Forest Policy and Economics 148 (2023) 102901

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

Private forest owner willingness to mobilise wood from dense, small-diameter tree stands

Matevž Triplat [a,b,*], Satu Helenius [c], Ruben Laina [d], Nike Krajnc [a], Thomas Kronholm [e], Zdenka Ženko [f], Teppo Hujala [c]

[a] Slovenian Forestry Institute, Večna pot 2, 1000 Ljubljana, Slovenia
[b] Biotechnical Faculty, Department of Forestry and Renewable Forest Resources, University of Ljubljana, SI-1000 Ljubljana, Slovenia
[c] University of Eastern Finland, Faculty of Science and Forestry, School of Forest Sciences, P.O. Box 111, FI-80101 Joensuu, Finland
[d] Polytechnic University of Madrid, ES-28040 Madrid, Spain
[e] Department of Forest Biomaterials and Technology, Swedish University of Agricultural Sciences, SE-90183 Umeå, Sweden
[f] Faculty of Economics and Business, University of Maribor, SI-2000 Maribor, Slovenia

ARTICLE INFO

Keywords:
Customer profiles
Factor analysis
Forestry services
Management objectives
Biomass
Communication strategies

ABSTRACT

Forests are a source of renewable biomass, and their utilisation will play a vital role in the transition towards a climate-neutral economy. Small-diameter tree management could contribute to this transition via providing renewable biomass for sustainable uses and fostering tree growth towards long-lifecycle bioproducts. The utilisation of small-diameter trees in the EU is still low since new technologies and work models are required to make the operations economically profitable, environmentally sound, and socially attractive. The supply of biomass from small-diameter tree stands is dependent on forest owners with diverse perceptions on their forests and diverse ownership objectives. However, there is scarce research on forest owner perceptions on small-diameter tree management, which encompasses home consumption, self-active work, and commercial forestry services. A survey in four EU countries was designed to identify the main factors affecting the motivation of forest owners to mobilise biomass from small-diameter stands. Factor and clustering analyses were used to identify four forest owner segments: weakly-engaged traders, well-being seekers, self-active profit-seekers, and well-informed service users. The willingness to utilise biomass from small-diameter tree stands and participate in the market was shaped by forest owner knowledge of forestry, economic and socio-cultural motivations, and sensitivity to service offerings. Forest owner preferences for market participation are heterogenous, and thus different policy implementation approaches are needed and proposed.

1. Introduction

Transitioning to a climate-neutral economy in the European Union (EU) requires substituting fossil-based materials with bio-based ones. This, together with the expected growing demand for wood driven by the EU's vision for a forest-based bioeconomy in the updated European Bioeconomy Strategy (European Commision, 2018), make forests an essential source of renewable biomass. To meet the increasing demand, it will be necessary to exploit additional underutilised sources of forest biomass, such as small-diameter forest stands (SDS), which are defined in this study as stands with trees with a diameter at breast height of up to 10 cm and also referred to as young, dense forest stands. Forest owner management decisions regarding silvicultural operations in young forests, such as early thinning, will not only ensure that future stands produce thicker and higher-value trees, but also increase biomass supply (Witzell et al., 2019). Young, dense stands provide large volumes of biomass, and only minor volumes of merchantable pulpwood can be expected (Bergström, 2009). SDS biomass resulting from silvicultural activities in the early stages is either collected for bioenergy feedstocks or left to decompose in the forest (Witzell et al., 2019). Hence, the collection of SDS biomass as part of sustainable forest management could be justified for increasing forest biomass that is derived as a by-product of silvicultural practices rather than that used as a primary feedstock. This would require a market demand for this type of product and forest owner interest in supplying it. A barrier to this has been the fact that the harvesting cost of SDS biomass has been significantly higher

* Corresponding author at: Slovenian Forestry Institute, Večna pot 2, 1000 Ljubljana, Slovenia.
E-mail address: matevz.triplat@gozdis.si (M. Triplat).

https://doi.org/10.1016/j.forpol.2022.102901
Received 31 May 2022; Received in revised form 18 December 2022; Accepted 21 December 2022
Available online 29 December 2022

than that for other types of forest biomass such as logging residues (Laitila et al., 2010). In an attempt to solve this issue, more cost-effective harvesting methods and technologies are being developed (Ahnlund Ulvcrona et al., 2017; Bergström and Di Fulvio, 2014; Bergström et al., 2022; Tolosana et al., 2021).

