Non-industrial private forest owners’ willingness to manage for climate change and biodiversity

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ABSTRACT
In boreal commercial forests, carbon sequestration, climate change adaptation, and biodiversity conservation can be promoted through various measures. This study examines the factors affecting non-industrial private forest (NIPF) owners’ preferences for such forest management practices. A systematic literature review serves as a reference for the empirical analysis of a survey data on the Finnish NIPF owners’ stated willingness to adopt thirteen distinct forest management practices. Binary logit models reveal socio-demographic factors, site-specific characteristics, previous forest management, and motivations for forest ownership that are associated with the stated adoption of management practices. Especially, environmental and financial motivations play an important role in decisions concerning forest management practices. Statistically significant factors vary depending on the forest management practice, reflecting the NIPF owner heterogeneity. Younger and highly educated forest owners are more supportive for various management practices that promote biodiversity, while older forest owners are reluctant towards deadwood retention. The results underline the importance of accounting for heterogeneous preferences regarding forest management practices when designing and implementing policies and advisory services aiming at enhancing carbon sequestration, climate change adaptation, or biodiversity in boreal commercial forests.

Introduction
Anthropogenic climate change has caused a need to promote carbon sequestration and storage in commercial forests, while increasing forest growth and risk of abiotic and biotic forest damages call for adaptive measures and resilience (IPCC, 2007; Kellomäki et al., 2018; Venäläinen et al., 2020). Halting the loss of biodiversity is inseparably connected to both climate change adaptation and mitigation in forests since biodiversity contributes to ecosystem functioning and provision of crucial forest ecosystem services (Brockerhoff et al., 2017).

Various forest management practices are available to promote carbon sequestration, adaptation to climate change, and biodiversity conservation in commercial forests. Extending the rotation period beyond economically optimal age is an example of an efficient measure to mitigate climate change (e.g. D’Amato et al., 2011; Pihlainen et al., 2014; Ekholm, 2016). Broadleaved mixtures and shortened rotation are examples of forest management practices that support adaptation to climate change by increasing resilience towards abiotic and biotic disturbances (Knake et al., 2008; Bolte et al., 2009). Biodiversity in commercial forests is promoted by imitating the characteristics of natural forests. Commercial forestry has caused degradation of forest habitats through e.g. changes in tree species proportions, lack of structural diversity, and reduced amount of deadwood. Corresponding measures such as mixed-species stands, continuous-cover forestry and deadwood retention improve habitats and thus promote biodiversity (Koskela et al., 2007; Kuuluvainen et al., 2012).

The role of a non-industrial private forest (NIPF) owner as decision maker concerning the forestland is crucial when it comes to carbon sequestration, climate change adaption and biodiversity protection. Approximately half of forestland is under NIPF ownership in both Europe and the U.S. (Forest Europe, 2015; Butler et al., 2016). The previous scientific literature on NIPF owners’ participation in carbon sequestration, climate change adaptation, and biodiversity protection exists mostly at a conceptual level. For instance, forest owners’ attitudes towards carbon sequestration, willingness to participate in carbon trading, or interest in wildlife habitat management have been popular research topics in the U.S. (e.g. Thompson & Hansen, 2012; Markowski-Lindsay et al., 2011; Joshi & Arano, 2009).

However, less is known about the NIPF owners’ preferences for forest management practices to promote carbon sequestration, climate change adaptation, and biodiversity conservation in their commercially managed forests. According to a wide range of studies, NIPF owners are a diverse...
group, and, in addition to timber production, they hold other motivations and objectives for their ownership (see e.g. Ficko et al., 2019). For example, dimensions such as timber sales income, outdoor activities and intangible values describe Finnish NIPF owners’ objectives for their ownership (Häyrinen et al., 2014). Reflecting on diversity of NIPF owners, as carbon sequestration, climate change adaptation, and biodiversity conservation can be promoted through a variety of measures, NIPF owners may differ in terms of willingness to manage climate change and biodiversity.

This study explores the factors affecting the NIPF owners’ willingness to adopt forest management practices and assesses whether these factors are consistent over practices. First, a systematic review of scientific literature builds an overview of relevant factors associated with forest management decisions, and second, the effect of factors is empirically tested with a series of statistical models. The latter utilizes the survey data of 405 Finnish NIPF owners to assess their willingness to adopt thirteen distinct forest management practices that contribute to climate change mitigation, adaptation to climate change, or biodiversity.

The rest of the study is organized as follows: “Findings from scientific literature” presents a literature review and “Empirical analysis” the empirical methodology and data. “Empirical results” summarizes results of empirical analysis, “Discussion” discusses, and “Conclusions” concludes.

Findings from scientific literature

Articles

The scope of review was defined as studies that provide insight on factors associated with the NIPF owners’ choice to adopt forest management practices that promote carbon sequestration, climate change mitigation, or biodiversity. The definition of forest management practice was considered as a fundamental criterion for inclusion; for example, studies assessing NIPF owners’ willingness to participate in carbon sequestration, climate change adaptation, or biodiversity protection were excluded from the review if forest management practices were not defined. The search terms for articles in SCOPUS online database were combinations of keywords representing NIPF owners (forest owner, land owner) and keywords related to forest management practices promoting carbon sequestration, climate change adaptation, or biodiversity (see supplemental material for the list of keywords used). The procedure included 54 combinations of search terms, yielding 2569 results in total. The screening based on title, abstract, and keywords in the initial phase, and, in the second phase, on the full article, resulted in a sample of 18 articles. In the first phase, the majority of search results were excluded due to the origin of the field of natural sciences or a clearly irrelevant scope. In the second screening phase, the lack of either NIPF owners’ viewpoint or the definition of forest management practices were the most common reasons for exclusion of the articles from the review.

Out of eighteen studies (Table 1), applying both nationwide and regional approaches, six were conducted in the U.S and twelve in Europe. Out of the European ones, six were conducted in Finland, two in Sweden, and one in Denmark, Germany, Georgia and Belgium each. The studies varied significantly in sample size, being 15 and 16 in qualitative studies and ranging from 253 to 1240 respondents in sixteen quantitative studies. Quantitative studies combined two statistical methods and three approaches: measuring the choice of forest management practices as dependent variables in the regression analysis, predicting with regression analysis the participation in payments for ecosystem services (PES) programs that require conducting forest management practices, and assessing the forest management practices as variables in factor analysis to identify forest management styles. Qualitative studies were based on face-to-face and telephone interviews.

