in the choices you would make if we were to cash out these amounts of money.

Please state your preference for each of the lottery [C27-C36]

Choice number	Option A	Option B
1	10% chance of €200; 90% chance of €160	10% chance of €385; 90% chance of €10
2	20% chance of €200; 80% chance of €160	20% chance of €385; 80% chance of €10
3	30% chance of €200; 70% chance of €160	30% chance of €385; 70% chance of €10
4	40% chance of €200; 60% chance of €160	40% chance of €385; 60% chance of €10
5	50% chance of €200; 50% chance of €160	50% chance of €385; 50% chance of €10
6	60% chance of €200; 40% chance of €160	60% chance of €385; 40% chance of €10
7	70% chance of €200; 30% chance of €160	70% chance of €385; 30% chance of €10
8	80% chance of €200; 20% chance of €160	80% chance of €385; 20% chance of €10
9	90% chance of €200; 10% chance of €160	90% chance of €385; 10% chance of €10
10	100% chance of €200; 0% chance of €160	100% chance of €385; 0% chance of €10

Page 26

In this final part of the experiment we would like to ask you some background questions. Just like the other parts of the experiment, your answers will be treated confidentially and anonymously.

In which region of the Netherlands are you mainly managing forests (see the image below)?

[C37]

A: The North

B: The East

C: The West

D: The South

Figure C4: NUTS1 regions in the Netherlands (Piccolo Modificatore Laborioso, 2008).

What is your gender? [C38]

A: Male

B: Female

C: Other (specify)

What age are you? [C39]

[Open field]

What is the highest level of education you have completed? [C40]

A: Less than high school degree

B: High school degree

C: Secondary vocational education (MBO)

D: Higher professional education (HBO)

E: University bachelor degree (WO)

F: University master degree (WO)

G: University specialized degree (PHD)

Do you have a degree in forest and nature conservation (at MBO, HBO or WO level)? [C41]

A: Yes

B: No

What did you specialize on within your studies? (multiple answers are possible) [C42]

A: Ecology

B: Economics

C: Timber trade

D: Recreation/tourism

E: Stewardship

F: None of the above/not relevant

How many years have you been active in forest management? [C43]

[Open field]

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Where are you employed? [C44]

A: 'Bosgroepen'

B: Own consultancy firm

C: Municipality

D: University of applied science

E: 'Landschappen NL'

F: Ministery of Defence

G: Ministery of Finance

H: 'Natuurmonumenten'

I: Province

J: State forest commission

K: University

L: Unemployed

M: Other (specify)

Is forest management your main or side occupation? [C45]

A: Main occupation

B: Side occupation

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You can make use of a slider to answer the follow set of questions.

How active are you in a professional association (such as the 'KNBV', 'NVR', etc.)? [C46]

0: Not active at all

1000: Very active

How professional do you consider yourself to be in the role of forest manager? [C47]

0: Amateur

1000: Professional

To what extent do you identify yourself as a forester? [C48]

0: Not at all

1000: Completely

How professional do you consider yourself to be in the role of forest manager? [C49]

0: Not at all

1000: Completely

To what extent do you identify yourself as a nature manager? *[C50]*

0: Not at all

1000: Completely

Page 28

You can make use of a slider to answer the follow set of questions.

How important are financial aspects in forest management? [C51]

0 = Not important at all

1000 = Very important

How important are natural values for forest management? [C52]

0 = Not important at all

1000 = Very important

How important are recreational values for forest management? [C53]

0 = Not important at all

1000 = Very important

How do you consider the current (June 2019) wood prices to be? [C54]

0: They are very low

1000: They are very high

Page 29

How large is the forest which you manage (in hectares)? [C55]

[open field]

Which type of forest do you manage? [C56]

A: Mainly broadleaf forest

B: Mainly coniferous forest

C: Mainly mixed forest

How are the growing conditions of the forest in which you manage? [B57]

0: Very bad

1000: Very good

Did you experience any large disturbances such as windthrow or forest fires in the forest you manage in the past five years? [C58]

A: Yes

B: No

Page 30

You have made it to the end of the questionnaire. We thank you sincerely for your participation. You can leave your e-mail address below in order to get the chance of winning the book 'Heibel in de polder'. You can also let us know whether you would mind us contacting you in future in order to clarify your answers or if you would like to receive feedback regarding the results of the study.

