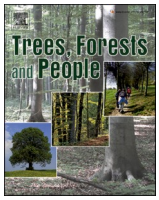
Trees, Forests and People 17 (2024) 100643

Contents lists available at ScienceDirect

Trees, Forests and People

journal homepage: www.sciencedirect.com/journal/trees-forests-and-people



Developing nudges, nudge+ and boosts to support climate change mitigation in practice – A case study on ash fertilization among Finnish private forest owners

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ARTICLE INFO

Keywords:
Climate change mitigation
Behaviour change wheel
Cognitive bias
Non-industrial private forests
Ash fertilization
Finland

ABSTRACT

Forests are crucial for climate change mitigation as they absorb and store large amounts of carbon dioxide. In Finland, ash fertilization of drained peatland forests has been identified as part of the climate change mitigation strategy, yet it is implemented notably less than it could be. Therefore, this study aimed to identify most effective nudges, nudge+ and boosts that could steer Finnish non-industrial private forest (NIPF) owners to adopt ash fertilization in their forest. Semi-structured interviews with 19 NIPF owners were analyzed using the Behaviour change wheel to identify key factors influencing owners' willingness to engage in ash fertilization. Most factors raised by forest owners were related to reflective motivation encompassing both drivers and barriers to practicing ash fertilization. We also identified possible cognitive biases that were influencing decisions. The suggested nudges, nudge+ and boosts address both the specific concerns of the forest owners and the underlying heuristics. For example, framing ash fertilization as a standard procedure of professional forest management and including it into forest management plans could facilitate overcoming status quo bias that may hinder the adoption of novel forest management practices. These findings are directly applicable for creating nudges, nudge+ and boosts on ash fertilization for experienced, professionally managing NIPF owners with larger forest estates. Our study also offers an approach that can be adapted for broader application in environmental and climate-friendly decision-making, contributing to the growing body of literature on the intersection of behavioral science and environmental management.

1. Introduction

Forests produce a wide range of forest ecosystem services (FES) and matching the supply and demand of FES is a central task for forest policy-making (Winkel et al., 2022). Climate change mitigation, one of the most prominent FES, is increasingly emphasized in political discussions and policy documents at both European (European Commission, 2019) and national levels. For example, in Finland, forests play a significant role in efforts to reach carbon neutrality by 2035 (Finnish Government, 2019). This necessitates new ways of thinking, as traditionally, Finnish forests have been perceived primarily as a source of timber and related income (Kotilainen and Rytteri, 2011).

Finland has a high percentage of non-industrial private forest (NIPF) ownership of forests. NIPF owners control over half of Finland's forests and around two-thirds of the growing stock volume (Natural Resources Institute Finland, 2023). Consequently, they often make the decisions concerning the management of Finnish private forests. NIPF owners are a heterogeneous group of individuals with different objectives, attitudes and decision-making modes (Hujala et al., 2007). Understanding and guiding forest owners' decision-making is crucial for optimizing the production of various FES desired by policy-makers and other stakeholders from Finnish forests. Finland, as many other forested countries in Europe, has a long tradition of employing diverse policy instruments for this purpose: laws and regulations, taxes, subsidies, recommendations, guidance documents, extension services and various forest-related organisations.

Among the various policy instruments, "nonfiscal and noncoercive interventions" (Hertwig and Grüne-Yanoff, 2017) have gained

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https://doi.org/10.1016/j.tfp.2024.100643

Available online 8 August 2024

increasing attention in discussions over the past two decades. For example, nudging, popularized by Thaler and Sunstein (2008), refers to soft guidance of decision-making towards more desirable choices by making predictable changes to the decision-making environment. Nudging has been viewed as an attractive addition to the existing set of policy instruments since, if successfully implemented, it can be an effective and cost-efficient tool for modifying behaviour. More recently, nudge+ that encourages reflection, and boosts, which aim to enhance the capacities necessary for decision-making, have gained more focus in the realm of behavioural interventions.

Consequently, governments are increasingly interested in using behavioural interventions based on voluntarism as a supplement to traditional policy instruments. For example, in Sweden, NIPF owners prefer voluntary measures over strict regulations for climate change adaptation (Eriksson and Sandström, 2022). Similarly, in Finland, many NIPF owners already support at least some forestry practices mitigating climate change (Vehola et al., 2022). This raises the question of how to assist forest owners in making choices that align with their interest.

We do not yet know if nudges, nudge+ or boosts can be used to guide NIPF owners to mitigate climate change in their forests because research on the topic is scarce. Valatin et al. (2016) were among the first ones to consider the potential of nudges in forestry, namely in encouraging forest owners in woodland creation. More recent research has examined the effects of linguistic nudging on forest-related perceptions, acceptability and/or preferences (Isoaho et al., 2019; Matthies et al., 2016; Ouvrard et al., 2020), but not on actual forest management activities. Research on the application of nudge+ or boosts in forestry context is even rarer. This does not mean that forest owners are not nudged or boosted. On the contrary, these behavioural interventions are included in the structures and measures of both private and public forestry organisations. Indeed, there is a choice architecture built around all policies and that architecture has been designed by someone with certain motivations in mind.

To harness nudges, nudge+ and boosts as a policy instrument for climate change mitigation, we need to design, empirically test and identify ones that suit the context of private forests and their owners. The foundation for developing this kind of behavioural interventions lies in the understanding of the choice architecture: how, when and based on what premises do forest owners make decisions concerning forestry activities. Also, gaining a clear understanding of the obstacles related to such decisions is important.

To address these research gaps, we follow a theory-based approach for designing nudges, nudge+ and boosts to mitigate climate change among Finnish NIPF owners. We interview forest owners to qualitatively examine their decision-making related to a particular forestry activity: ash fertilization. This forestry activity has climate change mitigation potential (Lehtonen et al., 2021) but is notably underused despite of its economic viability (Ahtikoski et al., 2008; Moilanen et al., 2015). We apply the Behaviour change wheel (BCW), a method for characterizing and designing behaviour change interventions, to identify factors affecting decisions on ash fertilization (Michie et al., 2011). Moreover, utilizing the BCW with additional focus on heuristics that influence our decisions, we aim to identify suitable nudges, nudge+ and boosts that could facilitate implementation of ash fertilization. This study aims to advance their use as a complementary policy instrument to existing ones, thereby supporting the development of an optimal mix of policy instruments for climate change mitigation.

The more precise objectives of this study are to i) identify the factors influencing NIPF owners' decisions on ash fertilization, ii) examine in closer detail the factors hindering its implementation, and iii) apply the BCW to identify potential nudges, nudge+ and boosts that could promote implementation of ash fertilization.

2. Theoretical framework

2.1. Behaviour change wheel

Michie et al. (2011) analysed 19 frameworks developed for behavioural interventions to develop a new systematic method, that would combine the understanding of the nature of the target behaviour with the suitable interventions. The outcome of this work was the BCW.

The core of the BCW is the COM-B system, consisting of Capability, Opportunity and Motivation, which together generate Behaviour. The outer layer of the BCW connects these components to appropriate intervention functions and finally to specific policy categories that could enable the desired behaviour. In other words, the COM-B elements help to identify what needs to change for the desired behaviour to happen and BCW indicates through which intervention functions and supporting policies these should be addressed.

After its launch in 2011, the BCW has been tested in different kinds of decision-making contexts. For example, it has been used to evaluate and further develop public transport messaging on real-time crowding information during COVID-19 pandemic in the UK (Krusche et al., 2022) and to inform the development of a mobile application aiming to increase physical activity levels of Canadian citizens (Truelove et al., 2020). Among farmers, BCW was used to analyse their decision-making on managing trees in farmlands for pests and diseases and to suggest ways to support this behaviour (Ambrose-Oji et al., 2022). In the forestry context, however, BCW has not yet been used.

2.2. Nudges and boosts

2.2.1. Classical nudges

There are several ways to define nudges. Thaler and Sunstein (2008), describe nudges as "any aspect of the choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentives". Here "choice architecture" refers to the environment in which the choice is made. This environment encompasses the way the alternatives are presented, for example the order of items in a list, how easy different foods are to find in a store, or the salience of the options on a web page.

Nudges are typically employed with the interest of the nudged in mind. For climate nudges or green nudges, the rationale is, however, to decrease negative externalities such as CO2 emissions or reductions in carbon sinks (Carlsson et al., 2021; Siipi and Koi, 2022).