Factors affecting the adoption of forest management practices

The factors identified are forest owner characteristics (such as age, gender, income, residence, and education), forest site characteristics, previous management, and owner motivations and objectives. In addition, studies assessing the

| Article                     | Region                  | N   | How is choice of measure assessed? | Included in PES program | # forest management practices assessed |
|-----------------------------|-------------------------|-----|-----------------------------------|-------------------------|---------------------------------------|
| Joa and Schraml (2020)      | Germany, Southwest      | 419 | Dependent variable                |                         | 2                                     |
| Juutinen et al. (2020)      | Finland                 | 1035| Dependent variable                | x                       | 3                                     |
| Kang et al. (2019)          | Georgia, Southeast      | 253 | Program participation             | x                       | 1                                     |
| Mäntymaa et al. (2018)      | Finland, Kuusamo area   | 476 | Program participation             | x                       | 1                                     |
| Karppinen et al. (2018)     | Finland Helsinki        | 15  | Qualitative                       |                         | 2                                     |
| Kooistra et al. (2018)      | USA, Oregon             | 441 | Dependent variable                |                         | 1                                     |
| Pynnönen et al. (2018)      | Finland, North Carelia  | 298 | Variables in factor analysis      |                         | 3                                     |
| Danley (2018)               | Sweden                  | 1264| Dependent variable                |                         | 1                                     |
| Khanal et al. (2017)        | USA, Southern states    | 735 | Program participation             | x                       | 1                                     |
| Vedel et al. (2015)         | Denmark                 | 283 | Program participation             | x                       | 4                                     |
| Kim and Langpap (2015)      | USA, Western states     | 513 | Dependent variable                |                         | 1                                     |
| Hallikainen et al. (2010)   | Finland, Northern       | 525 | Variables in factor analysis      |                         | 5                                     |
| Van Herzele and Van Gossum (2009) | Belgium, Flanders    | 276 | Dependent variable                |                         | 1                                     |
| Matta et al. (2009)         | USA, Florida            | 400 | Program participation             | x                       | 2                                     |
| Horne (2006)                | Finland                 | 1240| Program participation             | x                       | 2                                     |
| Hysing and Olsson (2005)    | Sweden, Örebro area     | 16  | Qualitative                       |                         | 1                                     |
| Kline et al. (2000a)        | USA, Pacific Northwest  | 403 | Program participation             |                         | 1                                     |
| Kline et al. (2000b)        | USA, Pacific Northwest  | 1004| Program participation             |                         | 1                                     |
willingness to adopt forest management practices through PES program underline the importance of program characteristics for participation. Since the payment aspect is beyond the focus of this study, the PES program characteristics are not reported in the review.

**Owner characteristics**

The effect of forest owners’ age varies depending on the forest management practice: increase in age is associated with an increased probability to allocate forest to long rotation management, short rotation management and traditional even-aged forestry, while regarding uneven-aged forestry, the effect of age may be contrary (Juutinen et al., 2020). Khanal et al. (2017) and Matta et al. (2009) propose that an increase in age reduces the willingness to extend the rotation period. Females are more nature-oriented in their forest management than males, and they prefer continuous-cover forestry and leaving set-aside areas more often than males (Juutinen et al., 2020; Pynnönen et al., 2018). Regarding residence, forest owners who live close to their properties are more likely to adopt extended rotation, establishing riparian buffer zones and conduct prescribed burning (Matta et al. 2009).

High education increases the NIPF owners’ willingness to adopt various forest management practices that promote carbon sequestration, climate change adaptation, or biodiversity: extended rotation (Matta et al. 2009; Kline et al., 2000a), converting monocultures into mixed broadleaved stands (Van Herzele & Van Gossum, 2009), and deadwood retention (Joa & Schraml, 2020). However, shortened rotation is negatively associated with high education, reflecting possibly that highly educated forest owners tend to value forest amenities higher and consider short rotation too intensive (Juutinen et al., 2020). Regarding the effect of occupation on the willingness to adopt forest management practices, agricultural entrepreneurs are likely to allocate forestland under traditional even-aged management and long rotation management (Juutinen et al., 2020). Membership in forest owners’ association decreases the probability to leave unmanaged areas in forests (Danley, 2018).

The positive association of forest owners’ higher income with increased willingness to adopt forest management practices has been evidenced concerning extended rotation (Khanal et al., 2017; Matta et al. 2009; Kline et al., 2000a) and riparian buffers (Matta et al. 2009). Concerning the importance of forestry-related income, the NIPF owners who are more dependent on timber sales are less likely to extend the rotation period (Kline et al., 2000a).

The NIPF owners’ perceptions, beliefs, and knowledge are associated with the willingness to adopt forest management practices in various ways. For example, broadleaved stands have higher resilience towards climate change, and the NIPF owners are willing to adopt such management based on positive perceptions (Vedel et al., 2015). Knowledge about carbon sequestration in forests is associated with the willingness to extend rotation (Khanal et al., 2017), and perceived benefits (e.g. enhanced biodiversity) of deadwood retention increase the probability to retain deadwood (Joa & Schraml, 2020). Likewise, negative remarks related to an increasing amount of deadwood in forests, such as worry of decaying timber, risk of pest invasions, and making work and recreation more dangerous, are common among the NIPF owners, and these perceptions reduce their willingness to adopt the related forest management practices (Joa & Schraml, 2020; Karppinen et al., 2018; Hysing & Olsson, 2005).

The perceptions of the quality of forest management at national level are associated with management decisions. The NIPF owners considering Finnish forests as well managed for either recreation purposes or biomass production favor short rotation management, while forest owners who are of opinion that Finnish forests are well managed from the perspective of timber production, biodiversity, or climate change mitigation, are more likely to favor traditional even-aged management instead of uneven-aged management (Juutinen et al. 2020). Also, political orientation may be a significant determinant concerning willingness to adopt forest management practices: Kooistra et al. (2018) found that conservative political attitudes are associated with the reluctance towards establishing wide riparian buffer zones, possibly due to lack of knowledge concerning the ecological outcomes of such management. Moreover, risk-averse NIPF owners are more favorable towards wide riparian buffers (Kang et al., 2019).