Around 60% of forestland in the EU is privately owned (Eurostat, 2020), with an estimated 16 million forest owners (FOREST, 2020). Therefore, most of the supply of forest biomass in the EU is dependent on the diverse perceptions and ownership objectives of individual forest owners. Since existing research on forest owner attitudes and current practices concerning biomass harvesting from SDS includes relatively narrow samples in terms of the geographical distribution of forest owners, and because forest owner attitudes and management objectives may change over time, more knowledge is needed on how forest owners in Europe currently utilise SDS and whether they are interested in supplying this product to the wood industry. Specifically, the aims of this study are (i) to identify the main factors affecting the level of interest and motivation of forest owners regarding biomass mobilisation from SDS and (ii) to investigate the role of forest management information and decision support in the willingness of forest owners to supply biomass from SDS. The study results will benefit both practitioners and policymakers in their endeavour to increase the use of renewable energy sources at the European level.

As a result of socio-demographic changes among forest owners, today forest owners are a heterogeneous group of individuals whose management strategies and practices and decision-making are guided by diverse values and objectives (Häyrinen et al., 2014; Hujala et al., 2012; Juutinen et al., 2021; Juutinen et al., 2022; Karppinen, 1998; Kumer and Štrumbelj, 2017; Lähdesmäki and Matilainen, 2013; Ní Dhubháin et al., 2007; Weiss et al., 2019; Wiersum et al., 2005). A vast body of literature has previously categorised European forest owners into different groups to provide an insight into their diverse attitudes, values, beliefs, management objectives, and behaviour (Ficko et al., 2019; Häyrinen, 2019). However, previous research has mainly developed typologies on the need to boost the mobilisation of roundwood and, more recently, ecosystem services (Ficko et al., 2019). Thus, previous studies have not explored the perceptions of forest owners regarding the mobilisation of biomass from SDS. So far, only a few studies have investigated the willingness of forest owners to harvest SDS and their potential interest in promoting forest management strategies that may increase the future supply of this type of biomass. The results from these studies have shown that in Finland and Sweden, forest owners generally favour biomass harvesting in SDS if the economic outcome of such operations is perceived to be acceptable. Depending on the forest owner characteristics, some groups were more positive than others; however, the most positive groups differed between the studies (Kronholm et al., 2020; Mynttinen et al., 2014; Rämö et al., 2009). Although not wholly similar, these findings are related to forest owner activity in the timber market, which is influenced by the socio-demographic characteristics and management objectives of forest owners (Favada et al., 2009; Kuuluvainen et al., 2014).

2. Materials and methods

2.1. Questionnaire

The questionnaire development started in 2019 in cooperation with researchers from Finland, Slovenia, Spain, and Sweden. The task was to acquire information on the motivation and willingness of forest owners to utilise SDS resources. The questionnaire was discussed and adapted to be relevant in all four participating EU countries with different forest owners and forest types. Several questions were developed to gain insight into the different types of forest owners and to identify their needs and motivating factors with respect to managing SDS. The questionnaire includes questions about forest holdings and forest owners, forest owners' perceived importance of different goods and services from the forest holding, management and harvesting operations of forests and those specific for SDS, and the utilisation of SDS. Respondents were asked to report their present situation and perceptions for the questions about forest holdings and forest owners, and forest owners' perceived importance of different goods and services from the forest holding, while questions related to management and harvesting operations of forests and those specific for SDS were requested to be reported for a five-year period. Respondents were asked to indicate the extent to which they agreed with the proposed statements. The beginning point (1) refers to "do not agree at all", the middle point (3) to "neutral", and the endpoint (5) to "strongly agree".

2.2. Sample and data collection

2.2.1. Finland

Data collection in Finland was carried out in May 2020 through Kantar TNS Agri's national Gallup Forum online panel and was conducted according to the International Organization for Standardization (ISO, 2019). The questionnaire targeted non-industrial private forest owners who own at least 2 ha of forest land. The invitation to participate in the survey was sent to forest owner panellists, accompanied by a briefing about the overall study aims. The questionnaire was pre-tested by being sent to two forest owners as a test to gain insight into the time required for completing it and was modified and refined to accommodate suggestions for improvement. Language options for both Finnish and Swedish were provided for the respondents.

The response rate was 30%, with a total of 1129 answers gathered. The non-industrial private forest ownership forms included (i) private persons alone or with their spouse, (ii) partnerships, and (iii) undistributed estates of deceased persons. For comparability purposes between the other project countries, undivided estates of heirs were excluded, meaning the final data included 972 forest owners. The data were then weighted to correspond to the official continental private Finnish forest owner statistics (Metsämaski, 2020) in order to represent forest holdings in terms of forest owner gender and the size of forest estates.

2.2.2. Sweden

A random sample of 1500 forest owners was requested from the mapping, cadastral, and land registration authority in Sweden. Forest owners with properties <6 ha were excluded from the sample since, although being numerous, they represent only a small share of the country's total forestland. Foreign forest owners and minors (< 18 years) were also excluded. The information collected from the national register included the forest owner's name, address, id-number, and forest property size. After removing duplicates, the final sample consisted of 1462 forest owners. The gender distribution was 65% males and 35% females, aligning with official forest ownership statistics.