You can fill in your e-mail address here to join the raffle [C59]

[Open field]

I am willing to clarify my answers if it turns out that would be necessary. [C60]

A: Yes

B: No

I would like to receive feedback on the results of this study [C61]

A: Yes

B: No

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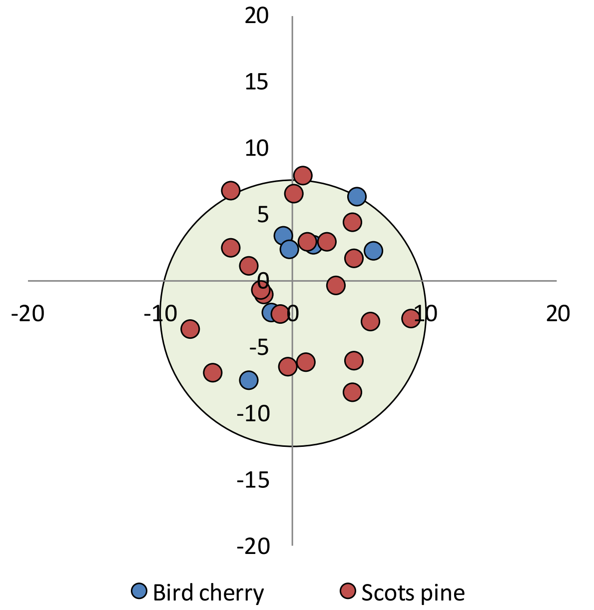
Thank you again for participating. You can now close this window.

Appendix D: Choice objects

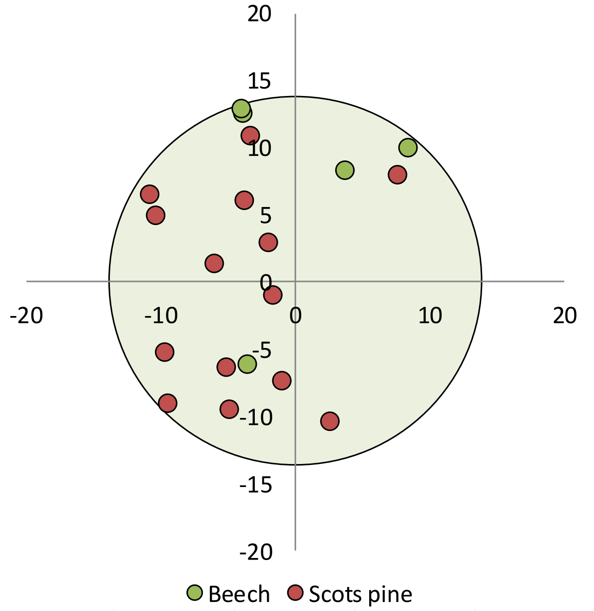
Plot 40066

Plot information	
Stand size	3 ha
Age	58 year
Ground area	40 m^2/ha
Volume	330 m^3
Estimated increment	8 m^3
Crown closure	90-100%
Shrub layer cover	5-10%
Volume lying dead wood	19 m^3
Volume standing dead wood	2 m^3
Main tree species	Scots pine
Diameter of the middle tree of the main tree species	27 cm
Main tree species count	668 ha^{-1}
Shannon-index	0.56
Average distance	8 m