**Forest site characteristics**

An increase in property size increases the probability of delaying harvest (Khanal et al., 2017; Mäntymaa et al. 2018), leave unmanaged areas (Danley, 2018), and convert monocultures to mixed broadleaved stands (Van Herzele & Van Gossum, 2009). Contrary findings regarding delayed harvest and riparian buffer zones are suggested to be due to increasing marginal returns of forestry (Kline et al., 2000a, 2000b). In addition to property size, forest site suitability for timber production affects the NIPF owners’ management decisions. Poor stand characteristics in terms of timber production have a positive effect on the probability to adopt various forest management practices promoting carbon sequestration, climate change adaptation, and biodiversity (Matta et al. 2009; Kim & Langpap., 2015; Joa & Schraml, 2020). Poor site characteristics in terms of timber production are strongly related to the willingness to leave unmanaged areas (Joa & Schraml, 2020; Horne, 2006).

**Previous forest management**

As to previous management decisions, NIPF owners having applied natural regeneration are more likely to apply uneven-aged management in the future, and previous clearcutting is associated with the intention to allocate forest under short rotation management (Juutinen et al., 2020). According to Kline et al. (2000a), the NIPF owners with intentions for clearcutting are less willing to delay harvest in the future. Intentions to allocate forest under long rotation management decrease with previous firewood harvesting (Juutinen et al., 2020). The probability to participate in PES
program requiring temporary set-aside is positively associated with previous clearcuttings (Mäntymaa et al., 2018).

**Owner motivations and objectives**

Diverse motivations and objectives of the NIPF owners are associated with the willingness to undertake forest management practices. The recreational emphasis of forest ownership is associated with the willingness to delay harvest (Khanal et al., 2017; Kline et al., 2000a) and to adopt wider riparian buffer zones (Matta et al. 2009; Kline et al. 2000b). Similarly, the NIPF owners with multiple objectives are willing to delay harvest in order to improve wildlife habitat (Matta et al. 2009; Kline et al., 2000a; 2000b), as well as NIPF owners with wildlife conservation objectives (Matta et al. 2009). A primary timber production objective decreases the willingness to delay harvest (Khanal et al., 2017).

According to Hallikainen et al. (2010), a positive attitude towards deadwood retention practices, leaving set-aside areas, selective cuttings, natural regeneration, broadleaved mixtures, and retention trees is positively correlated with biophilia (appreciation of original nature and living things) and recreational and conservation objectives of forest management. Likewise, biophilia and recreational and conservation objectives of forest management are associated with negative attitudes towards intensive forest management practices, such as large clearcuttings and soil scarification. According to Pynnönen et al. (2018), a large share of both economic and multi-objective NIPF owners is willing to diversify their forest management practices and apply uneven-aged forestry, emphasizing the importance of combining economical and other objectives in forest management.

**Empirical analysis**

**Theoretical framework**

In this study, a NIPF owner’s management decisions are assumed to base on utility-maximizing behavior. For a NIPF owner, forestland is a source of income through timber sales, to be used for the consumption of other goods and services, and of non-timber forest outputs (such as recreation, aesthetic values, biodiversity, carbon sequestration). A NIPF owner makes management decisions incorporating all these objectives. (Binkley, 1981) The forest management practices considered in this study affect timber production, biodiversity, carbon sequestration, climate change adaptation and other forest amenities, and a NIPF owner is assumed to choose whether or not to apply a certain forest management practice, considering all objectives in order to maximize utility. The utility index is unobservable, but the decision to engage in forest management is determined by a set of observable factors (Joshi & Arano, 2009). Following the framework from Joshi & Arano (2009), the determinants of adopting forest management practices are assumed to be a vector of socio-demographic characteristics, site-specific characteristics, previous management and objectives for forest ownership. The model for the NIPF owner’s management behavior is as follows:

\[ U_i = f(TN(INV)|S_i, F_i, M_i, O_i) \]  \hspace{1cm} (1)

where \( U_i \) equals forest owner utility derived by a NIPF owner \( i \) investing in forest management activities; \( TN \) is a production function for timber and non-timber output consumed by NIPF owner; and \( INV \) represents investments in forest management activities. Investments in forest management activities are determined by socio-demographic characteristics \( S_i \) (e.g. Matta et al. 2009; Khanal et al., 2017; Joa & Schraml, 2020, Juutinen et al., 2020), forest site characteristics \( F_i \) (e.g. Mäntymaa et al., 2018), previous management actions \( M_i \) (e.g. Juutinen et al., 2020), and a NIPF owner’s motivations and objectives \( O_i \) (e.g. Khanal et al., 2017; Kline et al., 2000a). \( U_i \) and \( TN \) are unobservable, but \( INV \) can be observed by whether or not a NIPF owner is willing to adopt a certain forest management practice. Since \( INV \) is determined by \( S_i, F_i, M_i, O_i \), the econometric model represents indirect utility:

\[ INV = f(S_i, F_i, M_i, O_i) + \varepsilon_i \]  \hspace{1cm} (2)

where \( \varepsilon_i \) equals random error term.

**Methods**

A NIPF owners’ willingness to adopt forest management practices is assessed with a set of binary logistic models, one model for each of the thirteen forest management practices. Independent variables include socio-demographic variables, site-specific characteristics, previously conducted forest management, and owner motivations. The binary logistic model can be expressed as follows:

\[ \text{logit}(fmp) = \beta_0 + \beta_1 S + \beta_2 F + \beta_3 M + \beta_4 O \]  \hspace{1cm} (3)

where \( \text{logit}(fmp) \) is the logit to adopt a forest management practice, \( \beta_0 \) is a constant, \( \beta \) is the coefficient of forest owners socio-demographic characteristics, \( \beta_2 \) is the coefficient of forest site characteristics, \( \beta_3 \) is the coefficient of previous forest management, and \( \beta_4 \) is the coefficient of forest owner’s objectives and motivations.

In order to identify latent constructions among the NIPF owners’ motivations and to incorporate them into the binary logistic model, principal component analysis (PCA) with Varimax rotation (e.g. Yong & Pearce, 2013) is applied. Components with eigenvalue greater than one are retained (Kaiser, 1960). Sampling adequacy of the data is assessed using Kaiser-Mayer-Olkin measure. To confirm the internal consistency of components, Cronbach’s alphas are evaluated (Tavakol & Dennick, 2011). The obtained principal components (the associated component scores) are used as explanatory variables in binary logistic regression models (Harell, 2015). All statistical analyses are conducted using SPSS 26.

