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The effect of information transfer related to soil biodiversity on Flemish citizens' preferences for forest management

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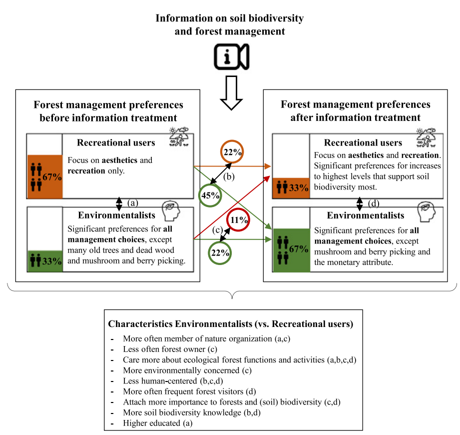
HIGHLIGHTS

- Despite its crucial role, forest soil biodiversity is under anthropogenic pressure.
- Forest management can support soil biodiversity but conflicts with public opinion.
- Public preferences are studied through a choice experiment and informational video.
- Valuation of biodiversity and sustainable tree logging increased after information.
- Respondents unfamiliar with forest management changed preferences most in response to information.

GRAPHICAL ABSTRACT



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ABSTRACT

Despite its essential role in the delivery of ecosystem services, forest soil biodiversity experiences pressures, especially of anthropogenic origin. Forest management can harm or support soil biodiversity, depending on the management decisions taken, but currently generally overlooks soils. Management decisions considerably depend on public opinion, that often conflicts with foresters' viewpoint and differs from what is ecologically optimal. Moreover, public opinion is mostly ignorant of soil biodiversity, creating opportunities for information to strengthen consideration of soil biodiversity amongst citizens. Therefore, this study assesses public preferences for forest management affecting soil biodiversity, and investigates the effect of an information treatment related to soil biodiversity on these preferences. For this purpose, we conducted a discrete choice experiment with a representative sample of 299 Flemish citizens, including an information treatment in a within subjects study design. Results showed that the information treatment significantly increased preferences for higher shares of old trees and dead wood, tree species mixing and tree logging through fixed logging roads, which support soil biodiversity. Heterogeneity in preferences was found but decreased after the information treatment. Specifically, 67% of the respondents focused on aesthetics and recreation before the information treatment, while their preferences for biodiversity components, tree logging and regulating ecosystem services considerably increased after the information treatment. Providing information is expected to increase preferences of these individuals most, who generally were less familiar with forests and soil biodiversity. On the other hand, familiar individuals more

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knowledgeable of soil biodiversity disclosed preferences that encouraged a wider set of forest management intensities. Policy makers can use this information to increase valuation of soil biodiversity by citizens regarding their forest management preferences. Eventually, this can help to achieve public acceptance of management choices that support soil biodiversity and foster adoption of such choices amongst foresters.

1. Introduction

Soils are being increasingly recognized for their essential role in the functioning of terrestrial ecosystems and are inherently linked with aboveground processes through plant-soil feedbacks (Aksoy et al., 2017; Keesstra et al., 2018; Korboulewsky et al., 2016). Crucial to healthy soils is their biological component, represented by the wide range of organisms present in soils (Bardgett and Van Der Putten, 2014). This soil biodiversity highly contributes to the delivery of forest ecosystem services through the ecosystem functions that they fulfil in a complex soil food web (Bardgett and Van Der Putten, 2014; Lukac, 2017; Mori et al., 2017). Despite their crucial role, soil biodiversity and soil biological functioning are currently under pressure, especially in agricultural areas (Orgiazzi et al., 2016). While forest soil biodiversity experiences mostly moderate risks, maintaining and optimizing its current level is crucial, as forests take up circa 40% the European Union's land area and are believed to play an essential role in climate change mitigation and future delivery of a wide range of ecosystem services (Eurostat, 2019; Gardi et al., 2013; Lukac, 2017).

Orgiazzi et al. (2016) categorized the origin of pressures on soil biodiversity in Europe into 13 categories, the majority of which are directly (e.g. intensive human use) or indirectly (e.g. land use change) linked to anthropogenic disturbances. As a result, an essential step to stop soil degradation is to create a culture amongst professionals and citizens that acknowledges and understands the essential role of soils and their biodiversity (Salhi et al., 2020). Of particular interest are management practices, as they have the potential to damage or support soil biodiversity, depending on the management decisions taken (Lukac, 2017). Generally, intensive management practices have been found to negatively impact soil biodiversity (Tibbett et al., 2020). First of all, biomass removal led to a functional homogenization of Oribatida and Collembola because of the lower availability of suitable microhabitats (Rousseau et al., 2019). Similarly, removing dead wood has been found to negatively affect small invertebrates (e.g. springtails), and saproxylic insects and fungi which are considered indicators of climate-smart forestry, because of the specific habitat niches that dead wood provides (Parisi et al., 2018; Raymond-Léonard et al., 2020). Secondly, soil compaction caused by tree harvesting using heavy machinery or recreation was found to have negative consequences on soil functioning and forest productivity due to reduced porosity limiting oxygen and water supply to for example soil microorganisms (Blasi et al., 2013; Cambi et al., 2015; Hartmann et al., 2014). A third example of the effect of forest management on soil biodiversity is through tree species mixing. Multispecies forest stands have been found to be associated with a higher complexity in bacterial communities compared to monospecific stands and hence a forest system with larger functionality (Prada-Salcedo et al., 2020). Similarly, Gillespie et al. (2020) concluded that microbial communities resisted drought better in mixed forest stands compared to monospecific stands. Hence, forest managers should consider soil biodiversity in their management decisions and opt for sustainable practices to support soil organisms and their functioning. During the last decades, close-to-nature forest management regimes have received increasing attention (Puettmann et al., 2015). These regimes are oriented towards conservation and sustainable provisioning of multiple ecosystem services, and take particularly aboveground diversity into account. Nevertheless, they mostly overlook specific soil characteristics, including soil biodiversity, and lack wide adoption. Similarly, Lukac (2017) and Vanermen et al. (2020) pointed out that forest management currently treats soils mostly as a black box, overlooking the importance of soil biodiversity.

Thus, forest soils and their management can be characterized as social-ecological systems that regard humans as an integral part of nature and include multiple positive and negative feedback loops between the social and ecological system (Berkes et al., 1998; Meyfroidt, 2013). While the ecological component, including soil biodiversity, has been increasingly studied, few studies investigated the social component related to forest soils, and its link with the ecological component (Amin et al., 2020; Hou et al., 2020). Studying such social-ecological perspectives has been characterized as one of the key priorities in applied forest ecology studies to improve forest management (Mori et al., 2017).

While forest management is a crucial component linking the social and ecological system related to forest soils, it is complicated due to the relatively long rotation lengths and the large number of factors and objectives to consider (de Bruin et al., 2015; Lukac, 2017; Smith et al., 2012). De Bruin et al. (2015) studied public and private forest managers' perception of the complexity of forest management in the Netherlands and found that public opinion was amongst the most relevant factors influencing decision making. Moreover, public opinion was considered to be uncertain, indicating that it is little predictable and hence contributes to the complexity of managing forests. Public preferences for forest management often differ from those of forest managers which can generate conflicts amongst stakeholders (Kearney et al., 2010; Nordén et al., 2017; Referowska-Chodak, 2019). In order to prevent such conflicts, it is crucial to integrate perceptions and preferences of the wider public into the forest management decision making process, especially in public forests (Paletto et al., 2013; Referowska-Chodak, 2019). While private forest managers are generally less directly influenced by public opinion, they also benefit from increased appreciation by citizens through for example new sources of public interest and additional income (FAO et al., 2003). Moreover, forests are increasingly managed and valued for the wide range of ecosystem services that they deliver, many of which are not traded in markets (especially related to soil), causing limited insights in their economic value and societal demand (e.g. water regulation, carbon sequestration) (Grilli et al., 2016; Mori et al., 2017; Sing et al., 2018). Environmental valuation through eliciting public preferences for management characteristics and ecosystem services related to soil biodiversity can help developing policies that are effective from an environmental point of view and socially accepted, and can foster adoption of management practices that support soil biodiversity (Varela et al., 2018, 2017). Moreover, the social dimension of sustainable forest management approaches received increasing attention during the last decades, but is generally not considered in the adoption decisions of management practices (Paletto et al., 2013; Puettmann et al., 2015). Hence, incorporating public preferences in forest management is a key element to realize sustainable and socially accepted forest management (Upton et al., 2012). Nevertheless, to our knowledge no studies investigated public preferences related to forest soils and forest soil biodiversity in particular, despite their crucial role and degraded state.