Theoretically, the mechanisms behind nudges are often explained using dual process model(s) (Kahneman, 2011; Thaler and Sunstein, 2008). According to this framework, decision-making stems from two distinct cognitive systems. System 1 is "fast", automatic, or inattentive, relying on heuristics whereas System 2 is "slow", deliberative, and takes an effort to utilize. Put simply, System 2 is associated with a cost but leads to better outcomes than the more automatic System 1 (Evans, 2008; Löfgren and Nordblom, 2020). System 1 applies cognitive shortcuts or biases, also called heuristics, that often result in suboptimal decision-making. Nudges aim to overcome the negative outcomes of these biases by strategically modifying choice architecture so that decision-making can lead to more desirable decision outcomes.

We define classical nudges narrowly as behavioural interventions targeting System 1 decision-making (Banerjee and John, 2021). They can target aspects of the choice architecture that are preference-irrelevant, i.e., that doesn't affect the preferences between the options, or alter the expected preference ordering within an inattentive choice situation but not in an attentive choice situation (Löfgren and Nordblom, 2020). Therefore, classical nudges can work in situations where forest owners don't hold strong views on the merits of different forestry practices a priori or where they perform some forestry practices by habit without consideration.

2.2.2. Nudge+

Nudge+ is one form of nudging that aims to achieve active reflection of the choice (Banerjee and John, 2021; 2022). Nudge+ consists of a classical nudge combined with a "think". The "think" traditionally relies on public deliberation, such as citizens' panels to find the right course of action (John et al., 2009). However, the "think" in nudge+ is relaxed and does not have to be public; an "element of reflection" is enough (Banerjee and John, 2021). The "think" can be delivered either together with the nudge or separately. Examples of nudge+ include dual self-pledge commitments with both long- and short-term goals or a commitment device joint with information on the aims of a process or with feedback (Banerjee and John, 2021). The aim of nudge+ is to encourage the involvement of System 2 thus making decisions deliberative. This has the added benefit of making nudge+ more transparent than classical nudges which might increase acceptability (Siipi and Koi, 2022; Banerjee and John, 2023, Thaler and Sunstein, 2008).

2.2.3. Boosts

Boosts improve decision-making by offering tools by which decision-makers can make better decisions. They differ from nudges in that they aim to improve the decision-making skills of the individual whereas nudges rely on changes in the choice architecture (Grüne-Yanoff and Hertwig, 2016). Typical boosts could, for example, teach the decision-maker new heuristics to improve decision-making. Furthermore, the effects of boosts should be longer lasting than those of nudges and should persist even after the intervention as they equip individuals to tackle similar problems in the future (Hertwig and Grüne-Yanoff, 2017; Grüne-Yanoff, 2018).

Hertwig and Grüne-Yanoff (2017) distinguish between short- and long-term boosts where the former improves context-specific competencies and the latter is more permanent and generalizable to other contexts. Examples of long-term boosts include risk literacy boosts that aim at increasing understanding of statistical information, and uncertainty management boosts that help create procedural rules to make better decisions and predictions under uncertainty (Hertwig and Grüne-Yanoff, 2017). Like nudge+, boosts are inherently transparent.

2.3. Utilizing BCW to design nudges, nudge+ and boosts

Recently, the effectiveness of nudges has been discussed and questioned in two meta-analyses and the discussion around them (Mertens et al., 2022; Dellavigna and Linos, 2022; Szaszi et al., 2022). In particular, the effect size of nudges is lower in real-life interventions than those reported in peer-reviewed research articles[1]. The main reason for this is publication bias or a tendency to publish only positive results (Dellavigna and Linos, 2022; Szaszi et al., 2022). However, the effect sizes of nudges vary greatly and depend only partly on the type of intervention and the domain in which it is applied (Mertens et al., 2022). It appears that psychological factors, attitudes and other moderators also matter.

In mapping the drivers and barriers influencing decisions, the BCW can bring additional value. While different approaches for the design and development of nudges have been created during the last decade (The Behavioural Insights Team, 2010, 2014; OECD, 2019), the BCW provides a simple yet efficient approach to map and analyse the choice architecture and decision-maker-specific factors. Further, the intervention functions and policy categories of the BCW indicate applicable behavioural interventions that could be used to influence decision-making. Therefore, we utilize the BCW to develop nudges, nudge+ and boosts for climate change mitigation (Fig. 1).

[1] In Dellavigna and Linos (2022), the nudge interventions increase take-up by 8.7 percentage points in the sample from academic journals and by 1.4 percentage points in the nudge-unit sample. In Mertens et al. (2022), the unadjusted effect size of nudges is reported in Cohen's d, with a small to medium size of d = 0.43. When they assume a moderate to severe publication bias the effect size decreases from d=0.31 to d=0.08. With different bias correcting methods Scazi et al. (2022), get even lower effect sizes.

3. Methods

3.1. Case

Ash fertilization of drained peatland forests is considered a forestry operation with climate change mitigation potential (Lehtonen et al., 2021). It corrects nutrient imbalances in peatland forests and, on appropriate sites that suffer from the lack of nutrients other than nitrogen, it can increase the growth of forests to 1.3-9 times for the next 25 to 50 years (Moilanen et al., 2004; Hökkä et al., 2012). The increased growth of trees may in certain sites allow for less ditch cleaning or possibly giving up ditch maintenance altogether, which would lead to smaller amounts of both soil emissions and water effects. Ash fertilization stimulates the microbial activity and therefore decomposition of the organic matter in the soil (Saarsalmi et al., 2014), which to some extent counteracts the climate change mitigating effect of the operation. This was further studied in low-productive peatland forests by Ojanen et al. (2019) who concluded that depending on the site, ash fertilization has a climate cooling effect at least in the decadal time scale.

The Finnish Climate Plan for Land Use Sector (Ministry of Agriculture and Forestry, 2022) aims to increase the annual area of ash fertilization from 11 000 hectares to 37 000 hectares per year. Currently, the main policy instrument encouraging forest owners to implement ash fertilization is a governmental subsidy provided under the Act on a Temporary Forestry Incentive Scheme (2023). This subsidy is 270 euros per hectare.

Around 27 % of forestry land in Finland are peatlands with thickness of peat over 30cm, predominantly found in the northern parts of the country. For example, in Northern Ostrobothnia, such peatland forests cover 43 % of the region's forestry land (Natural Resources Institute Finland, 2023). Despite of this potential, statistics of the Finnish Forest Centre (2022) indicate that only 0.2 % of the peatland forests with thickness of peat over 30cm in Northern Ostrobothnia received government subsidies for the implementation of health-related fertilizations (including both ash and boron applications) in 2022.

The reasons behind the low implementation levels of ash fertilization among NIPF owners remain poorly understood. To our knowledge, the factors affecting Finnish NIPF owners' decisions on ash fertilization have not been studied earlier. In Sweden, Ouvrard et al. (2019) conducted a choice experiment to estimate private forest owners' willingness-to-pay to spread ash in their forests. They found that willingness-to-pay for ash fertilization is higher for environmentally concerned forest owners who feel confident in applying wood ash (perceived control). Regarding Finnish NIPF owners' decisions on climate-friendly forest management in general, Laakkonen et al. (2018) concluded that some forest owners are lacking guidance and information on how to adapt their current forest management practices and that the role of the forestry professionals in guiding forest owners' decision-making is significant.

To target forest owners with peatland forests and hence potential for the implementation of ash fertilization, we collaborated with a Forest Management Association (FMA) Siikalakeus. This FMA operates in seven municipalities in Northern Ostrobothnia, providing services to around 3,000 forest owner members. The FMA has been offering and marketing ash fertilization to its members for several years, delivered through mainly terrestrial but also aerial distribution methods.