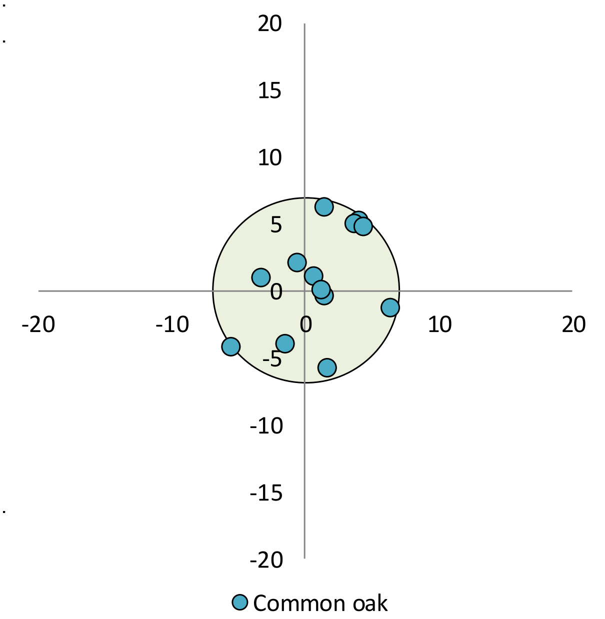
Plot 41691

Plot information	
Stand size	3 ha
Age	61 year
Ground area	16 m^2/ha
Volume	134 m^3
Estimated increment	5 m^3
Crown closure	75-90%
Shrub layer cover	25-50%
Volume lying dead wood	7 m^3
Volume standing dead wood	2 m^3
Main tree species	Scots pine
Diameter of the middle tree of the main tree species	29 cm
Main tree species count	211 ha^{-1}
Shannon-index	0.58
Average distance	12 m



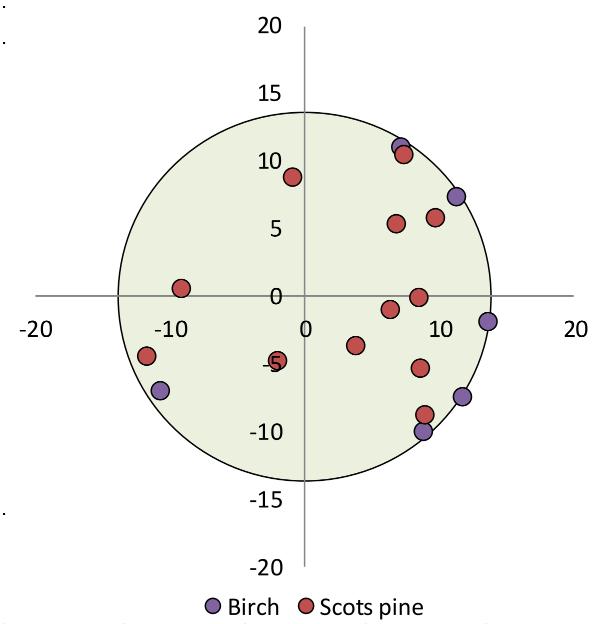
Plot 60271

Plot information	
Stand size	3 ha
Age	33 year
Ground area	25 m^2/ha
Volume	190 m^3
Estimated increment	7 m^3
Crown closure	75-90%
Shrub layer cover	0.0-0.1%
Volume lying dead wood	30 m^3
Volume standing dead wood	17 m^3
Main tree species	Common oak
Diameter of the middle tree of the main tree species	19 cm
Main tree species count	844 ha^{-1}
Shannon-index	0
Average distance	6 m



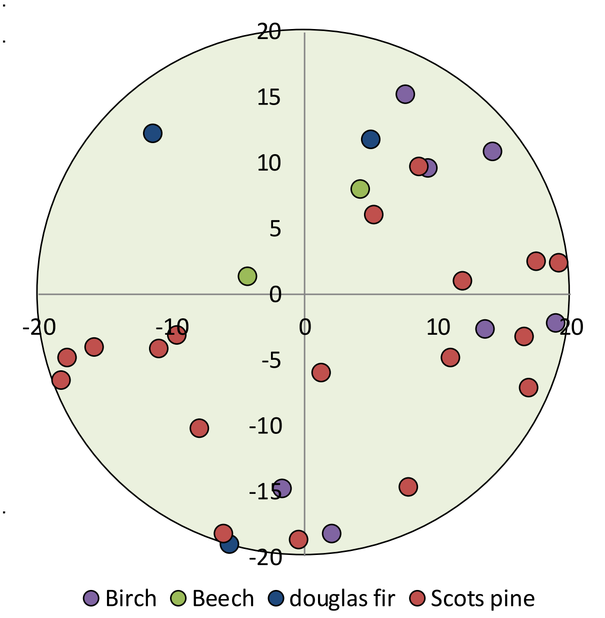
Plot 60284

Plot information	
Stand size	3 ha
Age	144 year
Ground area	30 m^2/ha
Volume	272 m^3
Estimated increment	4 m^3
Crown closure	50-75%
Shrub layer cover	25-50%
Volume lying dead wood	14 m^3
Volume standing dead wood	0 m^3
Main tree species	Scots pine
Diameter of the middle tree of the main tree species	43 cm
Main tree species count	195 ha^{-1}
Shannon-index	0.63
Average distance	13 m