Public opposition is often related to a lack of knowledge and understanding, known as the information-deficit model (Sturgis and Allum, 2004; Tranter, 2020). While this model received criticisms during the last decades regarding its assumptions related to the importance of social context (i.e. the model overlooks the role of social context and culture), the core idea still holds, especially related to soils and their biodiversity (Stedman et al., 2016). Soil biodiversity suffers from poor visibility, complex interactions and incomplete scientific understanding of the belowground system (Prager and Curfs, 2016; Xylander and Zumkowski-xylander, 2018). Providing information is believed to change an individual's attitudes and eventually behavior, depending on background and context (Stedman et al., 2016). Therefore, informing the public while accounting for social context could help achieving public acceptance of forest management practices that support soil biodiversity. Notably, previous stated preference studies found insignificant to positive effects on preferences and willingness-to-pay (WTP) for environmental goods and forest management, depending on social context, personal characteristics such as prior knowledge, familiarity with the good, visiting frequency and education level, and the type of information provided (Brahic and Rambonilaza, 2015; Gundersen et al., 2017; Hasselström and Håkansson, 2014; Needham et al., 2018; Rambonilaza and Brahic, 2016). The impact of information is inherent to stated preference studies and is commonly known under 'framing effects', which include the framing of attributes and their levels, the complexity of choice tasks and optionally a specifically designed information transfer (Kragt and Bennett, 2012; Latinopoulos et al., 2018). This implies that information can also manipulate respondents when it is value-laden, directional or conveyed in persuasive settings (van der Wal et al., 2014). Therefore, particular attention should be given to the information content of a discrete choice experiment (DCE) and its effect on findings, especially concerning complex or unfamiliar goods and non-use values (Needham et al., 2018). In particular, a positive information effect could be expected for the evaluation of non-use values, such as (soil) biodiversity, as individuals do not have any prior reason to improve their knowledge. On the other hand, non-use values are often considered to be linked to ethical and social concerns, which implies a limited expected impact of the information provided (Rambonilaza and Brahic, 2016). General practice includes providing background information on the public good and project to be evaluated, with trade-offs between providing sufficient information and including too much detail (Needham et al., 2018; Upton et al., 2012).

In this paper, we focus on two aspects that have received little attention in literature. Firstly, we investigate public preferences for a diverse set of forest management characteristics oriented towards multiple ecosystem services delivery from a soil biodiversity perspective. Secondly, we study the effect of information transfer related to soil biodiversity and forest management on these preferences similarly to an information campaign, taking social context into account, which is of particular interest to policy makers. Public information campaigns may help to make more informed choices as citizens' knowledge on soil biodiversity is expected to be limited. Summing up, the main study objectives are: (i) examine public preferences for forest management related to soil biodiversity, (ii) assess the effect of an information treatment related to soil biodiversity on public preferences for forest management, and (iii) investigate which socio-demographic, attitudinal and/or recreational characteristics influence public preferences and the effect of an information treatment on these preferences. Based on previous research, such information is expected to increase preferences for soil biodiversity friendly management practices, at least for part of the sample. To address these objectives, we use Flanders (Belgium) as a case study for a DCE in two rounds, one round before the information treatment and the other one after.

2. Methods

2.1. Case study

This study uses Flanders, northern Belgium, as a case study region. Flanders is a densely populated area (487 inhabitants/km^2) with high urbanization rates, a high pressure on land and a low forest cover of about 11% (Agentschap Natuur en Bos, 2019; De Valck et al., 2014; Statistiek Vlaanderen, 2020). Due to fragmentation, forest patches are relatively small and scattered and experience negative effects of neighboring land uses such as through atmospheric deposition and agricultural management (Decocq et al., 2016). These developments have put pressure on forest functioning, soil biodiversity and ecosystem services delivery, but at the same time have led to an increase in societal demand for forests and the diversity of ecosystem services that they can provide (Vandekerkhove, 2013). While forests were mainly used for wood provisioning (economic function) in the past, they are nowadays increasingly seen and managed for the socio-cultural ecosystem services that they provide, including recreation and nature conservation (Vandekerkhove, 2013). For example, the recreational value of a large Flemish forest complex (Meerdaalwoud) was estimated to be more than 30 times the yearly revenue of the sale of timber in 2000 (Moons et al., 2000). Regulations and management are generally oriented towards safeguarding forest area and maintaining the societal functions that forests deliver (Gembloux Agro-Bio Tech et al., 2018). This rationale is embedded in the Flemish forest law and covers both public and private forests. Crucial principles include sustainable management, the stand-still principle, sustainable harvesting, public access to forests and recently criteria for integrated nature management. As such, it applies a management vision for forests focusing on sustainable forest use in various ways by society. Furthermore, it acknowledges the need for increased involvement of the general public in the decision making process. Forest access is relatively strictly regulated because of the limited availability of forests and regulations foresee financial support for social goals, including public access (Gembloux Agro-Bio Tech et al., 2018). Officially, forests are accessible for pedestrians, irrespective of being public or private, unless otherwise indicated. Over time, the wider public has increasingly claimed insight and a voice in forest management decisions, which has led to several conflicts with forest management, especially concerning tree harvesting (Struyve, 2019; Vandekerkhove, 2013). Moreover, the wider public generally does not make the difference between public and private forests, which makes it also in the interest of private forest managers to take public opinion into account in their management decisions and pursue public acceptance through mutual understanding. This is also motivated by the fact that usually larger forest complexes are visited by citizens, which are often public forests or private forests as part of a forest grouping. Forest groupings are cooperative associations including public and private forest owners that were founded a couple of decades ago to support (private) forest owners in their management decisions (advice, information, administrative support, etc.). Moreover, they generally pursue similar goals regarding sustainable forest management and forest accessibility as public forests. They cover over 40% of the total forest area in Flanders and include over 30% of the private forest area (Koepel van de Vlaamse Bosgroepen, 2019; Van Gossum and De Maeyer, 2006). The latest forest inventory could not spot significant differences between Flemish public and private forests which indicates similar forest practices linked to sustainable forest management (Gembloux Agro-Bio Tech et al., 2018; Govaere, 2020; Vandekerkhove, 2013). As such, our case study stands as an example for densely populated areas that face pressures on forest resources while the demand for forest ecosystems is increasing, a policy-supported focus on multiple ecosystem services delivery and an increasing demand of society for involvement in forest management. Therefore, Flanders is an interesting case study to assess public preferences for multiple ecosystem services forest management.

2.2. Choice experiment method

DCEs are a widely applied stated preference method, with numerous applications in nature valuation (e.g. De Valck et al., 2014; Varela et al., 2017). In DCEs, a set of choice cards is presented to respondents where each choice card contains two or more alternatives between which respondents have to choose (Louviere et al., 2000). These alternatives differ in (a subset of) characteristics, or attributes, that describe them.

Based on an individual's repeated choices, preferences for hypothetical scenarios related to, for example, forest management can be modelled.

2.3. Study design and data collection

Fig. 1 displays the methodological approach used to design the DCE and collect the data. Specifically, four stages were completed starting with the selection of the attributes and the construction of the experimental design. Then, the survey was developed and responses were collected.

2.3.1. Attribute selection

For our DCE, we selected attributes that describe forest management oriented towards multiple ecosystem services and affect soil biodiversity using a process adapted from Jeanloz et al. (2016). Specifically, a list of 38 forest management related characteristics was drawn based on literature screening. Then, a scoring exercise was held amongst academic experts in bio-economics (N = 7) and forest and nature management (N = 10) in which they had to score the 38 attributes according to their relevance for a multiple ecosystem services forest management and for soil biodiversity. Based on the individual exercises, the 15 attributes with the highest average score were extracted for further discussion. The experts were then asked to collectively select a final set of six or seven attributes, including one cost attribute, by merging and eliminating attributes from the top-15 list. Finally, a set of ten attributes was selected, for which we defined levels through internal discussion. The attributes and levels were reviewed for clarity and correct interpretation in a focus group discussion amongst friends and family (N = 8). Table 1 shows the attributes and levels, of which nine attributes are categorical and the cost attribute is continuous. The categorical variables are dummy coded with the base level set to the least preferred level from a soil biodiversity perspective (i.e. with highest potential to harm soil biodiversity).

2.3.2. Choice design

The DCE was constructed using a Bayesian D-efficient design in the JMP Pro 14 software. Because the attributes 'forestry system' and 'vegetation layers' were not independent, these attributes were merged into a new attribute with six levels (Table 1). Nevertheless, both attributes were presented separately in the choice cards to include the effect of the forestry system on layering and the visual aesthetic value of a forest in a clear way for ease of understanding. Specifically, clear-cutting implies an even-aged forest structure, whereas group and selective cutting imply an uneven-aged forest structure. Hence, in the design and analysis of the DCE, 9 attributes were used to characterize a forest management scenario. In total, 48 choice cards of two alternative forest management scenarios were created and grouped in 8 blocks, or surveys, of 6 choice cards. These surveys were spread randomly and about evenly over the respondents (10%–15% per block). A forced choice structure was used in the design of the DCE presenting two alternative forest management scenarios. While it is usually common practice to include an opt-out or status quo option, this decision forms an integral part of the design process and is determined in the first place by the objective of the DCE (Johnston et al., 2017; Veldwijk et al., 2014). Generally, the inclusion of an opt-out or status quo option is considered crucial to mimic real life choices and be consistent with demand theory avoiding inconsistent welfare estimates (Penn et al., 2019). However, if the main objective is to determine the characteristics of the most preferred scenario, including an opt-out or status quo is unnecessary. Also, it leads to decreasing efficiency as parameters are estimated from fewer observations with increasing number of no-choices (Brazell et al., 2006; Veldwijk et al., 2014). Furthermore, previous studies found that the theoretical assumptions of choosing the opt-out or status quo underlying the utility maximization theory often conflict with practice. Specifically, respondents were found to select the opt-out or status quo option when trade-offs were difficult or complex in order to avoid cognitive effort to make a choice (Johnston et al., 2017; Veldwijk et al., 2014). As a result, the selection of the no-choice option might be concentrated in certain choice sets which would decrease the power of the DCE (Brazell et al., 2006). Moreover, limited studies have investigated the effect of including an opt-out or status quo compared to a forced choice form with mixed results (Livingstone et al., 2020; Mohamad et al., 2020; Penn et al., 2019; Veldwijk et al., 2014). This has led to multiple studies applying a forced choice structure in the DCE design (e.g. Hensher et al., 2005; Rambonilaza and Brahic, 2016). Hence, we used a forced choice structure because of four main reasons: (i) due to the relatively complex set-up of the DCE including nine attributes and relatively limited expected sample size, sufficient observations per respondent were needed, (ii) the main objective of our DCE is to study which characteristics of forest management are considered most important by respondents and/or are affected by information transfer, (iii) our study presents general forest management scenarios not linked to a specific local case study, which impedes the definition of a status quo option as this differs across the case study region, (iv) there will generally be some level of forest management throughout forests in the case study region, making a forced choice format relatively realistic. Because of this structure, no welfare analysis was performed.