3.2. Participants

To understand ash fertilization related decision-making among NIPF owners, we interviewed forest owners that were selected from the FMA member registry by the FMA staff members. The FMA had sent an ash fertilization offer to all contacted forest owners during 2021 based on

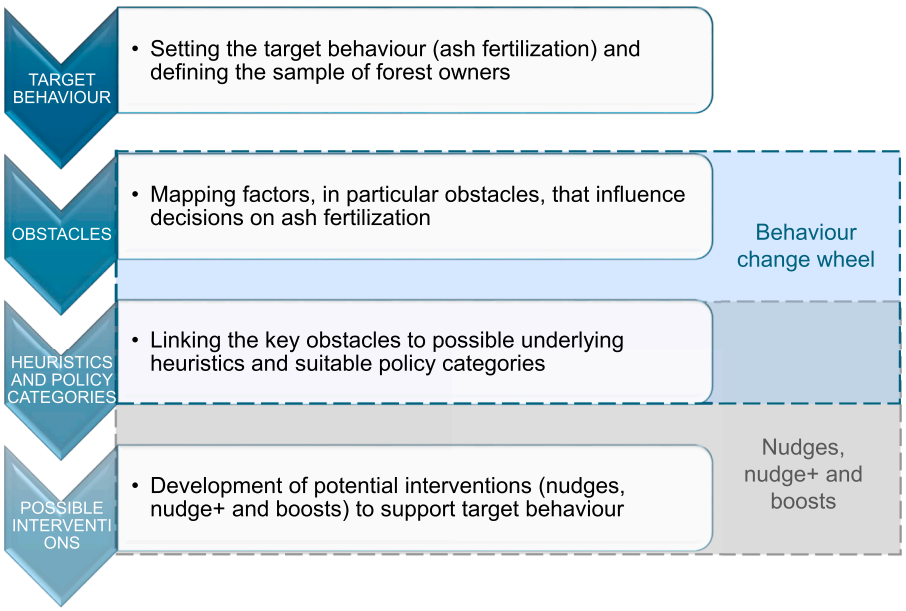

Fig. 1. The stages undertaken and respective theoretical approaches applied for the development of possible nudge, nudge+ and boost interventions in this study

forest resource data stored in the FMA's database. The goal was to interview approximately 10 to 15 forest owners who had rejected FMA's offer and five to ten of those who had accepted it. FMA staff members contacted forest owners first to seek their willingness to participate and obtain permission to share their contact details with the corresponding author.

The initial set of interviews consisted of 13 interviews. After preliminary analysis it became apparent that the interviewees were to some extent homogenous. To obtain more diversity in the sample, additional interviews were targeted to forest owners who were, on average, younger, owned smaller estates, and/or had shorter duration of ownership. A similar selection process was applied to these forest owners. In total, 19 interviews were conducted and due to signs of data saturation, considered adequate sample size.

Of the 19 interviewed forest owners, three were women, and 16 were men. The proportion of women interviewees was lower compared to all Finnish NIPF owners, estimated from the Finnish Forest Owner 2020 (FFO2020) study (Karppinen et al., 2020), where 25 percent of Finnish NIPF owners were women. Additionally, 67 % of the interviewees owned over 100 hectares of forest, which is significantly more than the average forest ownership size: only 12 % of the Finnish forest owners belonged to this category in FFO2020. Regarding age, slightly over half of the interviewees were between 45 and 64 years old, whereas according to Karppinen et al. (2020), the largest age group is 65 years or older (50 % of forest owners). The average ownership duration of the interviewees (21 years) was similar to that of the participants of the FFO2020 study (22 years).

Half of the interviewed forest owners had implemented ash fertilization in their forests, either through the FMA, other service providers, or on their own. According to unpublished, nationally executed forest owner survey data (n=1224) collected under the ClimateNudge research project in 2022, only nine percent of the respondents had implemented or were in the process of implementing ash fertilization, and seven percent had intentions to do so.

To summarise, the interviewees, compared to Finnish forest owners in general, were more frequently men, younger, owned considerably larger estates and had more experience with the implementation of ash fertilization.

3.3. Interview questions and analysis

The interview questions (provided in the supplementary information) were developed based on discussions with the FMA staff and the elements of the BCW framework (Michie et al., 2011). As implementation of ash fertilization can be fully outsourced to various service providers and does not require physical skills, the COM-B component related to Physical capability was deemed irrelevant for this study. In addition to the interview questions, the interviews started with some background questions concerning interviewees' age, duration of the ownership, forest area, and their general objectives for the forest ownership. The interviews, conducted by the corresponding author via phone, took place in January and February 2022, with durations ranging from 5 to 20 min. All interviewees provided an informed consent to be interviewed and audio-recorded. The recordings and transcripts were stored and analysed anonymously, without any personal data.

A content analysis of the interview transcripts was conducted using Atlas.ti software. In the beginning of the analysis, the corresponding author read the transcripts several times and identified factors that had influenced or were influencing forest owners' decision-making process regarding ash fertilization, in line with our research questions. Similar factors that had a parallel effect on the decision-making were grouped together to form codes. For instance, when the long-term effects of the ash fertilization were brought up, positive perceptions were coded apart from the negative perceptions.

Subsequently, a deductive approach to theme identification was applied (Kiger and Varpio, 2020). Each code was assigned to the most relevant COM-B component of the BCW. For example, the low level of knowledge concerning this activity expressed by the forest owner was categorized under Psychological capability. Then, the relevant transcripts were reviewed again to verify that the chosen COM-B component accurately represented the context and situation described in the interview.

4. Results

4.1. Results from the interviews

The factors raised by forest owners were associated with five COM-B components: Reflective motivation, Social opportunity, Physical opportunity, Automatic motivation and Psychological capability. Most of

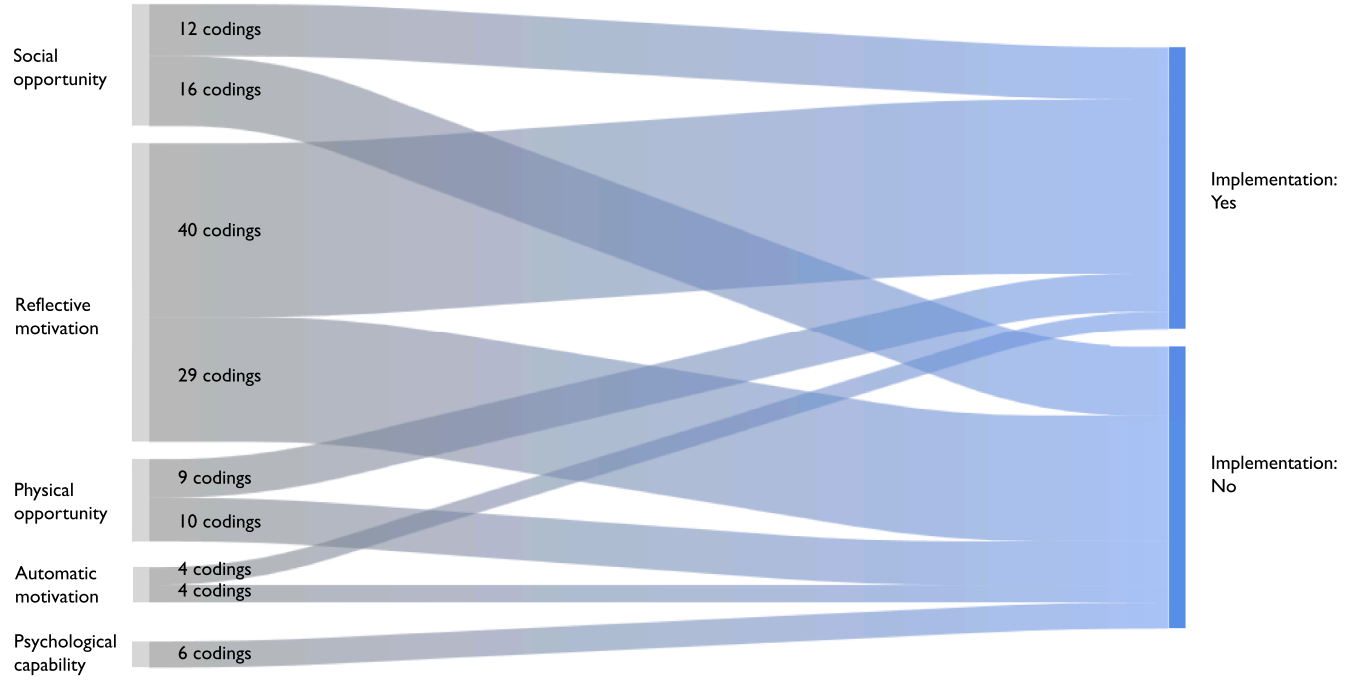

Fig. 2. Factors affecting the decision-making on ash fertilization categorized under the COM-B components. Codings indicate the number of forest owners mentioning factors under each COM-B component.

factors influencing decisions on ash fertilization were categorized under the Reflective motivation -component, which encompassed both drivers and barriers to the implementation of ash fertilization, typically based on forest owners' previous considerations and evaluations (Fig. 2).

4.1.1. Drivers to ash fertilization

Under Reflective motivation, the interviewees brought up various benefits of ash fertilization, particularly improved health and increased growth of the forest. The operation was also perceived as financially profitable, contributing to circular economy and climate change mitigation. Additionally, ash was considered as a more natural alternative compared to synthetic, phosphorus-based fertilizers. Among those who had not implemented ash fertilization, the primary benefit mentioned was the potential for increased growth of wood.