**Empirical data**

The survey questionnaire for the NIPF owners was designed in autumn 2018, with help of previous scientific literature, previous NIPF owner survey questionnaires as well as NIPF owner interviews while testing the draft questionnaire. In February 2019, the survey was administered in Finnish by a
professional polling company Kantar TNS using a nation-wide sample of NIPF owners available in their consumer panel. A 15-minute survey included questions on characteristics of forest property, motivations for forest ownership, stated enrollment to a new voluntary forest conservation program, stated intention to adopt various forest management practices, previous management, attitudes and perceptions on forest management, and NIPF owner characteristics. The English translation of the questionnaire is available from the authors by request.

In the core question for this analysis, the responses to which served as dependent variables in regression models, the NIPF owners were asked to state their willingness to adopt selected forest management practices that are associated with biodiversity protection, climate change mitigation, or climate change adaptation in commercial forests. The set of forest management practices presented in a survey originated from a workshop for forest professionals and researchers, organized in November 2018, aiming to serve ecological scenario modeling. When defining the set of practices, contemporary official recommendations for forestry (Äijälä et al., 2014) by Tapio, a government-owned company offering the consultancy and advisory services, served as a reference. In the survey, the question was “Forest management decisions affect timber production, carbon sequestration and storage, and biodiversity. How likely would you choose to carry out the following forest management practices at your forest land?” The 4-point answer scale included “definitely yes”, “probably yes”, “probably no”, “definitely no”, and, in addition, “I can’t say”.

Regarding motivations of forest ownership, the respondents were asked to assess the importance of sixteen statements that reflected economic, environmental and social aspects of forests at a 5-point Likert-scale, ranging from “Very important” to “Not at all important”, and, in addition, “I can’t say”. The statements were presented to the respondents in the sets of four statements, and the order of sets was rotated randomly between respondents. Simple data imputation (Allison, 2001) was applied for “I can’t say” responses, the amount of which ranged from one to eleven depending on the statement. These responses were recoded to the middle point at 5-point Likert-scale. The responses to the motivation statements were used, after the principal component analysis, as explanatory variables in the regression model.

To assess the representativeness of the data for the Finnish NIPF owners, the demographics of survey respondents (Table 2) were compared to the nation-wide Finnish Forest Owner survey (FFO2020) (Karppinen et al., 2020). Our survey demographics trended towards female, younger, absentee forest owners (not living permanently on the forest holding) with higher levels of education than the FFO2020. This bias may relate to the use of the consumer panel in the data collection as online consumer panels tend to be biased towards younger individuals and city-dwellers. Although the occupational data in two surveys are not fully comparable, our survey respondents are more often pensioners and less often wage earners than the FFO2020 respondents. Similarly, regarding the scales of household income, it can be noted that the share of households with yearly income less than 20,000 € was smaller than in FFO2020.

The Finnish NIPF owners are, on average, willing to adopt forest management practices associated with carbon sequestration, adaptation to climate change, or biodiversity enhancement (Figure 1). However, distributions of responses vary among measures. Among the most often accepted forest management practices are broadleaved mixtures, retention trees, game habitats, and buffer zones: more than two thirds of respondents would “definitely” or “probably” adopt these measures. Deadwood, continuous-cover forestry (CCF), and increased density have similar response distributions: 61%–64% of forest owners are likely to adopt these forest management practices. Notably, for CCF, the share of “definitely yes” answers is relatively high. Slightly over half of respondents are likely to adopt harvest residues, wind-felled trees, and fertilization. Shortened rotation, southern seedlings, and extended rotation are the least favored forest management practices as less than half of the respondents are likely to apply these forest management practices at their forest property.

For modeling purposes, the responses are modified as binary, allowing a more lucid comparison between forest management practices. In regressions, the responses “definitely yes” and “probably yes” are equal to the value of one, the responses “probably no” and “definitely no” are equal to the value of zero, and the “I can’t say” responses are treated as missing values.

### Table 2. Descriptive statistics.

| Forest owner characteristics | Survey (n = 405) | Finnish Forest Owner 2,020 (n = 6542) |
|-----------------------------|-----------------|--------------------------------------|
| Gender                      |                 |                                      |
| Female                      | 36              | 25                                   |
| Male                        | 64              | 75                                   |
| Age, %                      |                 |                                      |
| <45                         | 20              | 12                                   |
| 45–64                       | 31              | 37                                   |
| >65                         | 49              | 50                                   |
| Average age                 | 59              | 62                                   |
| Living permanently on the holding, % | 21 | 35 |
| Second residence on the holding, % | 36 | 27 |
| Occupation, %               |                 |                                      |
| Wage earner                 | 29              | 37                                   |
| Farmer                      | 4               | 37                                   |
| Entrepreneur                | 9               | 37                                   |
| Pensioner                   | 56              | 47                                   |
| Other (student, unemployed etc.) | 4   | 2                                    |
| Education                   |                 |                                      |
| No vocational education     | 15              | 28                                   |
| Vocational education        | 23              | 27                                   |
| College level- or polytechnic degree | 38 | 27 |
| University degree           | 23              | 18                                   |
| Yearly household income, %  |                 |                                      |
| < 20,000 €                  | 5               | 5                                    |
| 20,000–50,000 €             | 30              | 30                                   |
| 50,000–100,000 €            | 39              | 39                                   |
| >1,000,000 €                | 11              | 11                                   |
| Forest land characteristics  |                 |                                      |
| Average size, ha            | 50              | 48                                   |

*Not comparable/different scale. **Excluding income from timber sales.
Empirical results

Motivations for forest ownership

The results of principal component analysis (Table 3) show the four principal components (PC) extracted for the motivations for forest ownership: environmental, immaterial, financial motivations and a motivation related to self-employment and outdoor activities. The four PCs explain 67.7% of the total variance (KMO = 0.877, \( p \leq 0.001 \)). Cronbach’s alphas of the PCs range between 0.80 and 0.88, indicating sufficient internal consistency. Motivational statements are assigned to a principal component for which they have the highest loading.