In May 2020, a questionnaire was distributed to forest owners by traditional mail. The forest owners were provided with an envelope to return the completed questionnaire free of charge. Two weeks after the first mailing, a reminder was sent out to forest owners who had not responded. They also received a copy of the questionnaire and a return envelope on this occasion. When data collection for this study ended, 544 forest owners had returned the questionnaire, achieving a response rate of 33%.

2.2.3. Slovenia

From the whole geographic region of Slovenia, a representative sample of different private forest owners was prepared. Due to COVID-19 restrictions, a survey agency performed telephone interviews. Interviews were conducted in April 2020. In total, 2346 phone numbers were called. In 633 cases (27%), the call was not answered. Of those who were reached, 895 (38.1%) declined to participate in the survey. In 60 cases (2.6%), the questionnaires were not fully completed, and these surveys were excluded from the database. Finally, 509 complete

questionnaires were analysed. The survey had a response rate of 21.7%.

2.2.4. Spain

In Spain two methods were employed. A questionnaire was distributed by email to private forest owners through the Spanish Forest Owners' Association in May 2020. The national association sent the questionnaire to regional associations responsible for distributing questionnaires among private forest owners. Only 69 responses were collected, and 34 respondents where not interested in participating. Municipalities with significant forest resources were selected in the second stage, and phone numbers were selected randomly from the public phone list. Through 100 phone calls, 14 forest owner interviews were performed. The secure web platform REDCap was employed for building and managing the online databases and surveys.

2.3. Description of respondents

In all countries the majority of respondents were male (Table 1). The mean age of respondents was 61 years. Retirees made up the highest proportion of respondents in all countries. The vast majority of respondents self-assigned themselves to be a member of the middle class. In Finland, Slovenia, and Sweden, the highest proportion of respondents had a high school education, while in Spain the highest proportion of respondents had a master's degree. The vast majority of respondents in Slovenia and Spain inherited their forest estate. In Finland and Sweden, the proportion is similar between those who inherited their forest estate and those who became forest owners after purchase.

Table 1
Socio-demographic background information of the survey respondents.

	Country	Finland	Slovenia	Spain	Sweden
		$n = 972$	$n = 509$	$n = 74$	$n = 544$
Gender [%]	Male	67.1	68.6	80	77.7
	Female	32.9	31.4	20	22.3
Age	Mean	60.2	61.4	60.9	62.0
	< 53 years [%]	25	26.5	26.7	23.7
	54–67 years [%]	37	37.9	42.3	41.5
	> 68 years [%]	38	35.6	31	34.8
Class	Lower	18.3	26.4	32.8	28.3
	Middle	78.8	67	62.9	66.3
	Upper	2.9	6.6	4.3	5.4
Occupation	Self-employed in forestry or agriculture	7	12.6	15.3	14.7
	Self-employed in other industry or sector	6.9	4.7	6.9	13.5
	Employed	29	23.7	29.2	32.5
	Not employed (incl. student)	7.7	2.6	1.4	0.9
	Retired	49.4	56.4	47.2	38.4
Education	Elementary school	11.9	15.1	26.4	18.3
	High school	31.2	59.7	19.4	46.1
	Bachelor's education	29.8	22.6	16.7	20.2
	Master's education	27.1	1.8	30.6	13.5
	Doctoral education	0	0.8	6.9	1.9
Became owner after	Purchase	48.2	8.6	17.6	44.1
	Inheritance	50.2	89.8	75.7	45
	Other	1.6	1.6	6.8	10.9
Average size of forest property, ha		20	7	15	46.5
Distance to forest holding[1]	Very close	20	15	26	27
	Close	39	51	46	49
	Far	36	27	22	19
	Very far	6	6	7	6

[1] Qualitative attribute of the perception of distance, which represents forest owners' subjective valorization of the distance to their forest property, and which can reflect a combination of geographical and emotional distance.

2.4. Statistics methods

The analysis was performed with R software. R is a freely available language and environment for statistical computing and graphics (R Core Team, 2021). The results were scrutinised by factor analysis, which was performed using the *factanal* function for performing maximum-likelihood factor analysis on a covariance matrix. Variables were scaled (normalised). Factor rotations were used to clarify the results into a more interpretable structure and to minimise the complexity of each component. In the case of our study, ProMax rotation for oblique factors was used. Oblique rotations are more common for social sciences since they allow factors to be correlated (Osborne, 2015).

Factor analysis requires fully observed datasets without any missing values. The R function *factanal* deals with missing observations with listwise deletion, which means it performs an analysis only with complete cases. The sample size is reduced, leading to information loss. For these reasons, the R package missForest was used as a non-parametric method to impute missing values (Stekhoven and Buhlmann, 2012). It builds a random forest model for each variable. Then it uses the model to predict missing values in the variable with the help of observed values. Data imputations were performed separately for each country and later merged into a common dataset.