> *Mainly it's about increased yield so forest grows better. And forest is healthier too, and nowadays, when we go on and on about carbon issues, naturally forest absorbs more carbon when the growth increases. (man, 45-64 years, owns more than 100 ha, owner for 10-20 years, has not implemented)*

Also under Reflective motivation, several interviewees emphasized the long-term effectiveness of ash fertilization. For some, this aspect was viewed positively as it would bring benefits for the future generations. However, for others, uncertainty about the future ownership of the property and the beneficiaries of the ash fertilization raised concerns. Possible negative effects on environment such as heavy metal contents of the ash and runoffs to the water bodies were mentioned, too, although in general the risks were considered small.

> *I understand it very well that when the effect of ash is visible, if we assume that the effect is very positive, I'm the food of worms by then. But that's how it is, forest management. One cannot aim for fast bucks. (man, 65 years or older, owns over 100 ha, owner for over 20 years, has implemented)*

Regarding Social opportunity -component, two categories of influencers were commonly mentioned: forest professionals and other forest owners. The knowledge and expertise of forest professionals was highly valued when determining the suitability of the sites for ash fertilization. Forest owners' beliefs on other forest owners' experiences and attitudes towards ash fertilization were asked separately (questions 7 and 8 in the Supplementary information): most of the interviewees believed that other forest owners held positive views on ash fertilization, similar to their own perspectives. Few interviewees, however, were uncertain or believed that others' views were negative.

> *But it is important that forest professional actually looks at the site in the forest, what's the shape of trees and what's needed. Surely the professionals who go around in the forests all the time, they see it immediately if it's such a site, that it's worth considering. (man, 45-64 years, owns over 100 ha, owner for 10-20 years, has implemented)*

The most frequently mentioned factor under the Physical opportunity -component was cost of implementation, with almost all interviewees considering it expensive. For some, cost was the primary obstacle, while for others, the decision depended on their financial situation at that time. Majority of the interviewees were under the impression that they had suitable sites in their forests; only four forest owners were uncertain. A few interviewees noted that greater cooperation among forest owners would be necessary to build joint ash fertilization projects large enough to cover the costs.

> *Yes, I have intentions to implement it in the near future… so if the financial situation allows, I will seriously consider it. (man, 45-64 years, owns over 100 ha, owner for 10-20 years, has not implemented)*

Both Automatic motivation and Psychological capability were assigned only few issues influencing the decision-making of interviewees. Regarding Automatic motivation, the majority expressed positive thoughts and feelings towards ash fertilization, while no one had a negative approach. Responses seemed to be based on factual evaluation done earlier rather than emotional reactions. Those who seemed uncertain about their views, did not want to answer the question at all. Some interviewees considered the importance of ash fertilization low, at least compared to other forestry activities. Yet, some

interviewees viewed it as an essential part of professional and active forest ownership. Factors under Psychological capability mainly revolved around limited knowledge regarding ash fertilization.

> *Those who manage [forests] professionally, they see it positively but then there's always those who neglect their forests, they are probably not interested. (man, 45-64 years, owns over 100 ha, owner for over 20 years, has implemented)*

> *I just mentioned to my brother today that it is the last operation I would do in my forest. Ditching, thinnings, tending of young stands, all those come before that. (man, 45-64 years, owner for over 20 years, has not implemented)*

4.1.2. Barriers to ash fertilization

Fig. 3 illustrates that all COM-B components included factors that hindered forest owners' decision-making on ash fertilization. Some barriers were more prominent among interviewees who had not implemented ash fertilization, while other negative factors did not appear to impede implementation. For example, environmental concerns, such as heavy metal content of the ash and impacts on water bodies, were not significant barriers to the implementation of ash fertilization.

The most frequently cited concerns regarding the implementation of ash fertilization related to uncertainties surrounding the suitability of the site and profitability of the operation. These concerns were both coded under Reflective motivation. The two uncertainties are interconnected: if the site is unsuitable, ash fertilization won't be profitable. Interestingly, most of those who were uncertain about the suitability of the site had still implemented ash fertilization within the last few years and were waiting to see results. Uncertainty concerning profitability appeared to be a barrier to ash fertilization, as only one of those with doubts regarding profitability had implemented ash fertilization.

> *Well I suppose I need some more information on whether it is really good then, that it is really worth the money and increases the growth of the forest. (woman, 45-64 years, owns less than 50 ha, owner for less than 10 years, has not implemented)*

The cost of implementation (Physical opportunity) was the most frequently mentioned individual reason for not implementing ash fertilization. Many forest owners considered ash fertilization too expensive, and some indicated that funds for the investment need to come from the forest's harvest revenues. Many also indicated that ash fertilization should be linked to thinnings for operational reasons, as harvesting routes can be used for the terrestrial distribution of the ash.

> *Probably there would be [suitable sites] and also the need for it, but there's no… It requires money. In fact, the money should come from the forests, so in this site of mine, the principle was that half of the harvest revenues was used for the fertilization. (man, 45-64 years, owns over 100 ha, owner for 10-20 years, has implemented)*

There were also other less-frequently mentioned barriers that appeared to connect those forest owners, who had not implemented ash fertilization. Those who mentioned low level of knowledge concerning ash fertilization and/or general uncertainty as a rather new forest owner (Psychological capability) had not implemented ash fertilization. Forest

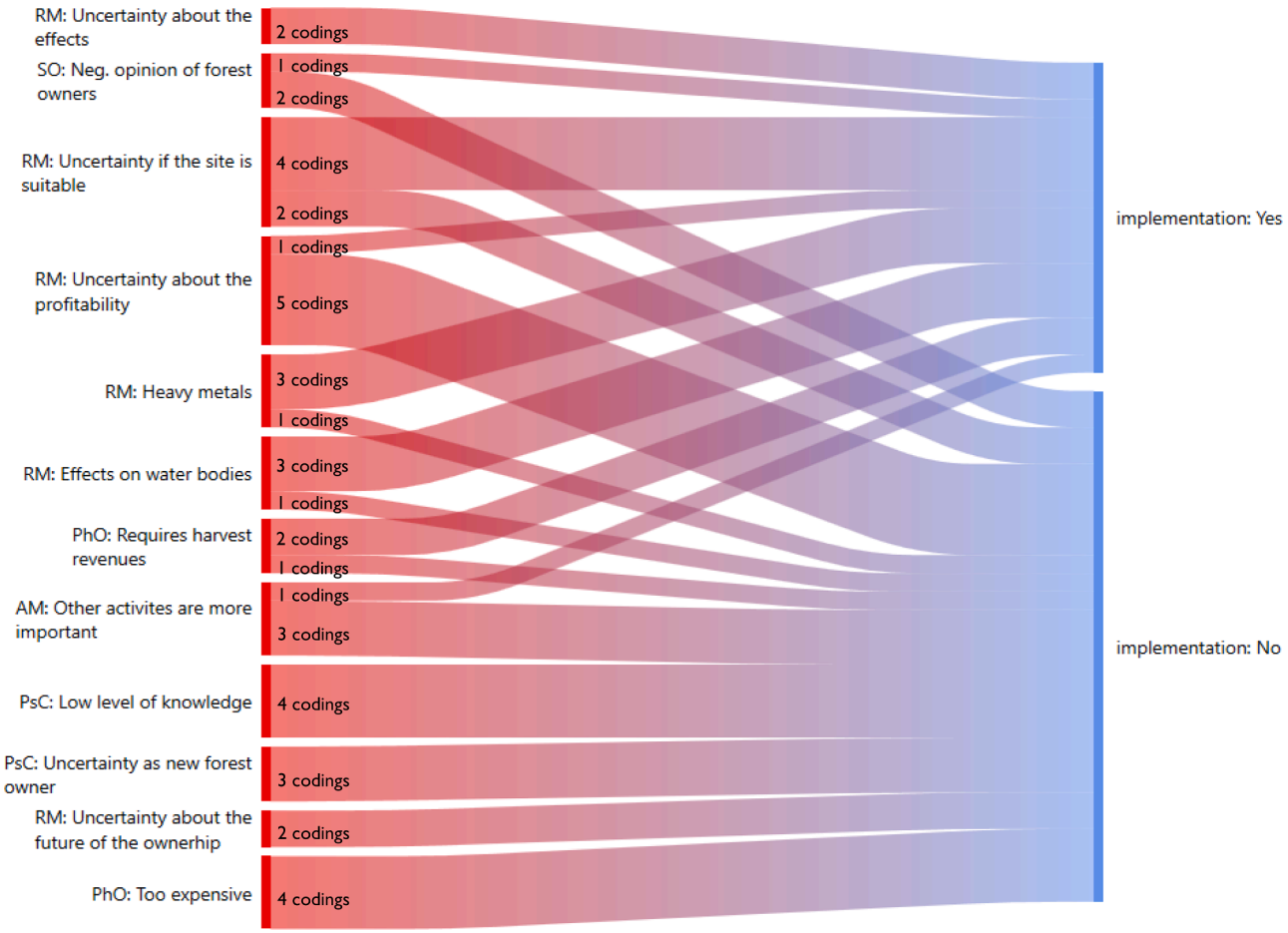

Fig. 3. Doubts and obstacles related to ash fertilization categorized under components connected to the implementation of the operation. Codings indicate the number of forest owners mentioning the doubt or obstacle. RM: Reflective motivation, SO: Social opportunity, PhO: Physical opportunity, AM: Automatic motivation, PsC: Psychological capability.

owners who considered ash fertilization less important than other forest management activities were also less likely to implement it (Automatic motivation). All those who were uncertain about other forest owners' views or believed their views to be negative (Social opportunity) had not implemented ash fertilization. Additionally, most of them did not know anyone who had implemented it. Uncertainty concerning the continuity of the forest estate (Reflective motivation) also seemed to prevent implementation for few forest owners.