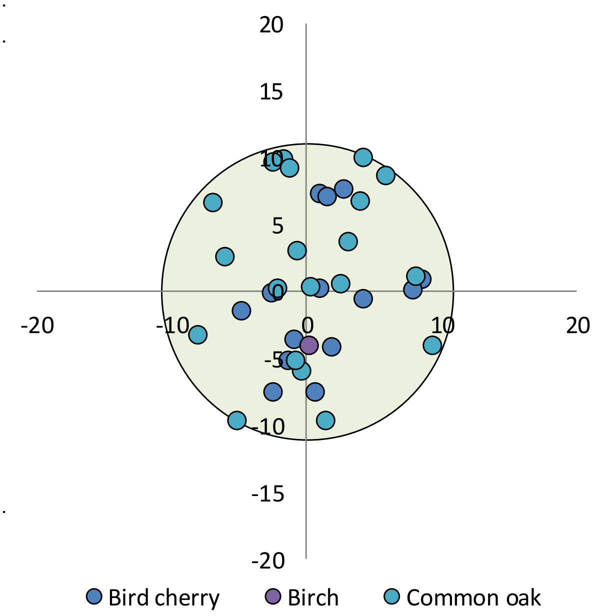
Plot 61588

Plot information	
Stand size	3 ha
Age	99 year
Ground area	19 m^2/ha
Volume	172 m^3
Estimated increment	4 m^3
Crown closure	25-50%
Shrub layer cover	50-75%
Volume lying dead wood	0 m^3
Volume standing dead wood	11 m^3
Main tree species	Scots pine
Diameter of the middle tree of the main tree species	39 cm
Main tree species count	144 ha^{-1}
Shannon-index	1.05
Average distance	19 m



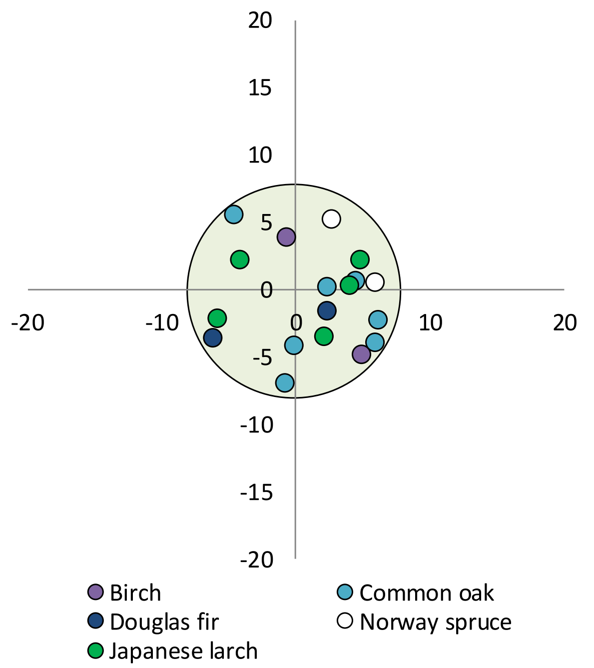
Plot 61808

Plot information	
Stand size	3 ha
Age	63 year
Ground area	37 m^2/ha
Volume	297 m^3
Estimated increment	8 m^3
Crown closure	90-100%
Shrub layer cover	50-75%
Volume lying dead wood	0 m^3
Volume standing dead wood	0 m^3
Main tree species	Common oak
Diameter of the middle tree of the main tree species	26 cm
Main tree species count	535 ha^{-1}
Shannon-index	0.79
Average distance	9 m