Financial motivation comprises of short- and long-term financial objectives related to forest ownership. Self-employment & outdoor motivation emphasizes business opportunities of one’s forest and outdoor activities such as hunting at the forest property. Immaterial motivation comprises of immaterial benefits and values related to forest ownership, such as relaxation, shared time with relatives and connection to one’s home region. Also, non-timber benefits, i.e. berry/mushroom picking and wood for domestic use are included in this PC. Environmental motivation reflects the NIPF owner’s ambition to provide non-market ecosystem services. Climate change mitigation, forest biodiversity protection, water protection, and air quality protection are all loaded strictly to environmental motivation PC.

The self-employment and outdoor component include cross loadings from financial motivation. Bequest motives for forest ownership, assigned to financial motivation, are

Table 3. Principal component analysis for motivations of forest ownership.

| Statement                                                                 | Financial motivation | Self-employment and outdoor motivation | Immaterial motivation | Environmental motivation |
|---------------------------------------------------------------------------|----------------------|----------------------------------------|------------------------|--------------------------|
| Financing major purchases and/or regular consuming                        | 0.78                 | 0.34                                   |                        |                          |
| Financial security                                                        | 0.81                 |                                        |                        |                          |
| Investment, increase in value of forest stands                            | 0.68                 | 0.35                                   |                        |                          |
| Bequest for relatives                                                     | 0.59                 |                                        | 0.47                   |                          |
| Income from work in own forest                                            | 0.51                 | 0.65                                   |                        |                          |
| Other business opportunities at forest property (e.g. nature tourism)     | 0.35                 | 0.72                                   |                        |                          |
| Hunting at forest property                                                | 0.73                 |                                        |                        |                          |
| Relaxation (outdoor activities, meditation, calming down)                 | 0.72                 |                                        | 0.31                   |                          |
| Forestry activities and/or wood for domestic use                          | 0.68                 |                                        |                        |                          |
| Shared time with family or relatives                                      | 0.71                 |                                        | 0.32                   |                          |
| Connection to home region                                                  | 0.41                 | 0.59                                   | 0.66                   | 0.30                     |
| Berry/mushroom picking at forest property                                 | 0.38                 |                                        | 0.83                   |                          |
| Climate change mitigation                                                 | 0.83                 |                                        |                        |                          |
| Forest biodiversity protection                                            |                      |                                        |                        | 0.83                     |
| Water protection through nutrient and sediment loading reduction           |                      |                                        |                        | 0.83                     |
| Air quality protection through pollutant filtration                       |                      |                                        |                        | 0.83                     |
| Cronbach’s alpha                                                         | 0.83                 | 0.80                                   | 0.81                   | 0.88                     |

Note: Factor loadings below 0.30 not included. Kaiser-Mayer-Olkin measure of sampling adequacy 0.877, Bartlett’s test for sphericity \( p \leq 0.001 \).
cross-loaded in immaterial motivation. Income from work in
own forest and other business opportunities as well as con-
nexion to the home region are cross-loaded in financial
motivation. Relaxation and shared time with relatives,
assigned to immaterial motivation, are cross-loaded in
environmental motivation, while berry/mushroom picking
are cross-loaded in both environmental motivation and self-
employment & outdoor motivation, while assigned in imma-
terial motivation.

**Stated willingness to adopt forest management practices**

For the binary logit regression models, explanatory variables
(Table 4) were selected based on backward selection pro-
cedure (Bursac et al., 2008). The explanatory variables in
the initial model (available as supplemental material) base on
the literature review. All significant factors were included in
the initial model, on condition of the availability in the
data. One at the time, explanatory variables that were
insignificant (p > 0.05) in all models were removed. The pro-
cedure was repeated until only significant variables remained
(p < 0.05 in at least one model).

In binary logistic regression models (Table 5), the explana-
tory power range from 61.4% to 83.3%. Nagelkerke R² values
range between 0.06 and 0.32. A potential reason for low R²
values in the models broadleaf mixtures, retention trees, and
*game habitats* models is the small amount of negative
responses. These models predict only 3.9%–12.7% of nega-
tive responses correctly. In terms of other models, the
model performance is considered sufficient. Variance
inflation factor (VIF) values ranged between 1.013 and
1.576, indicating that multicollinearity is not an issue in
analysis.

The socio-demographic variables, i.e. age, education, and
income are statistically significant at 5% level in at least one
model. The effect of age on willingness to adopt *deadwood*,
*wind-felled trees*, *extended rotation*, and *harvest residues*
is negative: increase in age decreases the probability to adopt
these forest management practices. Highly educated forest
owners are more likely to retain *deadwood* and *wind-felled
trees*. High income increases the probability to apply *extended
rotation*. Increase in forest land size has negative effect on
willingness to adopt *deadwood*, *CCF*, and *shortened rotation*.

Three forest management practices applied earlier by NIPF
owners (fertilization, ditching, nature management) are
statistically significant at 5% significance level in at least one
model. Forest owners who have applied fertilization before
are more likely to fertilize in the future. Previous ditching
has a negative effect on willingness to retain *deadwood*. Pre-
vious nature management is positively associated with the
willingness to adopt *buffer zones* and *deadwood*.

An increase in environmental motivation (measured by a
higher factor score) increases the probability to adopt most
of the studied forest management practices: *buffer zones*,
*deadwood*, *broadleaf mixtures*, *retention trees*, *wind-felled
trees*, *extended rotation*, *harvest residues*, *game habitats*, and
*CCF* models. Strong environmental motivation decreases
the willingness to adopt *shortened rotation*. Strong immaterial
motivation is positively associated with *harvest residues*, *game