> *Of course, I have had this forest for such a short time, so I don't really… But apparently it is a useful operation, based on what I have read, but I don't really have any firsthand knowledge about it. (woman, 45-64 years, owns less than 50 ha, owner for less than 10 years, has not implemented)*

> *We are such a household that neither of us has inheritors, so we're not willing to think of long-term investments for common benefits, as we won't see the profit personally. (woman, 45-64 years, own over 100 ha, owner for over 20 years, has not implemented)*

4.1.3. Suggestions for nudges, nudge+ and boosts

As described in Michie et al. (2011), deficiencies identified in one or more COM-B components can be improved with targeted interventions. These interventions can be connected to specific policy categories, i.e. actions by the authorities that enable or support interventions. Based on the COM-B components and the obstacles identified from the interview data, we identified first the possible cognitive factors or heuristics underlying the obstacles and then the most promising non-coersive and non-financial policy categories that according to the BCW could support implementation of ash fertilization: communication/marketing, guidelines, environmental/social planning and service provision. We then used the understanding on the obstacles to develop suggestions on nudges, nudge+ and boosts within these policy categories for this specific target group, taking advantage of both approaches (Table 1). As there is some overlap between the three intervention types, we have made the simplifying assumptions that nudges engage automatic decision making (system 1). If the intervention additionally encourages deliberation, it is classified as nudge+. Tools that aim to improve upon specific decision-making skills of individuals are classified as boosts.

Starting with Reflective motivation, the identified key obstacles are uncertainty of profitability and site suitability. Uncertainty might in addition encompass uncertainty about risks involved and fear of financial losses. Thus, for example loss aversion and risk aversion can affect decision making. Loss aversion has been recognized as a typical cognitive bias that produces inertia (Thaler and Sunstein, 2008). We identify three possible interventions under the BCW policy categories communication/marketing and guidelines. The first intervention summarizes information about ash fertilization and frames the choice in terms of possible losses (if left undone) and can therefore be classified as a nudge+ consisting of two parts. Our second suggestion focuses on highlighting the importance of site selection and how benefits (healthier soil and forest) of ash fertilization arrive sooner than the economic benefit, illustrated with photos. It encourages reflection and is multipronged and is therefore a nudge+. The third example consists of introducing forest owners to financial literacy tools to build capacities needed for the evaluation of the profitability and risks of investments and summarizes evidence on effects of ash fertilization on growth and long-term profitability. It makes reflection less costly and can therefore be considered mainly a boost.

The behavioural interventions for the other COM-B components are constructed in a similar way. For Physical opportunity (including financial opportunity) the interviews revealed concerns of costs and timing. Some forest owners stated that the cost of ash fertilization *feels* too expensive, maybe because the activity is new to them. This might be due to status quo bias: ash fertilization feels expensive compared to situation where it is not implemented. To alleviate some of these concerns, we came, as demonstrated in Table 1, up with three possible behavioral interventions. These consist of: (1) Highlighting examples of locally well-known and respected forest owners who have implemented aerial distribution of ash fertilization (timing of aerial distribution is more flexible than with terrestrial distribution). This is a classical nudge. (2) Including offers of ash fertilization to all harvest negotiations that take place in estates including suitable peatland stands. Offers could include a comparison of the price and expected return of ash fertilization to another, more familiar forest management activity. This is a multipronged nudge+. (3) Creating services that connect forest owners with small-scale ash fertilization sites into bigger, cost-efficient entities, possibly creating also an unofficial forum for discussion and reflection, which again is a nudge+ consisting of two parts.

For Psychological capability, low knowledge concerning ash fertilization clearly prevented some interviewees from making decisions. Here, adjusting complicated descriptions of ash fertilization to (new) forest owners less familiar with forestry vocabulary, together with encouragement to reflect, could be useful (nudge+), as could be decision support trees on key questions revealing if ash fertilization would be suitable activity in the forest in question (boost). The experienced low importance of ash fertilization under the Automatic motivation could be overcome by framing it as an integral part of good forest management in peatland forests that suffer lack of nutrients, possibly using photos before-after (nudge), or by comparing its effects to other, more commonly practiced forest management activity (nudge+). Also, including ash fertilization into forest management plans signals a strong recommendation for implementation, reinforced with reminders when activity is due (nudge).

Lastly, concerning Social opportunity, some interviewees felt that both they and other forest owners were unaware of or sceptical towards ash fertilization, indicating confirmation bias. This bias pertains to a situation where one seeks conformity between personal views and views of peer forest owners (Thaler and Sunstein, 2008). To contrast this assumption, it could be beneficial to raise awareness of the prevalence of ash fertilization implemented in the region (nudge). Moreover, providing possibilities for interaction and discussion among forest owners, for example through field events, would help to normalize ash fertilization as part of every forest owner's management decisions (nudge+).

In summary, most of the suggestions developed through this approach were nudge+. This was due to the reflective element very much visible in the decision-making of this particular group of forest owners, combined with the possible heuristics that were present for some forest owners. Also forest owners' lack of knowledge concerning issues that have been researched and for which we have results available, such as profitability and effects of ash fertilization, seem to support distribution of this information in behaviourally insightful manner. We believe that nudge+ could be particularly suitable to initiate or facilitate the reflective process necessary for the ash fertilization decision to take place.

Based on our analysis, we also identified opportunities for boosts. These opportunities relate to situations where interviewees' overall capabilities to compare different options or make forestry decisions could be improved. For instance, recent research has shown that a majority of Finnish forest owners face challenges in measuring the profitability of different forestry activities (Aalto et al., 2022), indicating that economic uncertainty as a barrier may extend beyond ash fertilization. In these cases, it would be advisable to ease access to already existing training materials on how to measure profitability in the forestry context. This kind of capacity building would have a long-term impact on the decision-making of those forest owners, who value profitability.

Despite of the reflective processes that precede ash fertilization decisions within this forest owner group, we also identified some classical nudges, such as salience and social comparison, that could be applied. In our sample, classical nudges seem suitable for situations where the forest owners are knowledgeable of ash fertilization and have possibly already reflected upon it. In these cases, the implementation may be hindered by

Table 1
Examples of possible nudges, nudge+ and boosts that could be used to advance implementation of ash fertilization based on the components, intervention functions and policy categories of the COM-B and the identified key obstacles and cognitive factors.