In order to reduce the cognitive burden on respondents that would result from varying all attributes simultaneously, a partial profile design

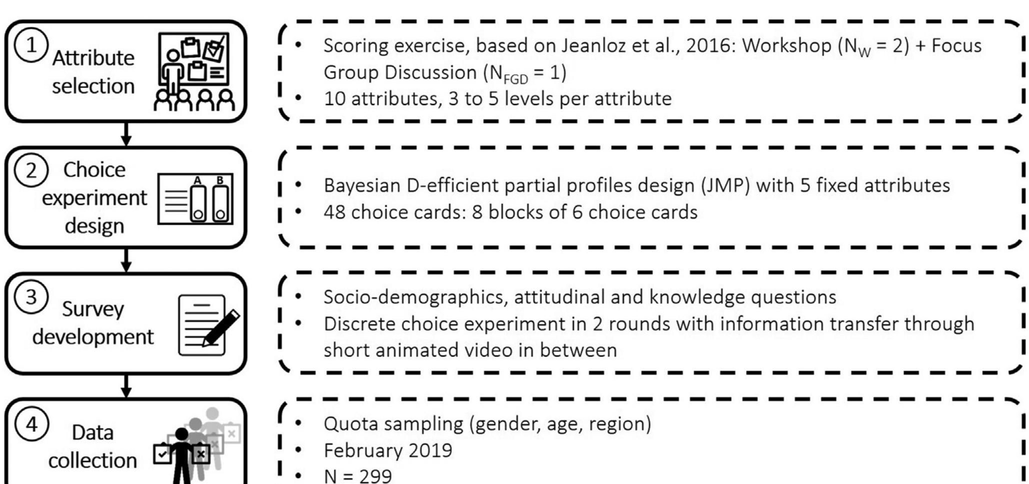

Fig. 1. Methodological approach for the DCE design and data collection.

Table 1
Overview of the ten attributes and their levels used in the DCE.

Attribute	Description to respondents	Levels	Combined levels considered in the analysis
Forestry system [a]	Method used to replace old trees with new trees. In clear-cutting the entire forest stand is replaced at one moment on 100% of its stand area. In group cutting groups of trees are replaced consecutively. In selective cutting individual trees are regularly replaced.	1. Clear-cutting 2. Group cutting 3. Selective cutting	**Forestry system – Vegetation layers** 1. Clear-cutting – Even-aged without understory *[base level]* 2. Clear-cutting – Even-aged with understory 3. Group cutting – Uneven-aged without understory 4. Group cutting – Uneven-aged with understory 5. Selective cutting – Uneven-aged without understory 6. Selective cutting – Uneven-aged with understory
Vegetation layers [a]	Extent to which different vegetation layers are present, including a tree layer, shrub layer and/or herb layer. In an even-aged forest stand, all trees in the tree layer belong to the same age class, whereas in an uneven aged forest stand, trees in the tree layer belong to different age classes and are of different height. Understory reflects the presence of a shrub and/or herb layer.	1. Even aged without understory 2. Even aged with understory 3. Uneven aged without understory 4. Uneven aged with understory	
Old trees and dead wood	Share of old trees (=remarkably old for its species) and dead wood (=dead and dying (parts of) trees), expressed relative to the total timber stock.	1. No old trees and dead wood (<1% of total timber stock) *[base level]* 2. Few old trees and dead wood (2-5% of the total timber stock) 3. Many old trees and dead wood (≥10% of the total timber stock)	
Tree species diversity	Extent to which tree species are mixed. In a slightly mixed stand one of the species is dominant, while in an intensively mixed stand all species are present in comparable numbers	1. Monoculture (1 tree species) *[base level]* 2. Slightly mixed (2 to 3 tree species) 3. Intensively mixed (minimum 4 tree species)	
Tree logging	Method used for logging of the wood. Specialized machines are used for logging and skidding the trails in which the use of fixed roads restricts machines to only ride on these marked strips and protection can be used to limit soil compaction.	1. Mechanical logging without fixed logging roads *[base level]* 2. Mechanical logging with fixed logging roads 3. Mechanical logging with fixed logging roads and additional protection (such as steel plates or a bed of branches)	
Carbon storage	Amount of CO_2 stored per 100 ha of forest, translated into yearly CO_2 emissions of a number of citizens. This process can mitigate climate change.	1. Low carbon storage (equivalent to yearly emissions of 250 citizens) *[base level]* 2. Moderate carbon storage equivalent to yearly emissions of 350 citizens) 3. High carbon storage (equivalent to yearly emissions of 450 citizens)	
Water retention	Rate at which (rain)water flows through the forest ecosystem, affecting water quality and storage through purifications and buffering. The slower the water flows, the higher the water quality and storage.	1. Rapid water flow (low water quality and storage) *[base level]* 2. Moderate water flow (moderate water quality and storage) 3. Slow water flow (high water quality and storage)	
Recreation	Possibility to recreate, expressed by the number of paths, the extent to which different user groups are allowed to access the paths and the extent to which motorized traffic is allowed.	1. Many paths, open to all user groups and motorized traffic *[base level]* 2. Many paths, open to all user groups 3. Many paths, user group specific 4. Few paths, open to all user groups 5. Few paths, user group specific	
Mushroom and berry picking	Availability of mushrooms and berries.	1. No mushrooms and berries available for picking *[base level]* 2. Moderate availability of mushrooms and berries for picking 3. Many mushrooms and berries available for picking	
Contribution to a fund	Compulsory yearly contribution per household to a forest fund specifically oriented towards forest maintenance.	€5, €20, €50, €100, €150	

[a] The attributes "Forestry system" and "Vegetation layers" were not independent and therefore merged into one new attribute with 6 levels for the design and analysis. Nevertheless, they were presented separately in the choice cards to make the choice cards as simple and clear as possible.

was adopted, keeping five out of nine attributes fixed per choice card (Kessels et al., 2015). This set of fixed attributes varied between choice cards in order to maximize the information that could be extracted from them. The Bayesian design relied on prior estimates of the mean and standard deviation for each parameter, which were set by internal discussion. We individually reported the expected sign of each parameter (−,0,+), the expected relative importance of the attributes and levels (−− to ++) and their expected level of uncertainty (+ to ++). After integration of the individual perspectives and internal discussion, a final set of prior estimates for the mean and standard deviation was agreed upon and implemented in the design construction. An example of a choice card, resulting from this design procedure, is shown in Fig. 2.

2.3.3. Survey development

In order to assess the effect of information transfer related to soil biodiversity on individual preferences, the DCE was organized in two rounds relying on an identical experimental design of the choice cards. In each round respondents answered six choice cards whose order was randomized and a self-made informative animated video of about three to four minutes related to soil biodiversity was shown in

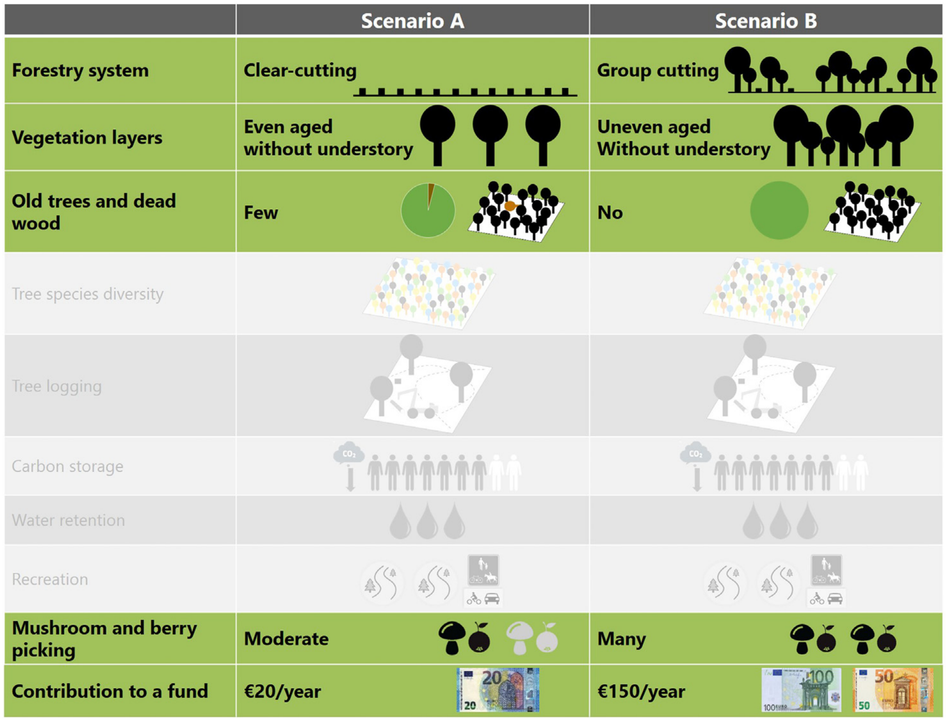

Fig. 2. Example of a choice card with the varying attributes of the partial profile design highlighted in green (translated to English). (For the colour referencing in this choice card, the reader is referred to the web version of this article.)