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**Table 4. Summary of variables in binary logistic regression models.**

| Variable name        | Description                                                                 | Min | Max | Mean | n    |
|----------------------|------------------------------------------------------------------------------|-----|-----|------|------|
| **Dependent variables** |                                                                              |     |     |      |      |
| Buffer zones         | Lighter managed buffer zones around important habitats and/or conservation areas | 0   | 1   | 0.77 | 361  |
| Broadleaf mixtures   | Mixed tree species in coniferous forest: at least one fifth of birches or other deciduous trees | 0   | 1   | 0.83 | 378  |
| Retention trees      | Leaving at least 5% of the logging volume as a stand (over 20 cm in diameter) E.g. keeping 10 m³/ha as a stand when logging 200 m³/ha | 0   | 1   | 0.78 | 374  |
| Deadwood             | Leaving at least 10 m³ of deadwood per hectare when logging                   | 0   | 1   | 0.69 | 374  |
| Wind-felled trees    | Leaving wind-felled trees to the ground according to the maximum limit determined by the law of forest damage. Maximum limit for spruce is 10 m³/ha and for pine 20 m³/ha | 0   | 1   | 0.57 | 377  |
| Harvest residues     | Leaving all logging residues at the terrain (e.g. not harvested for bioenergy) | 0   | 1   | 0.56 | 385  |
| Extended rotation    | Lengthening the rotation period by a quarter (e.g. lengthening the regeneration cut from 80 to 100 years) | 0   | 1   | 0.42 | 365  |
| Game habitats        | Saving habitats for game (e.g. thickets) at thinnings and tending of seedling stands | 0   | 1   | 0.79 | 371  |
| CCF                  | Continuous-cover forestry (no clearcutting, soil preparation, or tree planting) | 0   | 1   | 0.67 | 376  |
| Increased density    | Increasing growing density of the stand                                     | 0   | 1   | 0.68 | 364  |
| Fertilization        | Fertilizing low-yielding areas                                               | 0   | 1   | 0.55 | 381  |
| Shortened rotation   | Shortening the rotation period by a quarter (e.g. shortening the regeneration cut from 80 years to 60 years) | 0   | 1   | 0.53 | 362  |
| Southern seedlings   | Forest regeneration with southern seedlings that can adapt better to warming climate | 0   | 1   | 0.5  | 366  |
| **Independent variables** |                                                                              |     |     |      |      |
| Age                  | Age of respondent in years                                                   | 18  | 86  | 58.61| 405  |
| Edu                  | Equals 1 if respondent has university level or polytechnic degree, 0 otherwise | 0   | 1   | 0.47 | 405  |
| Income               | Equals 1 if household income exceeds 50,000 annually, 0 otherwise           | 0   | 1   | 0.59 | 346  |
| Size                 | Size of forest property in hectares                                         | 2   | 500 | 35.73| 377  |
| Fert man             | Equals 1 if respondent applied fertilization during 2016-2018, 0 otherwise | 0   | 1   | 0.12 | 405  |
| Dit man              | Equals 1 if respondent applied ditching during 2016-2018, 0 otherwise      | 0   | 1   | 0.18 | 405  |
| Nat man              | Equals 1 if respondent applied nature management during 2016-2018, 0 otherwise | 0   | 1   | 0.16 | 405  |
| Env mot              | Component score for environmental motivation                                 | −3.14 | 2.46 | 0    | 405  |
| Imm mot              | Component score for immaterial motivation                                     | −3.66 | 2.65 | 0    | 405  |
| Fin mot              | Component score for financial motivation                                     | −3.31 | 2.80 | 0    | 405  |
| Emp mot              | Component score for self-employment and outdoor activities motivation       | −2.24 | 2.70 | 0    | 405  |
Table 5. Binary logistic regression coefficients.

| Forest management practices | Constant | Age | Edu | Income | Size | Fert man | Dit man | Nat man | Fin mot | Emp mot | Imm mot | Env mot |
|-----------------------------|----------|-----|-----|--------|------|----------|---------|---------|---------|---------|---------|---------|
| Buffer zones                | 0.67     | 0.00| 0.30| 0.30   | 0.00 | −0.15    | −0.11   | 1.04*   | 0.35*   | −0.02   | 0.13    | 0.63*** |
| Broadleaf mixtures          | 0.43     | 0.02(*)| 0.47| −0.23  | 0.00 | 1.70*    | 0.28    | 0.16    | 0.18    | 0.05    | 0.22    | 0.42*   |
| Retention trees             | 2.40***  | −0.01| 0.29| 0.15   | −0.01(*)| 0.16    | −0.49   | −0.18   | −0.03   | −0.08   | 0.26(*) | 0.78*** |
| Deadwood                    | 2.72***  | −0.03**| 0.75*| −0.03  | −0.01*| 0.16    | −1.13** | 1.24**  | −0.15   | −0.07   | 0.09    | 0.69*** |
| Wind-felled trees           | 3.01***  | −0.05***| 0.93**| −0.01 | 0.00  | 0.21    | −0.52   | −0.21   | −0.13   | −0.17   | 0.19    | 0.77*** |
| Harvest residues            | 1.26*    | 0.32| 0.37| 0.00   | −0.15 | 0.21    | 0.63(*) | −0.08   | −0.02   | 0.27*   | 0.27*   |
| Extended rotation           | 1.20(*)  | −0.03***| 0.09| 0.84**| 0.00 | −0.34   | −0.59(*)| 0.03    | −0.22   | −0.03   | 0.16    | 0.67*** |
| Game habitats               | 1.27(*)  | 0.01| −0.07| −0.26 | 0.00 | −0.23   | −0.01   | 0.85    | 0.13    | 0.09    | 0.32*   | 0.78*** |
| CCF                         | 1.64*    | 0.00| −0.24| 0.27   | −0.01**| −0.12   | −0.31   | −0.55   | −0.21   | 0.31*   | 0.18    | 0.62*** |
| Increased density           | 1.35*    | −0.01| −0.14| 0.05   | 0.00 | −0.01   | −0.16   | −0.04   | 0.11    | 0.11    | 0.33*   | 0.23(*) |
| Fertilization               | 1.05(*)  | −0.02| −0.06| −0.22 | 0.00 | 2.18**  | 1.17**  | −0.34   | 0.56*** | 0.10    | 0.45**  | 0.16    |
| Shortened rotation          | 1.03     | −0.01| 0.26| −0.30  | −0.02**| 0.76(*) | 0.29    | −0.71(*)| 0.65*** | 0.46**  | 0.02    | 0.28*   |
| Southern seedlings          | 0.16     | 0.00| 0.22| −0.01  | 0.00 | 0.20    | 0.41    | 0.24    | 0.50*** | 0.26(*) | 0.07    | −0.01   |

*indicate significance level of 0.1, respectively.
*indicate significance level of 0.05, respectively.
**indicate significance level of 0.01, respectively.
***indicate significance level of 0.001, respectively.
habitats, increased density, and fertilization. An increase in financial motivation increases the probability to adopt buffer zones, fertilization, shortened rotation, and southern seedlings. Self-employment and outdoors motivation increases the probability to adopt CCF and shortened rotation.