The respective factor scores were used to cluster the owners with a k-means algorithm (without iteration) into four groups using the stats package. The k-means method aims to partition the points into groups such that the sum of squares from the points to the assigned cluster centres is minimised. At the minimum, all cluster centres are at the mean of their Voronoi sets, which means the set of data points nearest to the cluster centre (R Core Team, 2021). The four-cluster solution was accepted as the most interpretable model with a favourable distribution of respondents. The obtained clusters were compared by comparing the means of the owner variables. A pairwise chi-squared difference test for proportions or the Kruskal Wallis test followed by Dunn's test were used to identify which groups were different from mean values at a 5% significance level.

Binary Logistic Regression predicts the probability of forest owner membership for a dependent variable based on multiple independent variables. The logit model was considered suitable since the outcome measure is polychotomous by nature. The random component for the outcomes has a binomial distribution. The link function is the logit function. In logistic regression, a logistic transformation of the odds (referred to as logit) serves as the dependent variable (Cheng et al., 2021):

$$logit\ (p) = \alpha + x_i\beta_k$$

Where χ_i is a vector containing the values of m covariates for respondent i, and β_k is a vector of m + 1 parameters (β_{0k}, β_{1k}, β_{2k} …, β_{mk}) for each k = 1, 2, 3, …, j.

The probability of a respondent making a choice is:

$$P = \frac{exp(\alpha + x_i\beta_k)}{1 + exp(\alpha + x_i\beta_k)}$$

2.5. Variables used

In this study, econometric literature on forest owners' behaviour and selected variables that previously were found explaining silvicultural activity or timber sales was used. In addition, authors used some variables that the research group considered worth testing in the forest owner willingness to sell thinned biomass context. The variables (dependent and independent) with expected sign are explained in Table 2.

3. Results

In this section we present the results of the survey. The first part

Table 2
Definition of variables used in logistic regression model.

Variable	Expected sign	Definition
Dependent variable:		
Y		Dummy, forest owner willingness to sell thinned biomass: 1 = supplies small-diameter trees to the market (market activeness); 0 = does not supply small-diameter trees to the market (market passiveness).
Independent variables:		
Gender	+/−	Dummy, respondent gender: 1 = female, 0 = male. The variable is induced to check if gender effect willingness to sell thinned biomass.
Age	−	Continuous, respondent age (years). Expectation that age will negatively affect the willingness to participate in the SDS market is based on previous studies.
Education	+	Continuous, the formal education level of the respondent: 1 = elementary school, 2 = high school, 3 = bachelor's education, 4 = master's education, 5 = doctoral education. It is expected that the willingness to participate in the SDS market is affected by education level.
Employment	+/−	Dummy, current work activity status of the respondents: 1 = active (employed, sole entrepreneurs, farmers), 0 = inactive (retired, unemployed, student). Work activity status may be a characteristic that potentially affects the willingness to sell thinned biomass.
Social class	+/−	Dummy, the score of a respondent's self-assignment to a social class: 1 = lower class, 2 = middle class (reference class), 3 = upper class. Social class may influence forest owner willingness to sell thinned biomass. Social class may indicate a different level of attachment to the forest estate among forest owners.
Inherited forest	−	Dummy, respondent has inherited the forest estate: 1 = inherited, 0 = otherwise. Respondents that purchased forest are expected to be more willing to sell SDS biomass compared to those who inherited forest.
Years of ownership	+	Continuous, years being a forest owner (years). Experienced forest owners are expected to have a better connection to the SDS market.
Forest estate size	−	Continuous, size of forest property (including parts that the respondent co-owns in hectares).
Closeness	+	Dummy, respondent's self-assignment of the distance between his/her residence and forest holding: 1 = very close or close, 0 = otherwise. Qualitative attribute of the perception of distance, which represents forest owners' subjective valorization of the distance to their forest property, and which can reflect a combination of geographical and emotional distance. Respondents' personal perception of the proximity of their forest property can be considered as a characteristic influencing the willingness to sell thinned biomass. It is expected that respondents who live closer to their forest estates are more likely to be active in the SDS market.
Harvesting intensity	+	Continuous, 5-year amount of timber harvested in cubic meters of harvested roundwood (m^3)
FOA membership	+	Dummy, member of forest owners' association (FOA): 1 = members, 0 = non-members. FOA play role in supporting members in forest management and improving market conditions.
Share of SDS	+	Continuous, approximate share of respondent's forest holding covered by SDS (in percent). Respondents were asked to estimate the percentage of their forest estate that is covered by young, dense forest stands.
Available machinery	+	Continuous, the number of different available types of machinery in the respondent's household (chainsaw, clearing saw, small harvester, agricultural tractor with felling head, large size harvester, forwarder, all-terrain vehicle (ATV) or snowmobile with trailer, agricultural tractor with forestry winch or trailer, other). Available machinery may affect the decision to utilise SDS biomass.
Extract biomass after thinning in SDS	+	Dummy, respondent extracts biomass after thinning operations in SDS: 1 = yes, 0 = no, we leave woody biomass in forests.
Min. assortment	+	Continuous, minimum mid-section assortment diameter that the respondent extracts and uses or sells (in cm). Respondents were asked to report on current forest management activities; therefore, assortment refers to past harvests. It is expected that respondents who utilise thinner biomass are more likely to be willing to sell thinned biomass.
Home consumption	+	Dummy, respondent uses this type of biomass for his/her own household needs: 1 = yes, 0 = no. Respondents who use biomass for household heating are expected to be more likely to be interested in participating in the SDS market.
Country		Dummy, categorical variable with four categories (1 = Finland, 2 = Slovenia, 3 = Spain, 4 = Sweden, where category 2 is used as a reference).