between.[1] The video included a description of soil biodiversity, its relevance for society through ecosystem functions and services, and its relationship with forest management. The information treatment took the form of an information campaign and was designed based on literature and in consultation with forest experts. The content of the information transfer focused on ecological aspects as this was found to be most effective in previous studies of, amongst others, Gundersen et al. (2017), Rambonilaza and Brahic (2016) and van der Wal et al. (2014). The survey consisted of six sections and lasted about half an hour. First, after an introduction and informed consent, socio-demographic questions were asked. Second, questions on attitudes and values related to nature and forests were asked. Third, the DCE was introduced and attributes and levels were explained in detail (included in Appendix A). This was followed by the first round of the DCE. The fourth section questioned respondents' knowledge of soil biodiversity, Protection Motivation Theory (Rogers, 1975) and subjective norms. This section also included a multiple choice question on the definition of soil biodiversity, after which the correct definition was provided to make sure all respondents interpreted soil biodiversity in a similar way. The definition was deliberately kept relatively general and stated: "Soil biodiversity is the diversity of life that is present in soil and comprises bacteria, fungi, earthworms, small animals, plant roots, etc. Soil biodiversity includes every form of life that has at least one active life stage in the soil." Fifth, information on soil biodiversity and forest management was provided through the animated video. In order to control for the effect of the informative video on knowledge of soil biodiversity, the video and knowledge questions were inverted for about half of the sample through random allocation. Sixth, the second round of choice cards was presented. Ethical approval for this survey was obtained at the Social and Societal Ethics Committee (SMEC) of KU Leuven (G- 2018 11 1423). The text of the informational video and the outline of the survey are enclosed in appendix A.

[1] The original Dutch version of the informative video is available here: https://vimeo.com/456532484, and a shortened English version is available here: https://vimeo.com/358026640.

2.3.4. Data collection

Respondents were sampled through a market research agency (iVOX) using a quota sampling approach (Rambonilaza and Brahic, 2016). A representative sample of 300 Flemish citizens was obtained using age, gender and place of residence as main criteria. The survey was launched in February 2019 and remained online for two weeks. One respondent was omitted from the sample because of uninformative responses that followed a clear pattern over the entire survey (i.e. A-B-A-B- … over all choice cards and the middle category on likert-scales). Hence, the sample that was used for the analysis included 299 respondents.

2.4. Data analysis

2.4.1. Econometric framework

DCEs combine the characteristics theory of value (Lancaster, 1966) and the random utility theory of McFadden (1974). Lancaster's characteristics theory articulates that individuals derive utility from a good based on the characteristics that describe that good rather than from the good as a whole. McFadden's random utility theory considers individuals to be rational agents who maximize their utility when choosing from a set of alternative specifications of a good. By integrating these two theories, the utility that individual i derives from choosing an alternative j of a good out of a set of J alternatives in choice card t can be expressed as follows:

$$U_{ijt} = V_{ijt} + \varepsilon_{ijt} = \sum_{k=1}^{K} \beta_{ik} x_{ijkt} + \varepsilon_{ijt} \quad (1)$$

This utility consists of a deterministic component (V_{ijt}) and a random error term (ε_{ijt}) that is assumed to be independently and identically extreme value distributed (Hauber et al., 2016; Hole, 2007). The deterministic component includes a vector of K observed alternative-specific variables (x_{ijkt}) that are the characteristics, or attributes, of the good. A vector of parameters (β_{ik}) expresses individual preferences for each of these characteristics.

Based on respondents' observed choices, preferences can be studied by expressing the probability of an alternative forest management scenario to be chosen through a logistic distribution. Several models exist that differ in their assumptions and the extent to which they account for preference heterogeneity. The basic model is the conditional logit model that assumes preferences across individuals to be homogeneous (Hauber et al., 2016). Nevertheless, preferences mostly differ amongst individuals and assuming homogeneity can lead to biased estimates (Hauber et al., 2016). Preference heterogeneity can be taken into account through the mixed logit model which assumes that preference weights across the sample can be represented by a (normal) distribution with density $f(\beta|\theta)$ and θ the parameters of this distribution (Hauber et al., 2016; Hole, 2007). The probability that respondent i chooses alternative j in choice card t is then given by the following expression:

$$P_{ijt}(\beta_i) = \frac{e^{V_{ijt}(\beta_i, X_{ijt})}}{\sum_{h=1}^{J} e^{V_{iht}(\beta_i, X_{iht})}} \tag{2}$$

In this formula, β_i and X_{ijt} denote the K-dimensional vectors of parameters and attribute levels, respectively. The formula shows that the probability of choosing alternative j is a function of the attribute levels of that alternative as well as of those of all other alternatives within the choice card. Based on this expression, the probability of the sequence of choices over all choice cards for individual i can be calculated, using the following formula:

$$P_i(\theta) = \int \left[\prod_{t=1}^{T} P_{ij(i,t)t}(\beta_i)\right] f(\beta|\theta) d\beta \tag{3}$$

with $j(i,t)$ the alternative that has been chosen by individual i in choice card t.

Alternatively, the latent class finite-mixture model assumes that individuals can be grouped into a finite number of classes (Greene and Hensher, 2003; Hauber et al., 2016; Pacifico and Yoo, 2013). While preferences are expected to differ between classes, they are assumed to be homogeneous within each class. Therefore, the latent class model estimates preference weights within each class through a conditional logit model based on the following expression for the probability that individual i chooses alternative j in choice card t, conditional on being a member of class q:

$$P_{ijt|q} = \frac{e^{V_{ijt|q}(\beta_q, X_{ijt|q})}}{\sum_{h=1}^{J} e^{V_{iht|q}(\beta_q, X_{iht|q})}} \tag{4}$$

where $V_{ijt|q}(\beta_q, X_{ijt|q})$ is the deterministic component of alternative j in choice card t, conditional on being member of class q.

However, the class assignment and class probability are unknown up front. Therefore, the prior probability for an individual to be in class q (class assignment probability) can be calculated using this expression following a fractional multinomial logit:

$$H_q = \frac{e^{\theta_q}}{1 + \sum_{l=1}^{Q-1} e^{\theta_l}} \tag{5}$$

with θ_q the class membership model parameter for class q with θ_Q normalized to 0 to allow identification. In our analysis, the prior class probabilities are constants that sum to one and thus the same for all agents. The prior class assignment probability (H_q) is then used to calculate the choice probability that an individual chooses alternative j in choice card t by taking the sum over all classes of the product of H_q and expression (4).

2.4.2. Model estimation

The analysis was performed using Stata 16. Firstly, a mixed logit model (mixlogit) allowing for preference heterogeneity was estimated using the entire dataset, including the choices respondents made before and after the information treatment. To assess the effect of the information treatment, interaction effects were added between the attribute parameters and an information treatment dummy, that equals one for observations after the information treatment and zero for observations before the information treatment. Different specifications were tested and compared, and the model with the highest (or least negative) log-likelihood was selected.[2] This model keeps the monetary attribute fixed (contribution to a fund), as well as the variable linked to the attribute level 'clear-cutting – even-aged with understory'. Moreover, all interaction effects between the main effects and the dummy for the information treatment were kept fixed.

Next, preference heterogeneity and heterogeneity in response behavior to the information treatment were further investigated through latent class models (lclogit). Firstly, a latent class model was estimated using the choice data before the information treatment to detect classes of respondents with similar preferences. Then, the change in preferences for these classes was studied by running separate conditional logit models for each class using the choice data after the information treatment. Lastly, using the choice data after the information treatment, a latent class model was estimated to detect the optimal distribution of respondent classes after the information treatment. Moreover, individual switching patterns of respondents between classes before and after the information treatment were studied, based on posterior membership probability (Pacifico and Yoo, 2013). In order to choose the optimal number of classes, goodness-of-fit-measures were compared between a limited number of model specifications that differed in the number of classes specified (Pacifico and Yoo, 2013). The best model was then chosen based on the log-likelihood, information criteria and meaningful interpretation of the latent classes. After estimation of the latent class models, individuals were assigned to classes by calculating individual class probabilities for each class based on an individual's sequence of choices (see Pacifico and Yoo, 2013). Lastly, we investigated how socioeconomic, attitudinal and recreational characteristics differed both between classes, and between groups of individuals that responded differently to the information treatment, using two-sided t-tests. In short, we investigated response behavior to the information treatment in three ways: (i) we investigated the effect of the information treatment on preferences for the entire sample using interaction effects, (ii) we studied how the information treatment affected the preferences of the latent classes detected before the information treatment, and how these latent classes differed in socio-demographic characteristics, and (iii) we investigated which latent classes could be detected after the information treatment, how they differed in socio-demographic characteristics, and which type of individuals switched between the latent classes detected before and after the information treatment.

3. Results

3.1. Descriptive statistics

Table 2 summarizes the main characteristics of the sample ($N = 299$), and presents their average values for the Flemish population. The sample is representative of the Flemish population concerning the variables gender, province and household structure. However, it contains slightly more respondents who are higher educated compared to the population with a difference of nine percentage points (50% versus 41%). Furthermore, the age distribution of the sample differs significantly from the distribution in the population with an oversampling of individuals between 18 and 34 years old and an undersampling of individuals over 55 years old. Nevertheless, the sample includes a more or less equal spread over the three age categories. These deviations are due to the individual weighting factor used by the market research agency while determining the representativeness of its sample. About

[2] This was needed because Stata 16 allows a maximum of 20 random parameters in the mixed logit model, while our model included 22 (main effect) parameters.