COM-B Component[1]	Identified key obstacles[2]	Possible underlying cognitive factors[2]	Intervention functions[1]	Policy categories[1]	Examples of possible nudges, nudge+ and boosts (type)[2]
Reflective motivation	Uncertainty of profitability Uncertainty of the site suitability	Ambiguity aversion, loss aversion Status quo bias	Education Persuasion Incentivization Coercion	Communication/ marketing Guidelines Fiscal Regulation Legislation Environmental/ social planning Service provision	Nudge+ in communication/marketing: summarizing objective evidence on profitability of ash fertilization (think) framing the message in terms of possible losses if the activity is not implemented (nudge) Nudge+ in communication/marketing: highlighting the importance of site selection and how benefits (healthier soil and forest) of ash fertilization arrive sooner than the economic benefit (think). This could be illustrated with photos (nudge) Boost in guidelines: introducing forest owners with financial literacy tools that build up capacities needed for the evaluation of the profitability and risks of investments and summarize evidence on effects of ash fertilization on growth and long-term profitability
Physical opportunity	Too expensive Needs to be connected to harvests (for funding and/or terrestrial distribution)	Anchoring effect Hyperbolic discounting	Restriction Environmental restructuring Enablement	Guidelines Fiscal Regulation Legislation Environmental/ social planning Service provision	Nudge in environmental/social planning: highlighting examples of locally well-known and respected forest owners or jointly owned forests who have implemented **aerial** distribution of ash fertilization Nudge+ in service provision: including offers of ash fertilization to all harvest negotiations that take place in estates including suitable peatland stands (nudge). Offers could include a comparison of the price and expected return of ash fertilization to another, more familiar forest management activity (think) Nudge+ in service provision: creating services that connect forest owners with small-scale ash fertilization sites into bigger, cost-efficient entities (nudge), possibly creating also an unofficial forum for discussion and reflection (think)
Psychological capability	Low knowledge Uncertainty as new forest owner	Lack of knowledge	Education Training Enablement	Communication/ marketing Guidelines Fiscal Regulation Legislation Environmental/ social planning Service provision	Nudge+ in guidelines: including ash fertilization in educational materials targeted to new forest owners and framing it as standard procedure in certain peatland stands lacking nutrients (nudge), encouraging discussion, deliberation on materials (think) Boost in communication/marketing: summarising "ABC" of ash fertilization and developing decision support trees on key questions revealing if ash fertilization would be suitable activity in the forest in question
Automatic motivation	Experienced importance was low	Anchoring effect Status quo bias	Persuasion Incentivization Coercion Environmental restructuring Modelling Enablement	Communication/ marketing Guidelines Fiscal Regulation Legislation Environmental/ social planning Service provision	Nudge in communication/marketing: framing ash fertilization as an integral part of professional or good forest management in peatland forests that suffer lack of nutrients, possibly using photos before-after Nudge+ in communication/marketing: a salient description of ash fertilization (nudge) together with a table that compares its effects to other, more commonly used forest management activities (think) Nudge in guidelines: by default, including ash fertilization into forest management plans as a strong recommendation for suitable forest compartments, reinforced with reminders when activity is due
Social opportunity	Uncertainty of what others think Beliefs that others view negatively	Perceptions of social norms Confirmation bias	Restriction Environmental restructuring Enablement	Guidelines Fiscal Regulation Legislation Environmental/ social planning Service provision	Nudge+ in guidelines: sharing interviews of locally well-known forest owners who have implemented ash fertilization (nudge), including a description of the decision-making process and issues that affected it (think) Nudge in environmental/social planning: sharing information on the prevalence of ash fertilization implemented in the region Nudge+ in environmental/social planning: organizing events on ash fertilization where forest owners can interact and exchange views (combined elements of both nudge and think)

[1] Adopted from Michie et al. (2011)
[2] Based on the interview data

lack of examples or attention. In practice however, classical nudges can be easily combined with elements encouraging reflection, thus making them nudge+. In this way the intervention may benefit multiple target groups.

When designing behavioural interventions based on the findings of the BCW, we must contemplate the holistic nature of the approach and the interdependencies among its different components. As formulated by Michie et al. (2011): "*Because the target behaviour is part of a 'system,' a single intervention may have consequences for other parts of the system – these might work against sustainable change or in favour of it.*" This implies that, during the design of behavioural interventions, we should reflect on the potential positive or negative spin-offs that may result. For instance,

behavioural interventions aimed at reinforcing positive social norms related to ash fertilization may concurrently encourage forest owners to analyse implementation possibilities (Reflective motivation), alter automatic or emotional responses towards it (Automatic motivation) and build-up the related knowledge and skills (Psychological capability).

5. Discussion and conclusions

We investigated the applicability of the BCW framework to develop nudges, nudge+ and boosts that could promote the implementation of ash fertilization in Finnish private forests. Drawing from the qualitative analysis of 19 forest owner interviews, most of the factors affecting their decisions on ash fertilization fell under Reflective motivation, indicating that these decisions are oftentimes subject to careful evaluation and consideration. Ash fertilization was generally perceived as an operation that one has to know well or have experiences of to formulate an opinion of it, illustrated by a small number of factors under automatic motivation.

Among the interviewed forest owners, the effects of ash fertilization were predominantly viewed positively, with mainly environmental risks considered small. Many interviewees regarded ash fertilization as a part of professional, yield-focused forest management that they were proud to advance. The analysis identified various obstacles to the implementation, with uncertainty regarding profitability being the most frequently mentioned. This connects to the cost of implementation, which all interviewees considered high and many too high. Uncertainties surrounding profitability may also indicate an underestimation of the importance of site selection, despite scientific evidence suggesting on appropriately selected sites, ash fertilization is economically viable (Ahtikoski et al., 2008; Moilanen et al., 2015). Several forest owners stated that ash fertilization should be linked to harvests to secure funding for the investment and take advantage of the existing harvest routes. The latter implies that aerial distribution was not adequately considered, thus limiting suitable sites.

In our sample of forest owners, obstacles that appeared to entirely prevent ash fertilization related to a low level of knowledge, uncertainty stemming from being a relatively new forest owner (which connects to the low level of knowledge) and uncertainty regarding the future owner of the property. Additionally, those who were uncertain about other forest owners' views or believed their views to be negative (Social opportunity), had not implemented ash fertilization.

As the interviewed forest owners volunteered to participate in this study, our sample might suffer from self-selection bias. While half of the forest owners in our sample had implemented ash fertilization, which is significantly higher than the average, it is reasonable to assume that the lack of knowledge may pose a more common obstacle than indicated by this study. Correspondingly, the fact that half of the interviewees had already made a decision on ash fertilization might explain the prevalence of factors under Reflective motivation – they were already familiar with the activity, and the related pros and cons had been considered during the decision-making process. While interviewing these experienced forest owners provided a broader understanding of the various factors related to the operation, a more comprehensive picture of the obstacles could have been obtained by exclusively interviewing unexperienced forest owners. Among this group, factors under Psychological capability and Automatic motivation may have become more prominent.

Ash fertilization is an operation that the majority of Finnish forest owners have implemented either rarely or never. It is typically considered as an expensive activity, that has long-term impacts on the health and growth of the forest. These factors explain why ash fertilization decisions are typically not made in the spur of the moment, but instead carefully analysed. Therefore, we posit that classical nudges, which rely on the fast and automatic system 1 thinking, may not always be optimal in guiding forest owners regarding this operation. Instead, nudge+ and boosts that account for the reflective processes may prove more appropriate in certain cases. Obstacles stemming from uncertainties, unfamiliarity or unawareness could benefit from interventions targeting knowledge gaps and enhancing forest owners' capacities to determine their willingness and opportunities to implement ash fertilization.

Similar to other people, forest owners seek to streamline burdensome decision-making processes with certain rules-of-thumb. Despite the cognitive effort invested by many forest owners in the decision-making process, we identified several obstacles and related possible heuristics that influence decisions on ash fertilization, such as loss aversion, status quo and confirmation bias. The design of the behavioural interventions on ash fertilization should take these heuristics into account. In fact, we formulated several examples of interventions that could combine classical nudges to elements that encourage reflection or enhance decision-making capabilities. This kind of interventions would be particularly valuable for forest owners, who are keen to learn and retain decision-making control to themselves (Hujala et al. 2009).

The findings from this study can be leveraged to draw conclusions about the applicability of the BCW in designing nudges, nudge+ and boosts that support individuals' climate-wise decisions. We contend that this approach is versatile, applicable to a range of decisions, and reveals the diversity of factors influencing decision-making. It helps in identifying related heuristics and provides insights into potential policy categories. While the BCW is general by nature, its adaptability to specific contexts is a key strength. In conjunction with behavioural insights that recognize the often-unconscious role of heuristics, this approach fosters a comprehensive understanding of choice architecture and decision-making processes. We posit that the BCW is a valuable tool for policy makers aiming to design and test interventions that aid society in mitigating climate change. The integration of our approach in developing green nudges could enhance their precision and effectiveness.

In Finland, ash fertilization of drained peatland forests has been identified as part of the climate change mitigation strategy, yet it is implemented notably less than it could be. The data and findings of this study are directly applicable when creating nudges, nudge+ and boosts on ash fertilization for experienced, professionally managing NIPF owners with larger forest estates. This aligns with the growing interest in tailored nudging, where one-size-fits-all approach is inadequate. In fact, some of the possible interventions developed in this study have already been put into practice at local level. Our results support their wider implementation in the future, for this specific target group. Naturally, this approach could be applied also to other forestry activities that have climate change mitigation potential, such as continuous cover forestry practices in peatland forests.