presents the forest management preferences of the survey respondents. This is followed by the results of the factor analysis, which was performed to break down the number of independent variables. Four newly assigned factor variables were subjected to K-means cluster analysis using the factor scores for each respondent. The last part of the results section is the logit model for all identified groups of forest owners.

3.1. Forest management preferences

The respondents were asked to appraise forest management preferences based on their perception and importance of forest management (Fig. 1). The most important preference in all countries was "Nature and biodiversity conservation", with an average score of 3.58, followed by other "Amenities" (e.g. forestry tradition, emotional ties, aesthetics, public amenities), with an average score of 3.49. "Non-wood forest production" was recognized as the least important forest management preference, with an average score of 2.88. Roundwood production was assessed as highly important in Sweden and Finland. "Forest fuel production and home consumption of firewood" is the most important for forest owners in Slovenia, while "Non-wood forest production" and "Outdoor recreation" are of the highest importance for forest owners in Finland.

3.2. Factors

Factor analysis was performed to break down the number of independent variables to investigate forest owner management preferences. Respondents were asked to evaluate the influence of different preferences on their forest owner management decisions. The respondents' typology on SDS management preferences and long-term perceptions of forest management is based on how they influence management behaviour and the willingness to supply the market with SDS. The survey included a multi-part question where respondents were invited to rank a list of forest-related terms and statements on a five-point scale. Scale (lowest and highest) levels are presented in Table 3. Nineteen survey questions were used in the factor analysis.

The Kaiser Meyer Olkin (KMO) measure of sampling adequacy suggests that the data seem appropriate for factor analysis (KMO = 0.89). Bartlett's test of sphericity indicates that there is sufficient significant correlation in the data for factor analysis (χ^2 (171) = 23,448.36, $p <$ 0.001). For a non-graphical solution to the scree test, the *nFactors* package was used (Raiche and Magis, 2022), which suggested four factors. The eigenvalues exceeded 1 for each proposed factor component, explaining 24%, 13%, 11.2%, and 9.6% of the variances, respectively, meaning the components explain 57.9% of the combined