Table 2
Descriptive statistics of the Flemish sample and population.

Variables	Categories	Sample (N = 299) (Share)	Significance	Population (Share)
Gender (%)	Female	51.84%		50.92%
Age (%)[a]	Between 18 and 34 years	37.79%	*	25.39%
	Between 35 and 54 years	35.12%		32.84%
	Over 55 years	27.09%	*	41.78%
Province (%)[b]	Flemish Brabant	12.71%		17.44%
	Limburg	13.71%		13.24%
	Antwerp	29.10%		28.20%
	East-Flanders	24.75%		23.01%
	West-Flanders	19.73%		18.12%
Living in (rather) urban area (%)		43.81%		n.d.
Household structure (%)[a]	1-person household	18.73%		17.07%
	Family with children at home	42.14%		46.38%
	Family with children away from home	15.38%		36.55%
	Family without children	23.75%		
Education level (%)[c]	Secondary education or lower	49.83%	*	59.00%
	Bachelor degree	28.43%	*	41.00%
	Master degree or higher	21.74%		
Household income (%)	Below €2000/month	17.73%		n.d.
	€2001–€3000/month	23.08%		n.d.
	€3001–€4000/month	20.40%		n.d.
	€4001–€5000/month	10.03%		n.d.
	Over €5000/month	8.02%		n.d.
	Don't know/don't want to tell	20.74%		n.d.
Member of nature organization (%)		18.39%		n.d.
Forest owner (respondent or family member) (%)		4.68%		n.d.
Number of forest visits in the past 12 months (%)	Never or once	20.40%		n.d.
	2–5 times	29.43%		n.d.
	6–10 times	17.06%		n.d.
	11–19 times	6.35%		n.d.
	20 times or more	21.07%		n.d.
	I have no idea	5.69%		n.d.

Note: n.d. = no data; Significant differences between sample and population are based on chi-square tests and indicated with * $p < 0.01$.
[a] Source population statistics: Statistiek Vlaanderen (https://www.statistiekvlaanderen.be/en/flemish-official-statistics-population) (calculated on Flemish population above 18 years old).
[b] Source population statistics: Statbel (https://statbel.fgov.be/en/themes/population/structure-population) (calculated on total Flemish population, including below 18 years old).
[c] Source population statistics: Statistiek Vlaanderen (https://www.statistiekvlaanderen.be/en/population-by-educational-attainment-level-0) (calculated on Flemish population between 25 and 64 years old).

half of the sample declares to live in urban or rather urban areas, about 18% is member of a nature organization and 5% owns a forest or has a family member who owns a forest. Respondents are well spread over a wide range of household incomes and represent different frequencies of forest use, from occasional (less than 2 times per year) to regular (20 times or more per year) users.

3.2. General preferences for forest management and the effect of information transfer through interaction effects

Table 3 contains the results of the mixed logit model estimation that was run on all 3588 choices before and after the information treatment and therefore included interaction effects between the attribute levels and an information treatment dummy. In general, all attribute levels were significant, with levels that support soil biodiversity being preferred over levels that potentially harm soil biodiversity. Except for 'many old trees and dead wood', for which no significant difference was found, relative to 'no old trees and dead wood'. Nevertheless, a significant positive effect was found for the interaction effect between the information treatment and 'many old trees and dead wood', which indicates a significant increase in preferences for higher shares of old trees and dead wood after the information treatment. Additionally, significant positive interaction effects were observed for 'tree species diversity', 'tree logging' and 'the presence of few recreation paths that are user group specific'. This implies that respondents attached more importance to the associated attribute(s) (levels) after the information treatment, and therefore had stronger preferences for them. Furthermore, a positive significant interaction was present for the monetary attribute, which suggests that respondents were less averse for higher prices of forest management scenarios after the information treatment.

Through likelihood ratio tests,[3] we compared the relative importance of the attributes before and after the information treatment. Before the information treatment, the attribute 'forestry system – vegetation layers' was the most important attribute, followed by the monetary attribute and 'recreation', which were found to be more or less equally important. After the information treatment, the relative importance was spread more evenly over attributes with largest increases observed for 'tree species diversity', 'tree logging', 'recreation' and 'old trees and dead wood', while the relative importance of the monetary attribute decreased. Nevertheless, the attribute 'forestry system – vegetation layers' remained the most important attribute in explaining choices, also after the information treatment.

Additionally, the mixed logit model suggested heterogeneity in preferences across respondents, as shown by significant subject standard deviations for seven attributes. Only for the attribute 'water retention', no heterogeneity in preferences was identified, while the monetary attribute was set fixed. An alternative specification of the mixed logit model in which the interaction effects with the information treatment dummy were allowed to vary across respondents, also suggested heterogeneity in the effect of information treatment on preferences across respondents related to the attributes 'forestry system – vegetation layers', 'tree species diversity', 'old trees and dead wood', 'mushroom

[3] This method for calculating relative attribute importance relies on likelihood ratio (LR) tests for overall significance of attributes. The relative importance is calculated by $-\log_{10}$ (P value of the LR test) (Luyten et al., 2015)

Table 3
Mixed logit model estimates using data before and after the information treatment with a fixed interaction effect between each attribute level and an information dummy (set to 1 for choices made after the information treatment).

Attribute	Level	Main effect		Interaction effect[a]
		β	SD	β
Forestry system – vegetation layers	Clear-cutting – even-aged without understory	[Base level]		[Base level]
	Clear-cutting – even-aged with understory	0.188	fixed	−0.054
	Group cutting – uneven-aged without understory	2.021****	−0.359	−0.471
	Group cutting – uneven-aged with understory	2.219****	0.287	0.296
	Selective cutting – uneven-aged without understory	3.000****	−0.686*	−0.331
	Selective cutting – uneven-aged with understory	3.334****	1.808****	−0.115
Tree species diversity	Monoculture	[Base level]		[Base level]
	Slightly mixed	0.805****	−0.354*	0.471**
	Intensively mixed	1.107****	0.257	0.847***
Old trees and dead wood	None	[Base level]		[Base level]
	Few	0.446***	0.027	0.062
	Many	0.015	0.598***	0.569***
Tree logging	Without fixed logging roads	[Base level]		[Base level]
	With fixed logging roads	0.295**	0.066	0.481**
	With fixed logging roads and additional protection	0.611****	0.509***	0.445*
Carbon storage	Equivalent to yearly emissions of 250 citizens	[Base level]		[Base level]
	Equivalent to yearly emissions of 350 citizens	0.051	0.006	0.264
	Equivalent to yearly emissions of 450 citizens	0.631****	0.676***	−0.166
Water retention	Rapid water flow	[Base level]		[Base level]
	Moderate water flow	0.420***	−0.078	0.179
	Slow water flow	0.684****	−0.001	0.083
Mushroom & berry picking	Few	[Base level]		[Base level]
	Moderate	0.344**	0.019	−0.258
	Many	0.580****	0.517**	−0.248
Recreation	Many paths, open to all user groups and motorized traffic	[Base level]		[Base level]
	Many paths, open to all user groups except motorized traffic	1.293****	0.840***	−0.495
	Many paths, user group specific except motorized traffic	1.287****	0.450	0.066
	Few paths, open to all user groups except motorized traffic	1.561****	−0.807**	0.102
	Few paths, user group specific except motorized traffic	1.505****	1.378****	0.700**
Contribution to forest fund		−0.012****	(fixed)	0.005**
# choices		3588		
Log-likelihood		−2027.222		

Note: Significant coefficient estimates are indicated with * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ or **** $p < 0.001$.
[a] Interaction effect of each variable with an information dummy that equals 1 for choices made after the information treatment and 0 for choices before the information treatment.

and berry picking', 'recreation' and 'contribution to a fund' (see Appendix B). In order to gain insights in this preference heterogeneity, latent class logit models were estimated, the results of which are discussed in Section 3.3.

3.3. Studying preference heterogeneity by identifying classes of homogeneous preferences

3.3.1. Model estimation results

The results of the latent class estimation using the choice data before the information treatment are shown in columns 1 and 2 of Table 4. A model with two latent classes outperformed a model with three classes based on the Bayesian Information Criterion (BIC) and the Consistent Akaike Information Criterion (CAIC). The data did not support a model with more than three latent classes as the estimated variance matrix failed to converge.

Before the information treatment (columns 1 and 2 of Table 4), differences between the two classes seemed to be mainly linked to attributes related to biodiversity ('tree species diversity', 'old trees and dead wood'), one pure management practice ('tree logging'), regulating ecosystem services ('carbon storage', 'water retention') and one cultural ecosystem service ('mushroom and berry picking'). The first class comprised about 67% of the respondents and seemed to attach more importance to forest aesthetics and cultural ecosystem services, as witnessed by significant preferences for the attributes 'forestry system – vegetation layers', 'recreation' and a 'high availability of mushrooms and berries'. Nevertheless, this class also expressed a marginally significant preference for the levels 'high carbon storage' (equivalent to yearly emissions of 450 citizens) and 'tree logging with fixed logging roads and additional protection'. On the other hand, the second class included about 33% of the sample and had significant preferences for most of the attribute levels that support soil biodiversity compared to those that are less favorable from a soil biodiversity perspective, except for 'many old trees and dead wood' and 'mushroom and berry picking', for which preferences were insignificant. In general, the results suggest that class 1 respondents cared most about recreation and visual attractiveness through layering and the extent of open patches in the forest, while class 2 respondents additionally attached equal importance to biodiversity aspects, tree logging techniques and regulating ecosystem services. Hence, class 2 seems to align best with management that supports soil biodiversity, but includes only one third of the respondents. We defined class 1 members as recreational users and class 2 members as environmentalists.