To examine the actual value of the approach tested in this paper, and the behavioural interventions developed, empirical testing with a suitable target group of NIPF owners and data collection to analyse their effectiveness is necessary. Empirical piloting of nudges, nudge+ and boosts in the forestry context is not only the logical next step for our study but should be prioritized as an area of research more broadly. As we gain more experience with behavioural interventions and deepen our understanding of the factors influencing their effectiveness, the focus should shift towards tailored interventions: examining how specific forest owner characteristics influence the results.

As Sotirov et al. (2019) note, forest owners manage their forests in different ways. Some react to policy and socioeconomic changes as expected, some against expectations and some don't react at all. Recognizing the heterogeneity of the forest owners may be the key to cost-efficiently achieving the many FES that the society expects. Exploring the possibility of matching behavioural interventions, such as nudges, nudge+ and boosts, to certain forest owner' socio-demographic characteristics should be explored further, as there are indications that these characteristics can be linked for example to forest management intentions (Juutinen et al., 2020) or attitudes towards forestry activities that can mitigate climate change (Vehola et al., 2022).

Finally, we emphasize that nudges, nudge+ and boosts should be viewed as a useful addition to the array of policy tools, ones that can be used in concert with other tools, such as changes in incentives. The role

and effectiveness of behavioural interventions as part of policy mixes is also an interesting topic that should be explored further. The successful implementation of nudges, nudge+, boosts and other behavioural interventions necessitates fine-tuned information on the choice behaviour or choice architecture faced by individuals. The design of the tailored solutions and policy instruments can be time consuming and costly, which should be considered when judging the feasibility of these interventions and their scalability to larger populations.

Ethical considerations

Ethical approval was not required for this study on human participants in accordance with the local legislation and "The ethical principles of research with human participants and ethical review in the human sciences in Finland" published by the Finnish National Board on Research Integrity (2019)[2]. According to the instructions of this publication (p.20), none of the critical research designs that would require ethical review statement was present in this study. The participants provided their informed consent to participate in this study: the purpose of the interviews and their willingness to participate was first inquired by the staff of the Forest Management Association and secondly by the interviewer before the interview started. All the interviews were carried out anonymously and hence the analysed interview transcripts did not include any personal data.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT in order to improve language and readability. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Funding

This work was written in the context of a research project that received funding from the Strategic Research Council at the Academy of Finland (grant number 335186).

CRediT authorship contribution statement

Marjo Maidell: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Writing – review & editing. **Mats Godenhielm:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Funding acquisition. **Annukka Vainio:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Paula Salo:** Conceptualization, Methodology, Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Due to the limited number of interviewed forest owners and partly personal questions asked in this study, interview transcripts cannot be made publicly available. The interview transcripts excluding all possible identifying details are, however, available from the corresponding author upon reasonable request.

[2] https://tenk.fi/sites/default/files/2021-01/Ethical_review_in_human_sciences_2020.pdf

Acknowledgments

We thank the forest owners who participated in the interviews for sharing their views and experiences. We also thank the ClimateNudge research project team members for the inspiring discussions concerning the findings of this study as well as the Forest Management Association Siikalakeus for their assistance during the collection of data analysed in this study.

References

Aalto L., Antturi J., Horne P., Hurttala H., Hänninen J., Leppänen J. 2022. Puunmyyntitulojen käyttö ja metsätalouden kannattavuuden mittaaminen – Metsänomistaja 2020. PTT Raportteja 272.

Act on a Temporary Forestry Incentive Scheme (2023). Accessed 25 June 2024. https://finlex.fi/fi/laki/ajantasa/2023/20230071.

Ahtikoski, A., Moilanen, M., Hökkä, H., 2008. Profitability of fertilization of Scots pine on a drained peatland – a case study. After wise use – the future of peatlands.. In: Proceedings of the 13th International Peat Congress, 8–13 June 2008, Tullamore, Ireland. International Peat Society, Jyväskylä, Finland, pp. 460–462.

Ambrose-Oji, B., Goodenough, A., Urquhart, J., Hall, C., Karlsdóttir, B., 2022. 'We're Farmers Not Foresters': farmers' decision-making and behaviours towards managing trees for pests and diseases. Forests 13, 1030. https://doi.org/10.3390/f13071030.

Banerjee S., John P., 2021. Nudge plus: incorporating reflection in behavioural public policy. Behav. Public Policy, 1-16. 10.1017/bpp.2021.

Banerjee S., John P., 2022. Nudge and Nudging in Public Policy (December 28, 2022). Forthcoming in the Springer Encyclopedia of Public Policy edited by M. Gerven, C.R. Allison and K. Schubert, Available at SSRN: https://ssrn.com/abstract=4314881 or 10.2139/ssrn.4314881.

Banerjee, S., John, P., 2023. Nudge+: Putting Citizens at the Heart of Behavioural Public Policy. Research Handbook on Nudges and Society. Edward Elgar Publishing Ltd. https://doi.org/10.2139/ssrn.4315671.

Carlsson, F., Gravert, C., Johansson-Stenman, O., Kurz, V., 2021. The use of green nudges as an environmental policy instrument. Rev. Environ. Econ. Policy 15 (2), 216–237, 2021.

DellaVigna, S., Linos, E., 2022. RCTs to scale: comprehensive evidence from two nudge units. Econometrica 90, 81–116. https://doi.org/10.3982/ECTA18709.

Eriksson, L., Sandström, C., 2022. Is voluntarism an effective and legitimate way of governing climate adaptation? A study of private forest owners in Sweden. For. Policy Econ 140, 102751. https://doi.org/10.1016/j.forpol.2022.102751.

European Commission, 2019. The European green deal. communication from the commission to the european parlament, the European council. The European economic and social committee of the regions, Brussels, Belgium 24.

Evans, J., 2008. Dual-processing accounts of reasoning, judgment, and social cognition. Annu. Rev. Psychol. 59, 255–278.

Finnish Forest Centre, 2022. Kemera työmäärät 1.1-31.12.2022 maksujen perusteella, date 30.12.2022. Accessed 20.6.2023. https://www.metsakeskus.fi/sites/default/files/document/kemera-tyomaarat-koko-vuosi-2022_0.pdf.

Finnish Government, 2019. Pääministeri Sanna Marinin hallituksen ohjelma 10.12.2019. Sosiaalisesti, taloudellisesti ja ekologisesti kestävä yhteiskunta. Valtioneuvoston julkaisuja 2019 (31), 216.

Grüne-Yanoff, T., 2018. Boosts vs. Nudges from a welfarist perspective. Rev. Econ. Polit. 128 (2), 209–224.

Grüne-Yanoff, T., Hertwig, R., 2016. Nudge versus boost: How coherent are policy and theory? Minds Mach.: J. Artif. Intell. Philos. Cogn. Sci. 26 (1-2), 149–183. https://doi.org/10.1007/s11023-015-9367-9.

Hertwig, R., Grüne-Yanoff, T., 2017. Nudging and boosting: steering or empowering good decisions. Perspect. Psychol. Sci. 12, 6. https://doi.org/10.1177/1745691617702496.

Hujala, T., Pykäläinen, J., Tikkanen, J., 2007. Decision making among Finnish non-industrial private forest owners: the role of professional opinion and desire to learn. Scand. J. For. Res. 22, 454–463.

Hujala, T., Tikkanen, J., Hänninen, H., Virkkula, O., 2009. Family forest owners' perception of decision support. Scand. J. For. Res. 24, 448–460.

Hökkä, H., Repola, J., Moilanen, M., 2012. Modelling volume growth response of young Scots pine (Pinus sylvetris) stands to N, P, and K fertilization in drained peatland sites in Finland. Can. J. For. Res. 42 (7), 1359–1370.

Isoaho, K., Burgas, D., Janasik, N., Mönkkönen, M., Peura, M., Hukkinen, J.I., 2019. Changing forest stakeholders' perception of ecosystem services with linguistic nudging. Ecosyst. Serv. 40, 101028 https://doi.org/10.1016/j.ecoser.2019.101028.

John, P., Smith, G., Stocker, G., 2009. Nudge Nudge, think think: two strategies for changing civic behaviour. Polit. Q. 80, 361–370. https://doi.org/10.1111/j.1467-923X.2009.02001.x.

Juutinen, A., Tolvanen, A., Koskela, T., 2020. Forest owners' future intentions for forest management. For. Policy Econ. 118, 102220 https://doi.org/10.1016/j.forpol.2020.102220.

Kahneman, D., 2011. Thinking, Fast and Slow. Farrar, Straus and Giroux, New York.