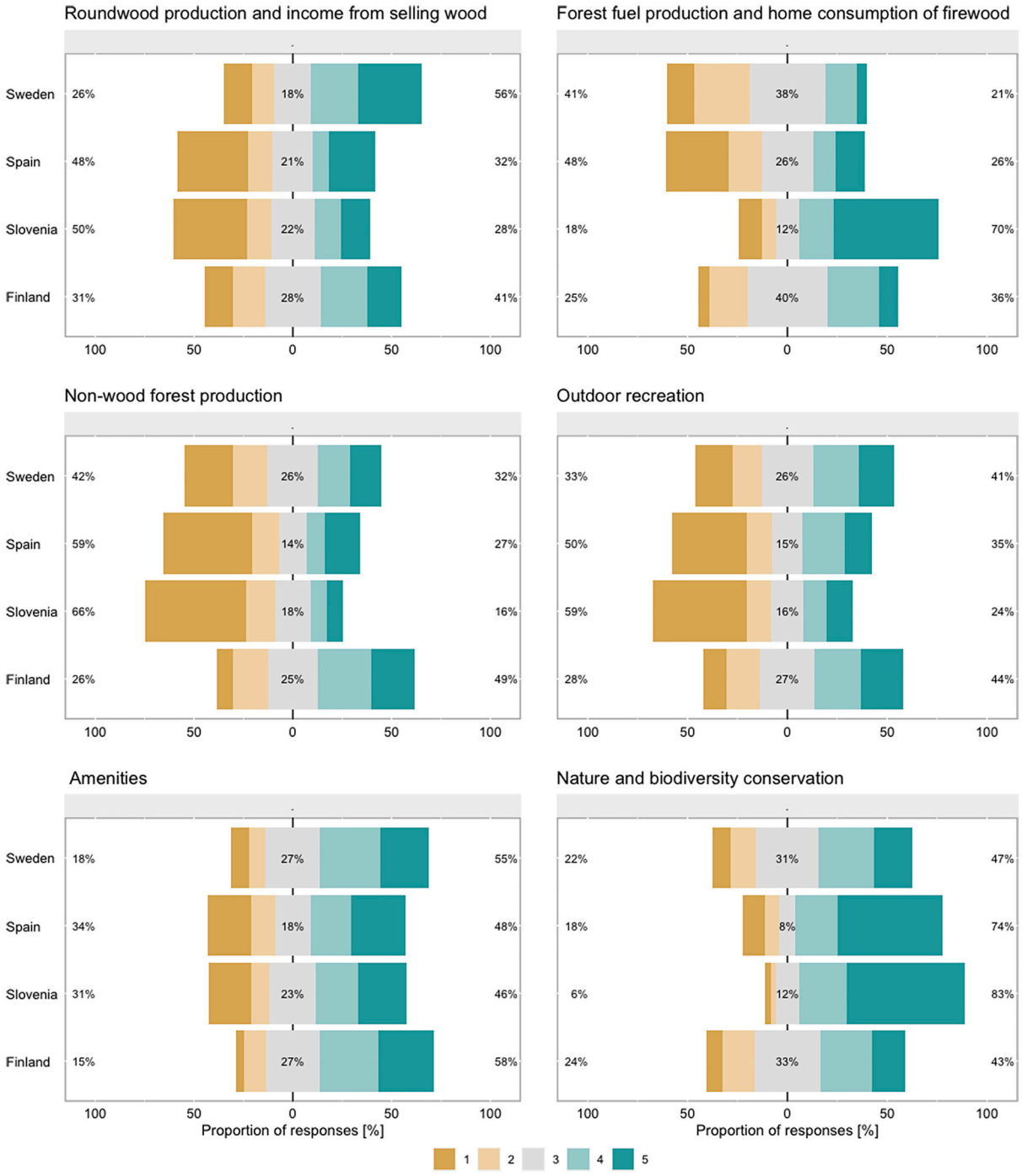

Fig. 1. Importance of different forest-holding goods and services based on the proportion of responses.

variances. Oblique rotation was performed, and the surfaced components are shown in Table 3. The last step of factor analysis was interpretation with the construction of factors labels. Factor labels were determined subjectively based on the examination of relations between grouped factor components. The factor correlations are presented in Appendix 2.

3.3. Clusters

To obtain meaningful groups of forest owners, a K-means clustering algorithm for cluster analysis was performed based on forest owner objectives, motivation, interest, and self-evaluation on forest management. Four newly assigned factor group variables were subjected to cluster analysis using the factor scores for each respondent. A discussion among the present authors, which examined all solutions from two to six clusters, identified four clusters as the best solution. Labelling was done according to how forest owners ranked their objectives, motivation, interest, and self-evaluation on forest management. The Pseudo-F of clustering results obtained by the K-means method is 611.1381. Each cluster's interpretation and labels were compiled with final cluster

Table 3
Rotated factor loadings of aspects influencing forest owner preferences on the management of SDS.

Service influence	Forestry knowledge-ability	Socio-cultural motivation	Economic motivation	Content elements
0.962				Favourable service offers [1 - Not effective for willingness to manage SDS; 5 - Highly effective for willingness to manage SDS]
0.940				Favourable service accessibility [1 - Not effective for willingness to manage SDS; 5 - Highly effective for willingness to manage SDS]
0.899				Relevant information about service providers [1 - Not effective for willingness to manage SDS; 5 - Highly effective for willingness to manage SDS]
0.832				Favourable service prices [1 - Not effective for willingness to manage SDS; 5 - Highly effective for willingness to manage SDS]
0.756				Relevant information on available techniques for harvesting in SDS [1 - Not effective for willingness to manage SDS; 5 - Highly effective for willingness to manage SDS]
0.549				Assurance from a service provider that the quality, production capacity, and value of the forest will increase [1 - Not effective for willingness to manage SDS; 5 - Highly effective for willingness to manage SDS]
0.537				Availability of equipment for harvesting in SDS [1 - Not effective for willingness to manage SDS; 5 - Highly effective for willingness to manage SDS]
	0.914			Forest management mastery [1 - I have not mastered forest management; 5 - I have mastered forest management.]
	0.820			Knowledge of forestry [1 - I have no knowledge of forestry; 5 - I have a broad knowledge of forestry.]
	0.741			Training in harvesting operations [1 - I have no training in harvesting operations.; 5 - I have extensive training in harvesting operations.]
	0.586			State of harvesting equipment [1 - I have no equipment for harvesting operations; 5 - I am well equipped for harvesting operations.]
		0.866		Outdoor recreation (adventure racing, backpacking, camping, caving, fishing, hiking, horseback riding, mountaineering, rock climbing, running, skiing). [1 - Not important at all; 5 - Very important]
		0.704		Non-wood forest production (production of game, berries, mushrooms, forest grazing) [1 - Not important at all; 5 - Very important]
		0.643		Amenities (forestry tradition, emotional ties, aesthetics, public amenities; i.e. public recreation/ enjoyment, education) [1 - Not important at all; 5 - Very important]
		0.375		Nature and biodiversity conservation [1 - Not important at all; 5 - Very important]
			0.884	Higher price for small-diameter wood [1 - Not effective for willingness to manage SDS; 5 - Highly effective for willingness to manage SDS]
			0.855	Larger market for small-diameter wood [1 - Not effective for willingness to manage SDS; 5 - Highly effective for willingness to manage SDS]
			0.537	Subsidies for harvesting in SDS [1 - Not effective for willingness to manage SDS; 5 - Highly effective for willingness to manage SDS]
			0.407	Roundwood production and income from selling wood [1 - Not important at all; 5 - Very important]