In order to investigate how the preferences of these two classes (recreational users and environmentalists) changed after the information treatment, conditional logit models were estimated for each class, using choices after the information treatment. The results are shown in columns 3 and 4 of Table 4. By comparing columns 1 and 3, we observe that the information treatment has most pronounced effects for the first class (recreational users). While recreational users had significant preferences for a limited set of attributes and mostly for those related to forest aesthetics and cultural ecosystem services before the information treatment, they expressed significant preferences for all attributes after the information treatment. The largest differences are linked to the attributes 'tree species diversity', 'old trees and dead wood' and 'water retention', which have become highly significant for explaining choices after the information treatment. Moreover, preferences increased in significance for the attributes 'tree logging' and 'carbon storage'. On the other hand, the information treatment had limited effects on the preferences of the second class (environmentalists). Specifically, the environmentalists expressed a significant preference for 'many old trees and dead wood' after the information treatment,

Table 4
Parameter estimates of the latent class model before the information treatment (columns 1 and 2), the conditional logit models after the information treatment using the two classes detected before the information treatment (columns 3 and 4), and the latent class model after the information treatment (columns 5 and 6).

Attribute	Level	Before information treatment		After information treatment			
		Latent class logit		Conditional logit		Latent class logit	
		Recreational users	Environmentalists	Recreational users	Environmentalists	Recreational users	Environmentalists
Forestry system- Vegetation layers	Clear-cutting – even-aged without understory	[Base level]		[Base level]		[Base level]	
	Clear-cutting – even-aged with understory	0.838**	−3.173*	−0.091	0.569	0.134	0.410
	Group cutting – uneven-aged without understory	2.059****	3.319***	1.066****	1.746****	0.251	2.774****
	Group cutting – uneven-aged with understory	2.044****	2.963***	1.888****	2.418****	0.740	4.018****
	Selective cutting – uneven-aged without understory	2.881****	3.482****	2.068****	2.531****	0.991**	4.556****
	Selective cutting – uneven-aged with understory	3.069****	1.341*	2.275****	2.646****	1.611***	4.468****
Tree species diversity	Monoculture	[Base level]		[Base level]		[Base level]	
	Slightly mixed	0.272	3.792****	0.976****	1.244****	0.268	1.939****
	Intensively mixed	0.393	6.022***	1.571****	1.864****	0.701*	2.649****
Old trees and dead wood	None	[Base level]		[Base level]		[Base level]	
	Few	0.198	1.640***	0.391***	0.419**	0.137	0.552**
	Many	−0.090	0.588	0.531***	0.434*	0.490*	0.710**
Tree logging	No fixed logging roads	[Base level]		[Base level]		[Base level]	
	Fixed logging roads	−0.192	2.723***	0.652****	0.639**	0.281	1.068****
	Fixed logging roads and additional protection	0.301*	1.604***	0.788****	0.917***	0.737*	1.085****
Carbon storage	Equivalent to yearly emissions of 250 citizens	[Base level]		[Base level]		[Base level]	
	Equivalent to yearly emissions of 350 citizens	−0.035	1.309**	0.307**	0.232	0.212	0.584**
	Equivalent to yearly emissions of 450 citizens	0.402*	2.657***	0.475***	0.730***	0.609**	0.753**
Water retention	Rapid water flow	[Base level]		[Base level]		[Base level]	
	Moderate water flow	−0.125	3.261***	0.500****	0.353	−0.279	1.032****
	Slow water flow	0.246	3.915***	0.547***	0.531*	−0.643	1.691****
Mushroom & berry picking	Few	[Base level]		[Base level]		[Base level]	
	Moderate	0.221	0.046	0.106	−0.052	−0.520**	0.626
	Many	0.620***	0.503	0.341*	0.262	0.310	0.418
Recreation	Many paths, open to all user groups and motorized traffic	[Base level]		[Base level]		[Base level]	
	Many paths, open to all user groups	0.775***	5.602**	0.481**	0.963**	0.896	0.614*
	Many paths, user group specific	1.225****	3.035**	0.845****	1.539****	1.634***	0.848***
	Few paths, open to all user groups	1.510****	3.284**	0.966****	1.800****	1.518**	1.394****
	Few paths, user group specific	0.691***	6.612***	1.416****	1.748****	1.264***	2.160****
Contribution to forest fund		−0.010****	−0.022***	−0.005***	−0.009****	−0.012***	−0.003
Class probability		66.9%	33.1%	66.9%	33.1%	32.8%	67.2%
Membership function constant		0.895 ***		/	/	−0.597	
# choices		1794		1200	594	1794	
Log-likelihood		−1006.3703		−668.1083	−319.2498	−983.5183	
BIC		2269.2605		1547.4470	794.2601	2223.5565	
AIC		2102.7406		1420.2170	682.4995	2057.0365	
CAIC		2314.2605				2268.5565	

Note: Significant coefficient estimates are indicated with * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ or **** $p < 0.001$.

Table 5
Comparison of socio-economic, attitudinal, recreational and knowledge related characteristics using two-sided *t*-tests. Comparison between classes before the information treatment (column 1–2) and after the information treatment (column 3–4), followed by comparison between groups with different switching behaviors between classes in response to the information treatment (column 5–8).

Before information treatment	Recreational users	vs.	Environmentalists				Recreational users (N = 200)			Environmentalists (N = 99)		
After information treatment				Recreational users	vs.	Environmentalists	Recreational users	vs.	Environmentalists	Recreational users	vs.	Environmentalists
	N = 200 66.9%	Sign.	N = 99 33.1%	N = 98 32.8%	Sign.	N = 201 67.2%	N = 66 22.1%	Sign.	N = 134 44.8%	N = 32 10.7%	Sign.	N = 67 22.4%
Member of nature organization	14.0%	***	27.3%	–		–	–		–	15.6%	*	32.8%
Forest owner (respondent or family member) (%)	–		–	–		–	–		–	9.38%	*	1.49%
Maximally secondary education	54.0%	**	41.4%	–		–	–		–	–		–
Forest function biodiversity[a]	3.71 (0.074)	**	4.02 (0.099)	3.54 (0.104)	***	3.95 (0.072)	3.52 (0.130)	*	3.81 (0.896)	3.59 (0.173)	***	4.22 (0.114)
Forest function environmental regulation[a]	–		–	3.67 (0.119)	****	4.20 (0.067)	3.70 (0.146)	***	4.16 (0.086)	3.63 (0.205)	***	4.23 (0.104)
Forest function conservation[a]	–		–	3.90 (0.111)	***	4.23 (0.063)	–		–	3.84 (0.196)	**	4.34 (0.103)
Activity nature observation[a]	1.89 (0.078)	***	2.29 (0.133)	1.82 (0.108)	**	2.11 (0.088)	–		–	–		–
Activity berry/mushroom picking[a]	–		–	1.12 (0.047)	*	1.31 (0.057)	1.11 (0.038)	**	1.34 (0.075)	–		–
Considered soil biodiversity in DCE (%)	58.0%	****	77.8%	–		–	–		–	–		–
Bio-centered attitude[b]	–		–	–		–	–		–	3.80 (0.105)	**	4.11 (0.086)
Human-centered attitude[b]	–		–	2.89 (0.078)	***	2.63 (0.049)	2.84 (0.096)	*	2.64 (0.058)	3.00 (0.132)	**	2.60 (0.090)
Forest visits [>19 times/past year] (%)	–		–	15.3%	*	23.9%	–		–	–		–
Importance of forests and (soil) biodiversity[b,d]	–		–	3.83 (0.078)	**	4.07 (0.054)	–		–	3.65 (0.121)	****	4.29 (0.098)
Worried about forests and (soil) biodiversity[b,d]	–		–	–		–	–		–	2.38 (0.204)	*	3.01 (0.202)
Knowledge of soil biodiversity[c,d]	–		–	7.48 (0.457)	*	8.51 (0.311)	7.30 (0.485)	*	8.32 (0.363)	–		–

Note: Sign. = Significance: significant coefficient estimates are indicated with * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ or **** $p < 0.001$.
[a] Mean score (and standard error) based on a 5-point likert scale with 1 item (with 1 = not important at all/disagree to 5 = very important/agree).
[b] Mean score (and standard error) based on a 5-point likert scale with multiple items (Bio-centered attitude (4), Human-centered attitude (4), Worried (4), Importance (4)) (with 1 = disagree or not concerned/important at all, to 5 = agree or very important/concerned). The bio-centered attitude reflects a central positioning for nature in forests, whereas the human-centered attitude reflects a central positioning for humans in forests.
[c] Score (and standard error) on 10 based on 14 knowledge items that were scored on a 5-point likert scale (with 1 = disagree, to 5 = agree) that was rescaled to represent correct versus incorrect answers.
[d] Including only respondents who answered the knowledge questions before watching the informative video (N = 37 and N = 76 for recreational users who remained recreational users and became environmentalists respectively; N = 15 and N = 28 for environmentalists who became recreational users and remained environmentalists respectively).
The item(s) for each of these variables is (are) lined out in detail in the questionnaire that is available upon request.

while this effect was insignificant before the information treatment. Moreover, after the information treatment, they preferred only 'high carbon storage' and 'slow water flow', while they also preferred 'medium carbon storage' and 'moderate water flow' before the information treatment. Hence, the information treatment seems to have had a large effect on the preferences of the first class (recreational users), leading to enlargement of attention to all attributes, including biodiversity related management characteristics, pure management practices and regulating ecosystem services, and increased support for forest management that supports soil biodiversity.