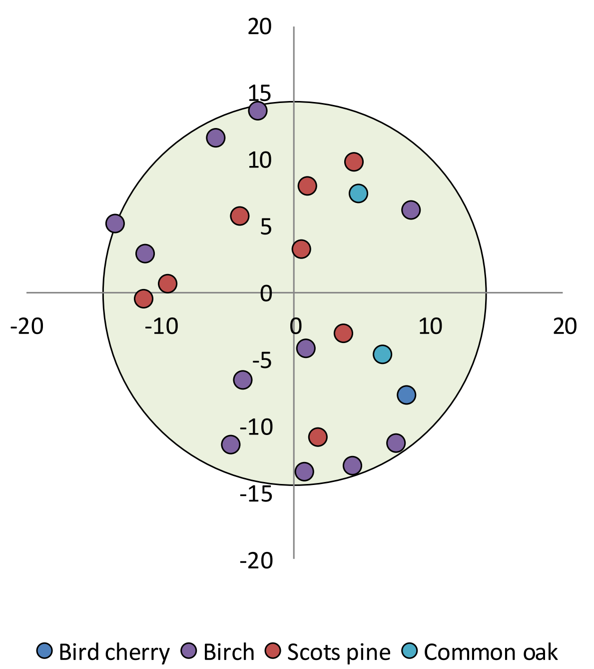
Plot 62239

Plot information	
Stand size	3 ha
Age	85 year
Ground area	26 m^2/ha
Volume	199 m^3
Estimated increment	8 m^3
Crown closure	25-50%
Shrub layer cover	0.0-0.1%
Volume lying dead wood	3 m^3
Volume standing dead wood	9 m^3
Main tree species	Common oak
Diameter of the middle tree of the main tree species	26 cm
Main tree species count	348 ha^{-1}
Shannon-index	1.46
Average distance	7 m



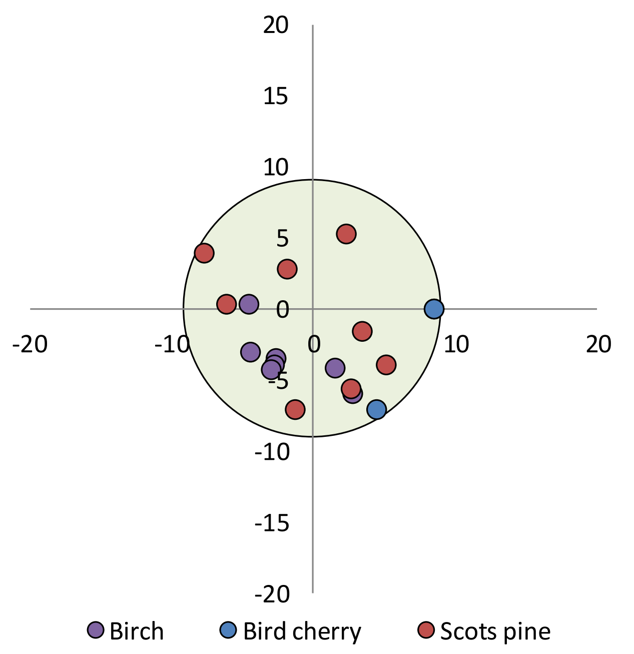
Plot 66700

Plot information	
Stand size	3 ha
Age	65 year
Ground area	15 m2/ha
Volume	127 m^3
Estimated increment	4 m^3
Crown closure	50-75%
Shrub layer cover	0.1-1%
Volume lying dead wood	4 m^3
Volume standing dead wood	0 m^3
Main tree species	Scots pine
Diameter of the middle tree of the main tree species	35 cm
Main tree species count	127 ha^{-1}
Shannon-index	1.07
Average distance	14 m