Table 4
Grouping based on factor analysis scores; K-means clustering ($n = 2099$).

		Service Influence		Forest knowledge		Economic motivation		Socio-cultural motivation	
Group	n	Cluster means	(SD)	Cluster means	(SD)	Cluster means	(SD)	Cluster means	(SD)
1 Weakly-engaged traders	549	0.0021	(0.8366)	−1.0910	(0.7729)	0.2402	(0.7662)	−0.2766	(0.9887)
2 Well-being seekers	633	−0.0124	(0.8619)	0.2986	(0.8526)	−0.3355	(0.7762)	0.9155	(0.7515)
3 Self-active profit-seekers	352	−1.2742	(1.2160)	0.0692	(1.2511)	1.3680	(1.1685)	0.1031	(1.2796)
4 Well-informed service users	565	0.8057	(1.1239)	0.6824	(1.0523)	−0.7098	(1.1954)	−0.8210	(1.0380)
F-value (df = 2097)		77.72		415.8		1.955		896.4	
p-value		<2e-16 ***		<2e-16 ***		0.162		<2e-16 ***	

Table 5
Characteristics of clustered forest owners. Numbers in parentheses show which groups significantly differ between groups in a pairwise chi-squared difference test for proportions or the Kruskal Wallis test followed by Dunn's test to identify which groups are different for mean values at a 5% level of significance. The numbers in brackets show standard deviations.

	1 Weakly-engaged traders	2 Well-being seekers	3 Self-active profit-seekers	4 Well-informed service users
Gender (share of male)	53.6 (2,3)	82.3 (1)	80.6 (1)	69.3
Age	62.0 [13.5] (3)	62.5 [13.0] (3,4)	59.1[12.5] (1,2)	59.7[14.2] (2)
Education	2.6 [1.01] (2,3)	2.36 [0.947] (1,4)	2.37 [0.942] (1,4)	2.55 [0.975] (2,3)
Employment	0.415 (3,4)	0.428 (3)	0.567 (1,2)	0.495 (1)
Inherited forest	0.676 (3,4)	0.629 (3,4)	0.503 (1,2)	0.543 (1,2)
Years of ownership	20.6 [14.3] (2,3,4)	24.8 [14.8] (1)	23.0 [13.5] (1)	22.9 [14.2] (1)
Forest estate size	42.2 [107] (3)	63.7 [233] (3)	60.1 [88.7] (1,2,4)	64.2 [192] (3)
Closeness	0.543 (2,3,4)	0.662 (1)	0.719 (1)	0.699 (1)
Harvesting intensity	378 [923] (2,3,4)	970 [7061] (1,3)	799 [1526] (1,4)	679 [2427] (1,3)
FOA membership	0.492 (2)	0.413 (1,3)	0.506 (2)	0.477
Share of SDS	0.238 [0.246]	0.236 [0.204]	0.219 [0.178]	0.211 [0.190]
Available machinery	2.20 [1.08] (2,3,4)	2.55 [1.14] (1,3)	2.77 [1.10] (1,2)	2.60 [1.11] (1)
Extract biomass after thinning in SDS	0.692	0.662 (4)	0.675	0.753 (2)
Min. assortment	9.41 [9.14] (3,4)	8.24 [7.77] (4)	7.14 [4.27] (1)	7.61 [8.22] (1,2)
Home consumption	0.676 (2,3,4)	0.772 (1,4)	0.825 (1)	0.852 (1,2)

Table 6
Proportions of cross-tabulated clustering of forest owner intention towards future forest management (as a general rule, the independent variable is the row variable; the dependent variable is the column variable). The forest owner group showing the highest proportion in each column is indicated in bold.