Analogous to the latent class results before the information treatment, a model with two latent classes was also found optimal after the information treatment (columns 5 and 6 of Table 4) with class 1 comprising 33% of the respondents and class 2 comprising 67% of the respondents. Members of class 1 expressed preferences towards the most supportive levels for soil biodiversity of nearly all attributes, except for the ecosystem services 'water retention' and 'mushroom and berry picking'. For the latter, a significant aversion was found for the moderate level. So generally, class 1 members after the information treatment only valued an increase from the lowest to the highest levels with respect to support for soil biodiversity for most attributes. Nevertheless, they preserved a focus on recreation and aesthetics, as indicated by the highly significant preferences for levels of the attributes 'forestry system – vegetation layers' and 'recreation', compared to the marginally significant preferences for 'intensively mixed forests', 'many old trees and dead wood' and 'tree logging with fixed logging roads and additional protection'. Conversely, class 2 after the information treatment showed significant preferences for most of the attribute levels, except for 'clear cutting – even-aged forests with understory' (compared to 'clear-cutting – even-aged forests without understory'), 'mushroom and berry picking' and the monetary attribute 'contribution to a fund'. The latter indicates that after the information treatment members of class 2 seemed indifferent to the cost of the forest management scenarios. Overall, class 1 preserves a focus on recreation and aesthetics, despite moderate but increasing attention for most other attributes, and represents 'recreational users'. On the other hand, class 2 remained relatively similar to class 2 detected before the information treatment and represents 'environmentalists'.

3.3.2. Characterization of latent classes and groups with different switching behavior in response to the information transfer

Table 5 shows the results of the *t*-tests that assess the effect of socio-economic, attitudinal, recreational and knowledge-related characteristics on the heterogeneity in preferences and switching behaviors between latent classes. Firstly, 'recreational users' and 'environmentalists' were compared, both before (columns 1–2) and after (columns 3–4) the information treatment. Before the information treatment, respondents who expressed significant preferences only for recreational and aesthetic aspects ('recreational users') were less often member of a nature organization, were lower educated, attached less importance to the biodiversity function of forests, visited forests less often for nature observation and stated less often to have considered soil biodiversity when making their choices in the DCE. While after the information treatment, differences in preferences were smaller, 'recreational users' still focused more on recreational and aesthetic aspects of forest management. This class attached less importance to forests, (soil) biodiversity, and ecological and conservation forest functions. Moreover, they visited forests less often for nature observation or mushroom and berry picking, and scored higher on a human-centered attitude scale towards forests, indicating that they believe forests should mainly serve humans and human intervention is beneficial. Lastly, members of this class were less often frequent forest visitors (more than 19 times in the past 12 months) and scored lower on knowledge questions related to soil biodiversity, forest functioning and management. Hence, 'recreational users' generally attached less importance to ecological forest functions and soil biodiversity, and less often visited forests, especially for ecology-related activities.

Secondly, individual switching behavior between classes in response to the information treatment was studied in detail, relying on the individual posterior class probabilities (columns 5–8 of Table 5). Specifically, 44.8% of the respondents changed from 'recreational users' before the information treatment to 'environmentalists' after the information treatment, while 22.1% remained member of 'recreational users' after the information treatment. The former group (i.e. 'recreational users' to 'environmentalists') attached more importance to ecological forest functions (biodiversity and environmental regulation), more often visited forests for mushroom and berry picking, and scored lower on a human-centered attitude towards forests, indicating that they are less convinced that forests should serve humans and that human intervention is beneficial. Lastly, this group scored higher on knowledge questions related to soil biodiversity, forest functioning and management. On the other hand, 10.7% of the respondents switched from 'environmentalists' before the information treatment to 'recreational users' after the information treatment, while 22.4% remained within the class 'environmentalists' after the information treatment. The latter group (i.e. remained 'environmentalists') was more often member of a nature organization, but less often owned a forest or had a family member who owned a forest. Furthermore, this group attached more importance to ecological and conservation forest functions. This group also scored higher on a bio-centered attitude, and lower on a human-centered attitude, which implies that they value forest for their nature value rather than as primarily serving humans. Lastly, this group found forests and (soil) biodiversity more important and were more concerned about their state. In conclusion, attaching more importance to ecological and nature values and functions of forests, being member of a nature organization and knowing more about soil biodiversity were generally connected with a switching behavior that is most supportive of soil biodiversity in response to the information treatment and corresponded with a switch towards 'environmentalists' after the information treatment (from both 'recreational users' and 'environmentalists' before the information treatment). A small share of respondents (10.7%) switched from 'environmentalists' before the information treatment to 'recreational users' after the information treatment. This suggests that the information treatment made them less supportive for soil biodiversity, in contrast to all other switching patterns. Looking at the socio-economic and attitudinal characteristics of this group, we observe that this group included significantly more individuals who own a forest or have a family member who owns a forest (9.3% vs. 1.5%). A possible explanation could be that forest owners only value the most extreme changes in management choices after the information treatment towards levels that support soil biodiversity most and hence end up in the class 'recreational users', rather than because of a focus on recreational and aesthetic management aspects. Moreover, preferences of both classes were more similar after the information treatment, with increasing attention for biodiversity aspects in both classes and the monetary attribute was only significant for 'recreational users' after the information treatment. These findings provide possible alternative explanations for this small share of respondents who switched from 'environmentalists' to 'recreational users'.

4. Discussion

4.1. General preferences for forest management and the overall effect of information transfer

Based on the full sample results, we found that respondents generally preferred forest management choices that are most supportive of soil biodiversity already before the information treatment, except for the attribute 'old trees and dead wood' of which limited shares were preferred. A limited amount of dead wood in forests was also found preferable in a review study that combined 109 publications of European studies on public forest preferences (Ciesielski and Stereńczak, 2018). Nevertheless, the information treatment in our study significantly increased full sample preferences for high shares of old trees and dead wood. Similarly, Gundersen and Frivold (2011) and Gundersen et al. (2017) found that Norwegian citizens preferred photographs of forests with no or little dead wood, but that including a short text on the ecological benefits of dead wood, significantly increased the probability of a photo with dead wood to be preferred. Additionally, Rambonilaza and Brahic (2016) found that providing information generally significantly increased WTP of French citizens for the less known forest biodiversity attribute fallen deadwood. The topic of dead wood has received increasing attention in Flemish forestry planning during the last decades. Maintaining dead wood has been included in the management goals and shares of dead wood in forests have recently increased (Govaere, 2020). Additionally, our study indicated that the information treatment increased valuation of diverse tree stands, the use of fixed logging roads (whether or not with additional protection) and few recreation paths that are user group specific. Nevertheless, no significant effects of the information treatment were found for regulating ecosystem services and the cultural ecosystem service mushroom and berry picking. This could be linked to the information treatment that included explicit links between forest management practices and soil biodiversity at the end of the video, while the importance of soil biodiversity for the delivery of ecosystem services was discussed at the beginning of the video. Alternatively, mushroom and berry picking is not culturally embedded in the Flemish society, compared to other European countries such as Finland or Romania (Pröbstl et al., 2010). Moreover, citizens could have more feeling with ecosystem services as they are the end-product of forest management decisions to society, while citizens are less familiar with specific management practices and biodiversity aspects, and hence information could potentially have a larger effect on their valuation.

4.2. Heterogeneity in preferences and in the effect of information transfer

Whereas general preferences of the full sample supported soil biodiversity for all considered management choices, exploring preference heterogeneity revealed that the majority of respondents (67%) focused on management choices related to forest aesthetics and cultural ecosystem services, neglecting other management choices (regulating ecosystem services, biodiversity components and pure management practice). This complies with the focus in forest valuation literature on public preferences for recreation, aesthetics and structural forest characteristics (e.g. Ciesielski and Stereńczak, 2018; Edwards et al., 2012; Giergiczny et al., 2015). Similar to our results, these studies mostly encountered preferences for layered, uneven-aged forests and opposition against large areas of clear-cuts.

The information treatment was found to have the largest effect on preferences of respondents who focused on forest aesthetics and cultural ecosystem services before the information treatment (recreational users), leading to increased consideration of management choices related to biodiversity, technical operations and regulating ecosystem services. This finding is in line with the observation of van der Wal et al. (2014) who found that information on biodiversity and deer management altered respondents' reasoning when choosing their preferred understory density of woodland. Specifically, they reasoned from an aesthetic perspective before the information treatment, while from the perspective of nature and wildlife after the information treatment. Moreover, we found that this group generally included lower educated respondents who felt less connected with ecology, nature and forests. Similarly, van der Wal et al. (2014) found that respondents who regularly visit forests changed their preferences after information treatment less often, while Hasselström and Håkansson (2014) only encountered differences of the type of information on WTP changes for unfamiliar respondents. Additionally, as observed for the full sample, the information treatment led to significant preferences for 'many old trees and dead wood' for both classes (environmentalists and recreational users). This is in contrast with the findings of Brahic and Rambonilaza (2015) who found that providing information only led to significantly increased WTP for fallen deadwood amongst French citizens who were familiar with biodiversity and regularly used forests.