Discussion

The empirical analysis of the Finnish NIPF owners identified socio-demographic (age, education, income) and site-specific characteristics (property size), previously conducted forest management (fertilization, ditching, nature management), and motivations (environmental, immaterial, financial, self-employment & outdoor) that are associated with the willingness to adopt forest management practices promoting forest biodiversity, climate change mitigation or adaptation in commercial forests. While the directions are mostly consistent across thirteen studied forest management practices, the exceptions, subject to both negative and positive effects depending on practice, are environmental motivation and previously conducted ditching and nature management activities.

One of the main findings of the study is that older forest owners are less willing to adopt forest management that increases the amount of deadwood in commercial forest (i.e. leaving deadwood at harvest, allowing wind-felled trees decay, leaving harvest residues in the forest, and extending rotation period). Previous scientific literature has recognized that negative perceptions related to deadwood, such as pest and pathogen invasions, or considering deadwood retention contrary to the established image of a well-managed forest may reduce the NIPF owners’ willingness to increase the amount of deadwood (Joa & Scraml, 2020; Karpinnen et al., 2018; Hysing & Olsson, 2005). Possibly, older age is associated with such perceptions. Concerning negative effect of age on willingness to extend rotation, the finding is consistent with Khanal et al. (2017) and Matta et al. (2009). Contrary results obtained by Juutinen et al. (2020) may associate with differences in approaches, the latter focusing on the proportion of land allocated under different management regimes instead of a binary adoption decision.

Contrary to age, high education associates with higher willingness to adopt forest management practices that increase the amount of deadwood in forests (retaining deadwood and wind-felled trees). Previous literature also discloses that highly educated forest owners are willing to promote biodiversity conservation by adopting various forest management practices (Joa & Scraml, 2020; Rämö et al., 2013; Dickinson et al., 2012; Markowski-Lindsay et al., 2011, Matta et al., 2009, Kline et al., 2000a). Yet another main finding of the study regarding demographics of NIPF owners is that higher income increases the willingness to extend rotation period. Possibly, more wealthy forest owners are less in a hurry to realize profits from final felling.

Previous literature suggests that females, resident forest owners, and non-members of forest owners’ association are more likely to adopt forest management practices promoting carbon sequestration, climate change adaptation, or biodiversity (Matta et al., 2009; Danley, 2018; Juutinen et al., 2020). Moreover, regarding gender, forests owned by males are more actively managed (Lidestav & Berg Lejon, 2013), females sell timber less frequently (Kuuluvainen et al., 2014), and males are more often compensation oriented in terms of biodiversity conservation in commercial forests (Koskela & Karppinen, 2020). However, according to our study, gender, residence on forest property, membership in forest owners’ association and previous regeneration management actions are not statistically significant factors of the adoption of forest management practices for biodiversity or climate change.

The role of forest property size in forest management behavior is ambiguous and varies between forest management practices. Large forestland size is positively associated with leaving unmanaged areas (Danley, 2018) and converting monocultures to mixed broadleaved stands (Van Herzele & Van Gossum, 2009), while the effect on the delayed harvest is ambiguous (Khanal et al., 2017; Mäntymaa et al., 2018; Kline et al. 2000a). In this study, the effect of property size on adopting the forest management practices studied is generally negative.

Previously conducted intensive forest management with a strong timber production orientation may be a relevant indicator of NIPF owner’s preferences. These owners may have primarily financial objectives for their ownership, and consider nature-oriented management activities contradictory. The NIPF owners who have conducted costly management practices, such as ditching and fertilization that aim to increase the productivity of the forest site are more willing to conduct such management also in the future. Similarly, according to Juutinen et al., (2020), previously conducted intensive forest management practices, such as clearcutting and ditching, might be associated with willingness to conduct intensive forest management practices such as short rotation management or fertilization in the future, and to avoid economically conflicting forest management with emphasis on nature. Further, the NIPF owners with previous experience in ditching, causing strain on the water system, are less willing to retain deadwood, which might indicate the emphasis of timber production and financial objectives of forest ownership over environmental motives.

As to the positive association of previously conducted nature management with the willingness to retain deadwood and to establish buffer zones around protected areas, it is somewhat peculiar that previous nature management is significant in only these two models. Strong environmental motivation, potentially reflecting similar management preferences to some extent, affects the willingness to adopt all forest management practices, except for southern seedlings and fertilization. This may result from data deficiency, since only 16% of respondents stated that they had conducted nature management activities such as leaving snags, retention trees, or riparian buffers. However, a modest share seems odd, since approximately 90% of commercial forests in Finland are PEFC-certified, according to which leaving retention trees is generally required. It is possible that some respondents may have misunderstood the meaning of the statement, or they may have outsourced the management of their forest and are unaware of such practices.
This study confirms the role of diverse motivations for forest ownership in NIPF owners’ willingness to adopt forest management practices that promote carbon sequestration, climate change adaptation, or biodiversity conservation. For instance, in previous literature, recreational and multi-objective emphasis of forest ownership are associated with willingness to adopt various forest management practices (Khanal et al., 2017; Matta et al., 2009; Kline et al., 2000a; 2000b). Recreationists harvest slightly less than other NIPF owners and avoid intensive forest management, such as mechanized site preparation (Karppinen, 1998). In our study, environmental and financial motivations stand out as important determinants of willingness to adopt the studied forest management practices.

Strong environmental motivation increases the probability to adopt many of the forest management practices studied, an exception being a negative association with shortened rotation period. This seems reasonable as shortened rotation potentially has negative implications for biodiversity (Ranius et al., 2003; Mönkkönen et al., 2014; Felton et al., 2016). These indicate that the NIPF owners’ willingness to accept a wide range of practices in their commercial forests to provide environmental benefits, as long as they do not conflict with biodiversity.

Strong financial motivation increases the probability to adopt fertilization, shortened rotation, and use of southern seedlings in regeneration, the management practices that do not necessarily contradict with economically optimal timber production, rather promote it. Financial motivation also increased the probability to adopt lighter managed buffer zones around protected areas, although adopting such forest management practice might not be economically optimal. Previous literature suggests that Finnish NIPF owners are generally favorable towards small-scale conservation, and half of owners might be willing to accept a minor loss of income resulting from conservation (Hallikainen et al., 2010). This might consider even forest owners who have strong economical motivation for their ownership.