Karppinen H., Hänninen H., Horne P., 2020. Suomalainen metsänomistaja 2020. Luonnonvara- ja biotalouden tutkimus 30/2020. Luonnonvarakeskus. Helsinki. 73 s.

Kiger, M.E., Varpio, L., 2020. Thematic analysis of qualitative data: AMEE Guide No. 131. Med. Teach. 42, 846–854. https://doi.org/10.1080/0142159X.2020.1755030.

Kotilainen, J., Rytteri, T., 2011. Transformation of forest policy regimes in Finland since the 19th century. J. Hist. Geogr. 37, 429–439. https://doi.org/10.1016/j.jhg.2011.04.003.

Krusche, A., Wilde, L., Ghio, D., Morrissey, C., Froom, A., Chick, D., 2022. Developing public transport messaging to provide crowding information during COVID-19: application of the COM-B model and behaviour change wheel. Transp. Res. Interdiscip. Perspect. 13, 100564 https://doi.org/10.1016/j.trip.2022.100564.

Laakkonen, A., Zimmerer, R., Kähkönen, T., Hujala, T., Takala, T., Tikkanen, J., 2018. Forest owners' attitudes toward pro-climate and climate-responsive forest management. For. Policy Econ. 87, 1–10. https://doi.org/10.1016/j.forpol.2017.11.001.

Lehtonen, A., Aro, L., Haakana, M., Haikarainen, S., Heikkinen, J., Huuskonen, S., Härkönen, K., Hökkä, H., Kekkonen, H., Koskela, T., Lehtonen, H., Luoranen, J., Mutanen, A., Nieminen, M., Ollila, P., Palosuo, T., Pohjanmies, T., Repo, A., Rikkonen, P., Räty, M., Saarnio, S., Smolander, A., Soinne, H., Tolvanen, A., Tuomainen, T., Uotila, K., Viitala, E.J., Virkajärvi, P., Wall, A., Mäkipää, R., 2021. Maankäyttösektorin ilmastotoimenpiteet: Arvio päästövähennysmahdollisuuksista. Luonnonvara- ja biotalouden tutkimus 7/2021. Luonnonvarakeskus. Helsinki 121.

Löfgren, Å., Nordblom, K., 2020. A theoretical framework of decision making explaining the mechanisms of nudging. J. Econ. Behav. Organ. 174, 1–12.

Matthies, B.D., Kalliokoski, T., Eyvindson, K., Honkela, N., Hukkinen, J.I., Kuusinen, N. J., Räisänen, P., Valsta, L.T., 2016. Nudging service providers and assessing service trade-offs to reduce the social inefficiencies of payments for ecosystem services schemes. Environ. Sci. Policy 55, 228–237. https://doi.org/10.1016/j.envsci.2015.10.009.

Mertens, S., Herberz, M., Hahnel, U.J.J., Brosch, T., 2022. The effectiveness of nudging: a meta-analysis of choice architecture interventions across behavioral domains. Proc. Natl. Acad. Sci. U. S. A. 119 (1), e2107346118.

Michie, S., van Stralen, M.M., West, R., 2011. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Implement. Sci. 6, 42. https://doi.org/10.1186/1748-5908-6-42.

Ministry of Agriculture and Forestry, 2022. Government report on the climate plan for the land use sector. Publications of the Ministry of Agriculture and Forestry 2023:12. https://urn.fi/URN:ISBN:978-952-366-592-7 . 117.

Moilanen, M., Hytönen, J., Hökkä, H., Ahtikoski, A., 2015. Fertilization increased growth of Scots pine and financial performance of forest management in a drained peatland in Finland. Silva Fenn. 49 (3) https://doi.org/10.14214/sf.1301 article id 1301.

Moilanen, M., Silfverberg, K., Hökkä, H., Issakainen, J., 2004. Comparing effects of wood ash and commercial PK fertiliser on the nutrient status and stand growth of Scots pine on drained mires. Balt. For. 10 (2), 2–10.

Natural Resources Institute Finland, 2023. Statistics database. Forest statistics, Structure and production. Natural Resources Institute Finland. https://statdb.luke.fi/PxWeb/pxweb/en/LUKE/. Accessed 13 May 2023.

OECD, 2019. Tools and Ethics for Applied Behavioural Insights: The BASIC Toolkit. OECD Publishing, Paris. https://doi.org/10.1787/9ea76a8f-en.

Ojanen, P., Penttilä, T., Tolvanen, A., Hotanen, J-P., Saarimaa, M., Nousiainen, H., Minkkinen, K., 2019. Long-term effect of fertilization on the greenhouse gas exchange of low-productive peatland forests. For. Ecol. Manag. 432, 786–798. https://doi.org/10.1016/j.foreco.2018.10.015.

Ouvrard, B., Abildtrup, J., Bostedt, G., Stenger, A., 2019. Determinants of forest owners attitudes towards wood ash recycling in Sweden - Can the nutrient cycle be closed? Ecol. Econ. 164, 106293 https://doi.org/10.1016/j.ecolecon.2019.04.005.

Ouvrard, B., Abildtrup, J., Stenger, A., 2020. Nudging acceptability for wood ash recycling in forests: a choice experiment. Ecol. Econ. 177, 106748 https://doi.org/10.1016/j.ecolecon.2020.106748.

Saarsalmi, A., Smolander, A., Moilanen, M., Kukkola, M., 2014. Wood ash in boreal, lowproductive pine stands on upland and peatland sites: long-term effects on stand growth and soil properties. For. Ecol. Manag. 327, 86–95. https://doi.org/10.1016/j.foreco.2014.04.031.

Szaszi, B., Higney, A., Charlton, A., Gelman, A., Ziano, I., Aczel, B., Goldstein, D.G., Yeager, D.S., Tipton, E., 2022. No reason to expect large and consistent effects of nudge interventions. Proc. Natl. Acad. Sci. 119 (31), e2200732119.

Siipi, H., Koi, P., 2022. The ethics of climate nudges: central issues for applying choice architecture interventions to climate policy. Eur. J. Risk Regul. 13 (2), 218–235. https://doi.org/10.1017/err.2021.49.

Sotirov, M., Sallnäs, O., Eriksson, L.O., 2019. Forest owner behavioral models, policy changes, and forest management. An agent-based framework for studying the provision of forest ecosystem goods and services at the landscape level. For. Policy Econ. 103, 79–89. https://doi.org/10.1016/j.forpol.2017.10.015. Models and tools for integrated forest management and forest policy analysis.

Thaler, R.H., Sunstein, C.R., 2008. Nudge: Improving Decisions about Health, Wealth and Happiness. Yale University Press, New Haven & New York.

The Behavioural Insights Team, 2014. East. Four Simple Ways to Apply Behavioural Insights. The Behavioural Insights Team. https://www.bi.team/wp-content/uploads/2015/07/BIT-Publication-EAST_FA_WEB.pdf.

The Behavioural Insights Team, 2010. Mindspace. Influencing Behaviour Through Public Policy. The Behavioural Insights Team. https://www.bi.team/wp-content/uploads/2015/07/MINDSPACE.pdf.

Truelove, S., Vanderloo, L.M., Tucker, P., Di Sebastiano, K.M., Faulkner, G., 2020. The use of the behaviour change wheel in the development of ParticipACTION's physical activity app. Prev. Med. Rep. 20, 101224 https://doi.org/10.1016/j.pmedr.2020.101224.

Valatin, G., Moseley, D., Dandy, N., 2016. Insights from behavioural economics for forest economics and environmental policy: Potential nudges to encourage woodland creation for climate change mitigation and adaptation? For. Policy Econ. 72, 27–36.

Vehola, A., Malkamäki, A., Kosenius, A.K., Hurmekoski, E., Toppinen, A., 2022. Risk perception and political leaning explain the preferences of non-industrial private land-owners for alternative climate change mitigation strategies in Finnish forests. Environ. Sci. Policy 137, 228–238. https://doi.org/10.1016/j.envsci.2022.09.003.

Winkel, G., Lovrić, M., Muys, B., Katila, P., Lundhede, T., Pecurul, M., Pettenella, D., Pipart, N., Plieninger, T., Prokofieva, I., Parra, C., Pülzl, H., Roitsch, D., Roux, J.L., Thorsen, B.J., Tyrväinen, L., Torralba, M., Vacik, H., Weiss, G., Wunder, S., 2022. Governing Europe's forests for multiple ecosystem services: Opportunities, challenges, and policy options. For. Policy Econ. 145, 102849 https://doi.org/10.1016/j.forpol.2022.102849.