Familiarity with, interest for and understanding of nature, forests, (soil) biodiversity and environmental aspects were generally found to be drivers for forest management preferences with highest support of soil biodiversity, both before and in response to the information treatment. This impact of social factors on preferences and perception of forests has been found in many previous studies (e.g. Ciesielski and Stereńczak, 2018). Specifically, the importance of familiarity with forests, awareness or knowledge of biodiversity and the (recreational) use of forests (frequency and activity) was also found in previous studies on public forest preferences in several European regions. Brahic and Rambonilaza (2015) and Rambonilaza and Brahic (2016) (France) found that attribute levels were more decisive in choices concerning biodiversity aspects of forests for familiar individuals, and that familiar individuals expressed significantly higher WTP for attribute levels that promoted biodiversity preservation, compared to unfamiliar individuals. Additionally, Grilli et al. (2016) found that valuing non-productive ecosystem services of forests resulted in a higher probability of preferring mixed forests over monocultures in a Polish context, while no effect was found of socio-economic characteristics. Czajkowski et al. (2014) identified that frequent Polish forest visitors had higher preferences for ecological attributes and levels such as the highest increase in area for protecting ecologically valuable forests. Furthermore, Upton et al. (2012) concluded that knowledge of trees significantly affected preferences for forest management in Ireland, especially related to level of mixing and preferred tree type. Moreover, Bartczak (2015) found a positive effect of environmental concern on preferences for naturalness of forests and restrictions on the number of visitors amongst Polish respondents. Lastly, Juutinen et al. (2017) detected preference heterogeneity linked to socio-economic characteristics and recreational profiles in Finland, including education level, age, frequency of visits, nature watching and fishing.

4.3. Methodological considerations

As mentioned in the introduction, the information type and content often largely influence the effect of an information treatment. In this study, we used a treatment similar to an information campaign presented in the form of a video, which included a description of the link between soil biodiversity and all ecosystem services and management practices included as attributes in the DCE. However, a direction of the effect of management practices on soil biodiversity was provided, while this was only implicitly presented for ecosystem services. This could potentially have contributed to the absence of an overall effect of the information treatment on preferences for carbon storage, water retention and mushroom and berry picking, although significant effects were detected for subgroups within the sample. Also no overall effect of information was found on the attribute forestry system – vegetation layers.

While our study uses a within-sample test of the effect of information transfer, previous studies often relied on a split-sample test with half of the respondents receiving the information treatment (e.g. Gundersen and Frivold, 2011; Rambonilaza and Brahic, 2016). Both types of design have their advantages and disadvantages and the choice of design crucially depends on the research question and practical implementation (Charness et al., 2012). Within-sample tests do not depend on random assignment across individuals which might be difficult to assess because of unobserved respondent characteristics (Charness et al., 2012). Moreover, a within-sample test was considered better aligned with our research question (Charness et al., 2012; Rousseau and Vranken, 2013). We studied the effect of an information treatment formulated in the form of an information campaign on public preferences. Hence, the theoretical mindset would be that an individual reacts to the information, which corresponds to a within-sample test rather than a between-sample test. Lastly, within-sample tests have higher statistical power compared to split-sample tests which we considered especially relevant for our study because of the rather complex choice experiment design (i.e. nine attributes in a partial profiles design) and relatively small sample size (Charness et al., 2012). On the other hand, within-sample tests also have weaknesses that could be overcome using split-sample tests. Specifically, split-sample tests allow to reduce the potential confounding between the information treatment effect and learning or fatigue effects on preferences when respondents move through the DCE (Czajkowski et al., 2016; Meyerhoff and Glenk, 2015). Fatigue effects imply that individuals might become bored and start using heuristics more frequently when proceeding in the DCE, while a learning effect implies that preferences become more precise when individuals gather experience in choosing (Czajkowski et al., 2016). However, previous literature has found mixed results on the presence of such effects in DCEs (Mørkbak and Olsen, 2015; Olsen et al., 2011; Wuepper et al., 2019). While we are not able to formerly test the presence of such effects, a learning effect suggests that the degree of randomness in choices is larger at the start of the DCE (Meyerhoff and Glenk, 2015). Therefore, a generalized multinomial logit model was estimated with the scale parameter being a function of the information treatment dummy (i.e. choices made before versus after the information treatment). No significant effect was found of the information treatment dummy on scale heterogeneity, which indicates that the degree of randomness did not change between choices made before versus after the information treatment and hence hints towards the absence of a learning effect. In conclusion, the disadvantages of a within-sample test should be kept in mind when interpreting the results of our study. While we cannot completely rule out the confounding of ordering effects, our study does reveal interesting results in line with previous literature concerning the management choices for which information seems to have most impact on preferences and how different groups of citizens express distinct preferences and react differently to the information treatment. In order to strengthen these findings, we largely encourage future studies to investigate the effect of a similar information treatment in a split-sample test. Moreover, in line with Section 2.3.2 in the methodology, future studies could investigate the effect of including an opt-out or status quo option.

Furthermore, our results indicate that information on soil biodiversity has the potential to strengthen preferences towards management choices that support soil biodiversity on the short term. Nevertheless, we acknowledge that our approach does not allow to derive strong conclusions on the long-term effect of the information treatment. However, the presence of a short-term effect should encourage researchers to investigate the long-term effect of information treatment by retaking the questionnaire at a subsequent point in time, as was done for example by Czajkowski et al. (2016) to investigate stability of WTP and preferences for forest management over time.

4.4. Policy recommendations

Recently, policy makers have become increasingly aware that public participation in policy development is required to obtain effective forest policies that fulfil various societal needs and allow to solve conflicts between forest conservation and forest use by society (Referowska-Chodak, 2019). While policies for aboveground biodiversity not necessarily support soil biodiversity, management of soil communities could strengthen the conservation of many aboveground species because of their crucial role in plant diversity and regulating ecosystem services (Turbé et al., 2010). Our study provides first insights in Flemish citizens' preferences for forest management related to soil biodiversity. Our general findings revealed potential for information campaigns to increase acceptance of higher amounts of dead wood in forests. Dead wood offers microhabitats for specialized organisms, leading to higher soil biodiversity levels (Parisi et al., 2018; Raymond-Léonard et al., 2020). Moreover, information provision could increase awareness of and attention for a wider range of management choices, including tree species mixing, shares of old trees and dead wood and tree logging, especially amongst lower educated citizens who are slightly less familiar and concerned with forests and (soil) biodiversity, and have a more human-centered attitude towards forests. This group of citizens was found to value only management choices related to recreation and aesthetics before the information treatment, while tree species mixing, levels of old trees and dead wood, and tree logging methods are expected to have more pronounced effects on soil biodiversity (Blasi et al., 2013; Korboulewsky et al., 2016; Orgiazzi et al., 2016; Parisi et al., 2018). By increasing public attention for and acceptance of such practices, adoption by forest managers might be facilitated. On the other hand, highest support for management choices that support soil biodiversity is expected from citizens who are more familiar with forests and (soil) biodiversity and care more about nature and ecology. This group of citizens also valued management choices of intermediate intensity that may provide an in-between step for forest managers to facilitate consideration of soil biodiversity in their management decisions. The need for less emphasis on strict stand structures and application of principles was detected previously as it increases flexibility (Puettmann et al., 2015). Moreover, Sing et al. (2018) point at the need for a diversity of management approaches to maintain the delivery of multiple ecosystem services, including practices of higher intensity levels for wood production. Hence, support for management choices of intermediate intensity suggests acceptance of such diverse set of management approaches. The information treatment was found to strengthen support for a wide set of intensities amongst the majority of the sample, with highest support amongst citizens who attach more importance to ecological forest functions and activities, have more knowledge on soil biodiversity and are more often frequent forest visitors.

5. Conclusion

In this study, we investigated the effect of an information treatment related to soil biodiversity and forest management on preferences of Flemish citizens for forest management choices impacting soil biodiversity. We found general attention for a wide set of management choices supporting soil biodiversity already before the information treatment. Nevertheless, significant effects of the information treatment were detected concerning management choices related to tree species diversity, old trees and dead wood, and tree logging, with increasing preferences for levels supporting soil biodiversity after the information treatment. Moreover, we also found preference heterogeneity amongst the sample with the majority valuing only management choices related to aesthetics and recreation before the information treatment. Nevertheless, changes in preferences in response to the information treatment were more pronounced for this group, which included lower educated individuals who were less environmentally concerned and cared less about forests. On the other hand, individuals who possessed more knowledge on soil biodiversity, visited forests more frequently and were more environmentally concerned were found to support a wider range of management practices both before and after the information treatment, and to value practices of intermediate pressure on soil biodiversity after the information treatment (compared to individuals that care less about nature, forests and (soil) biodiversity). Moreover, the size of this group increased from 33% to 67% after the information treatment. Valuation of practices with intermediate pressure could strengthen soil biodiversity consideration amongst forest managers as they represent intermediate steps and provide higher levels of flexibility in forest management. Moreover, the preference pattern of this group suggests support for a wide range of management approaches needed for multiple ecosystem services delivery. Based on our study, we recommend policy makers in Flanders to use simple and illustrative information campaigns related to the importance of soil biodiversity and its relationship with forest management to increase valuation and acceptance of management practices that support soil biodiversity amongst citizens, especially related to the share of old trees and dead wood. Additionally, such information campaigns can increase attention for and acceptance of a wider range of forest management choices amongst less concerned and less familiar citizens, as well as acceptance of a wider range of management intensities amongst more familiar and concerned citizens, in line with the current call for forest management oriented towards the delivery of multiple ecosystem services in response to global challenges.

CRediT authorship contribution statement

Iris Vanermen: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Visualization. **Roselinde Kessels:** Methodology, Software, Validation, Data curation, Writing – review & editing. **Kris Verheyen:** Conceptualization, Methodology, Writing – review & editing, Co-supervision. **Bart Muys:** Conceptualization, Methodology, Writing – review & editing, Co-supervision. **Liesbet Vranken:** Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration, 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.

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Appendix A. Supplementary data

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