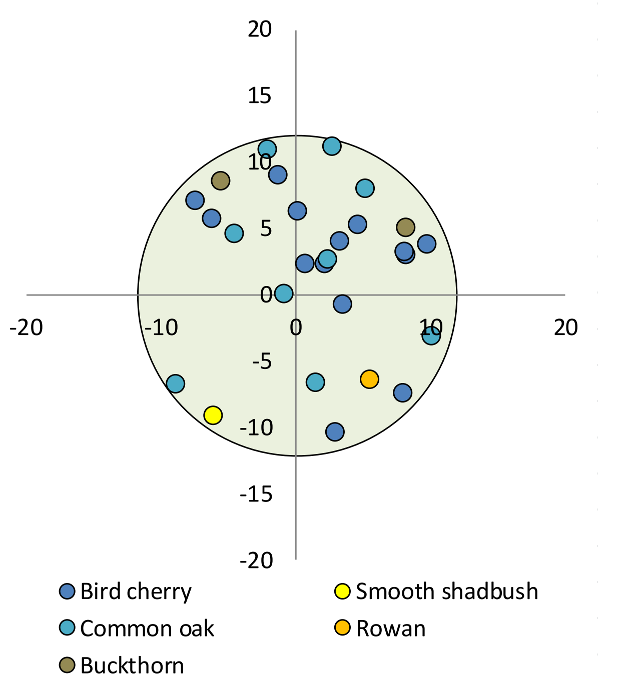
Plot 67671

Plot information	
Stand size	3 ha
Age	51 year
Ground area	19 m^2/ha
Volume	142 m^3
Estimated increment	5 m^3
Crown closure	75-90%
Shrub layer cover	25-50%
Volume lying dead wood	3 m^3
Volume standing dead wood	0 m^3
Main tree species	Scots pine
Diameter of the middle tree of the main tree species	23 cm
Main tree species count	314 ha^{-1}
Shannon-index	1.03
Average distance	8 m



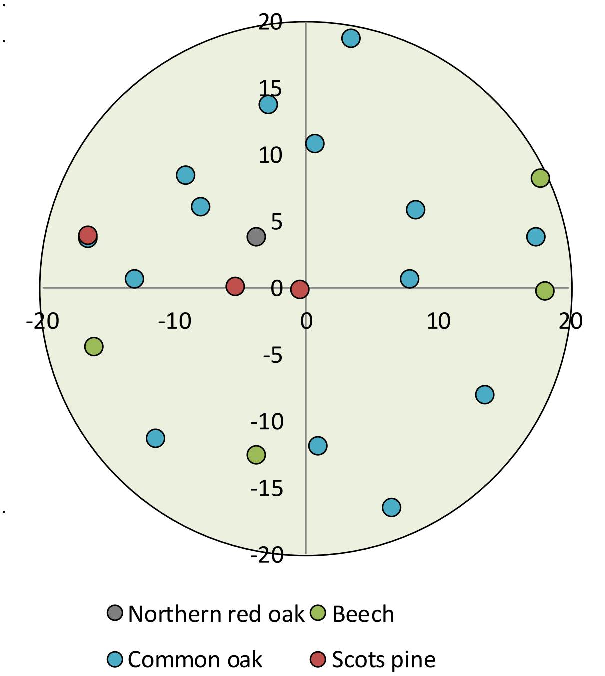
Plot 74028

Plot information	
Stand size	3 ha
Age	107 year
Ground area	27 m^2/ha
Volume	228 m^3
Estimated increment	5 m^3
Crown closure	90-100%
Shrub layer cover	5-10%
Volume lying dead wood	1 m^3
Volume standing dead wood	18 m^3
Main tree species	Common oak
Diameter of the middle tree of the main tree species	26 cm
Main tree species count	442 ha^{-1}
Shannon-index	1.19
Average distance	11 m



Plot 74629

Plot information	
Stand size	3 ha
Age	71 year
Ground area	17 m^2/ha
Volume	154 m^3
Estimated increment	5 m^3
Crown closure	75-90%
Shrub layer cover	0.1-1%
Volume lying dead wood	1 m^3
Volume standing dead wood	0 m^3
Main tree species	Common oak
Diameter of the middle tree of the main tree species	24 cm
Main tree species count	111 ha^{-1}
Shannon-index	0.74
Average distance	19 m



Plot 77883

Plot information	
Stand size	3 ha
Age	21 year
Ground area	18 m^2/ha
Volume	87 m^3
Estimated increment	8 m^3
Crown closure	75-90%
Shrub layer cover	1-5%
Volume lying dead wood	0 m^3
Volume standing dead wood	2 m^3
Main tree species	Common oak
Diameter of the middle tree of the main tree species	10 cm
Main tree species count	2299 ha^{-1}
Shannon-index	0
Average distance	5 m