Regarding the willingness to adopt continuous-cover forestry (CCF), the positive association with strong self-employment and outdoor activities motivation for forest ownership reflects the recognition of these benefits related to, e.g. hunting and tourism opportunities. On the other hand, strong self-employment and outdoor motivation increases the willingness to practice short rotation management, being potentially controversial with valuing wider range of ecosystem services. A common factor for CCF and shortened rotation is increased resilience towards abiotic and biotic hazards induced by climate change (Felton et al., 2016), which offers potential explanation for association of these forest management practices with self-employment and outdoor motivation. To note is that a relatively large share of NIPF owners (24%) are “definitely” willing to adopt continuous-cover forestry, in comparison to other practices studied. Given that under certain conditions (e.g. high regeneration costs and poor site productivity) CCF might be economically optimal management regime in boreal coniferous forests (e.g. Parkatti et al., 2019; Tahvonen & Rämö, 2016; Pukkala et al., 2010), these confident NIPF owners may consider CCF economically reasonable. They may also value the provision of non-market benefits, i.e. a wider range of ecosystem services and multifunctionality of forests compared to even-aged commercial stands (Peura et al., 2018).

As to the two most favored forest management practices, in line with Vedel et al. (2015), the popularity of broadleaved mixtures may relate to perceived benefits, such as increased resilience towards risks induced by climate change. In turn, a favorable attitude towards retention trees may relate to the fact that it is required by the PEFC certification and therefore familiar for most forest owners. The willingness to save game habitats, retention trees, and establish buffer zones around protected areas might stem from the favorability towards small-scale conservation (Horne, 2006).

As to the three least favored forest management practices, increased clearcuts in the landscape and inflated forest amenities might decrease the NIPF owners’ willingness to shorten rotation period. The use of southern seedlings, in turn, might be unfamiliar for Finnish NIPF owners, demonstrated also by a high share of uncertain responses in the adoption question regarding this management practice. A relatively low willingness of forest owners to implement extended rotation may relate to a concern for abiotic and biotic hazards and delayed income from final felling. The monetary compensation may increase the NIPF owners’ willingness to participate in carbon sequestration or biodiversity conservation (e.g. Khanal et al., 2017; Kline et al., 2000a).

While previous scientific literature provides insight on factors affecting forest owners’ willingness to adopt forest management practices, many studies either focus on one practice at time, thus not allowing for comparison or building a wider view on the acceptability of forest management practices. In addition, many studies emphasize on the objectives of forest management rather than on conducting the forest management practice itself, especially when assessing the participation in PES programs. While providing information on the forest owners’ views towards the objectives of forest management rather than management practices to achieve them, the results may differ when switching the focus to another objective associated with the same forest management practice. As clearly demonstrated in this study, the NIPF owners are not indifferent in terms of the forest management they are willing to conduct in their forestland. Possible explanations for the variation in the acceptability of management practices are perceived benefits and threats of different management practices, economical aspects, familiarity of forest management practices, feasibility, and easiness of implementation.

Regarding the generalizability of empirical results to the NIPF population in Finland, the results on the acceptability of forest management practices can be taken as directional, given the bias towards younger forest owners and city-dwellers in the study sample. On the other hand, the set of dimensions identified in the principal components analysis, i.e. financial, self-employment/outdoor, immaterial, and environmental motivation, mimics well the corresponding analysis of the Finnish nation-wide forest owner survey (FFO2020), in which “financial”, “employment opportunities and outdoor” and “immaterial” dimensions were extracted (Karrppinen et al., 2020). The similarities indicate that the study data
reflects well multiple objectives of the NIPF owners in Finland, increasing the credibility of the study data. Moreover, the study results suggest that a wide set of environmental motivational statements is needed to allow for revealing the role of environmental aspects in decision making concerning forest management.

Low goodness of fit ($R^2 < 0.19$) in some logistic regression models may stem from a small share of negative responses in models considering the most favored forest management practices (i.e. broadleaved mixtures, game habitats, retention trees, buffer zones). Alternatively, the reason may be a share of the “Cannot say” responses deleted from the regression analysis, resulting in a smaller sample size for the models for increased density and southern seedlings. These results are to be interpreted with some reservations. Yet another issue related to the reliability of the results is that the empirical analysis bases on the stated intention to adopt forest management practices rather than observed behavior or revealed commitments. However, unlike in non-market valuation where individuals may overstate their economic valuation (Murphy et al., 2005), in this survey, an obvious incentive for respondents to over- or understate the likelihood to adopt forest management practices does not exist.

Conclusions

This study presents a new perspective in NIPF owner literature by assessing their willingness to adopt various forest management practices related to climate change and biodiversity. The study confirms that these management intentions are, to great extent, guided by motivations for forest ownership: forest owners accept forest management practices consistent with their motivations, and are reluctant towards conflicting practices. Especially environmental and financial motivations play a role in the decision making on management practices in privately owned commercial forests. Information on the characteristics associated to the potential adoption of forest management practices is useful when identifying forest owners who have such ambitions. Therefore, our findings can be applied when implementing environmental policies such as PES schemes, incentivizing forest owners to adopt forest management practices.

As suggestions for future research beyond this stated intention study, integrating information of the revealed commitments would provide more in-depth information about potential future adoption of forest management practices. A qualitative more-in-detail analysis on forest owners’ views towards distinct forest management practices and the associated benefits and disadvantages would reveal the bottlenecks in the adoption of practices and policies related to biodiversity and climate change. However, given the importance of economic aspects of forest ownership for NIPF owners, the further analysis of compensation claims in relation to contracts on forest management practices would serve policy makers in promoting the mitigation of climate change, the adaptation to climate change, and biodiversity conservation in commercial forests.

NIPF owners are not indifferent what forest management they are willing to adopt to promote carbon sequestration, climate change adaptation, or biodiversity conservation. This issue needs more attention in research. Many NIPF owners are willing to adopt small-scale conservation measures and tolerate minor economic loss. On the other hand, some forest management practices, such as extended rotation, may need to be monetarily subsidized to reach the adequate level of implementation. Policy makers benefit from information on which measures can be implemented through recommendations, advice and education of NIPF owners, and for which stronger policies are needed.

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