	Forest management plans in the future (5 years)				Total
	More intensively than in the last five years	The same as in the last five years	Less intensively than in the last five years	No management at all	
1 Weakly-engaged traders	104	312	44	**57**	517
	20.1%	60.3%	8.5%	**11%**	100%
2 Well-being seekers	112	355	**66**	26	559
	20%	63.5%	**11.8%**	4.7%	100%
3 Self-active profit-seekers	**84**	**224**	35	8	351
	23.9%	**63.8%**	10%	2.3%	100%
4 Well-informed service users	135	393	58	37	623
	21.7%	63.1%	9.3%	5.9%	100%
Total	435	1284	203	128	2050
	21.2%	62.6%	9.9%	6.2%	100%

$\chi^2 = 35.950 \cdot df = 9 \cdot Cramer's\ V = 0.076 \cdot p = 0.000$

centre information (Table 4).

The cluster analysis model placed 549 owners (approx. 26%) in the group of *Weakly-engaged traders*, where the highest cluster mean can be found in the economic motivation and the lowest in forest knowledge. Most respondents were placed into the group with the highest cluster means in socio-cultural motivation and were named *Well-being seekers*, where respondents that appreciate non-harvesting oriented ecosystem services can be found. The least respondents were placed into the *Self-active profit-seekers*, corresponding to forest owners characterised by high economic motivation and a negative impact of service influence, meaning that they are probably self-engaged in biomass harvesting. In contrast, 565 (approx. 27%) private owners formed the *Well-informed service users* cluster, corresponding to those with good forest management knowhow but probably no resources to be self-active in forest operations and relying on forestry service providers. A more detailed description of the four clustering solutions is presented in Table 5.

Table 6 presents the cross-tabulated clustering of forest owner intention towards future forest management. This relationship between clustered groups of forest owners and forest management plans in the future is statistically significant ($\chi^2 = 35.950$; $p = 0.000$). A Cramer's V of 0.076 indicates a moderate association between clustered groups of forest owners and forest management plans in the future.

Cross tabulations indicated that the proportion of forest owners who do not plan to manage the forest in the next five years was most significant, with 11%, in the group of *Weakly-engaged traders*. The proportion of forest owners who plan to manage forests less intensively than in the last five years was most significant, with 11.8%, in the group of *Well-being seekers*. Furthermore, the proportion of forest owners who plan to manage forests more intensively or with the same intensity as in the last five years was 24% (64% in the group of *Self-active profit-seekers)*.

The results in Table 7 show the logistic coefficient for each independent variable per alternative category of the dependent variable in the logit model. The category of inactive respondents on the market is kept as a base category in the model. The likelihood ratio suggests the model has the power to reliably explain behaviours that lead to forest owner willingness to participate in the market.

Table 7 indicates that employment was positively and significantly correlated with the activeness of forest owners in the market ($p < 0.05$) relative to the base category in the group of *Weakly-engaged traders* and the group of *Well-informed service users*. Employed forest owners in the group of *Weakly-engaged traders* are 20% more likely to supply small-diameter wood to the market (11% in the group of *Well-informed service users*), which is higher than that among forest owners who are not employed or are retired.

The share of respondents' forest holdings covered by SDS was negatively and significantly correlated with forest owner market activeness ($p < 0.01$) relative to the base category in the group of *Well-being seekers*. A 1 % increase in the share of SDS may, in turn, decrease the probability of the supply of small-diameter trees to the market by 28% relative to the base category (market passiveness). Forest owners' association membership is negatively and significantly correlated with a forest owner's decision to supply biomass from SDS to the market ($p < 0.01$) in the group of *Well-being seekers*, the group of *Self-active profit-seekers*, and the group of *Well-informed service users*. Forest owners who are members of forest owners' associations are 13% less likely to supply small-diameter wood to the market in the group of *Well-being seekers* (20% in the group of *Self-active profit-seekers* and 11% in the group of *Well-informed service users*), which is lower than that for forest owners who are not members of a forest owners' association. Home consumption positively and significantly correlates with forest owner market activeness ($p < 0.01$) relative to the base category in all investigated groups. Forest owners who use biomass for their own consumption are 27% more likely to supply small-diameter wood to the market (up to 38% in the group of *Self-active profit-seekers*), which is higher than forest owners who do not use biomass for their own consumption.

4. Discussion

The study investigated forest owner characteristics that represent barriers to or opportunities for increasing the future supply of biomass from small-diameter forest stands (SDS) and the main factors that could potentially affect forest owner level of interest in and motivation for biomass mobilisation. The results of this study show, in concordance with earlier research, that forest owners are heterogeneous, and there is no unique model for predicting their willingness to mobilise small-diameter wood. However, a characteristic of small-diameter wood mobilisation is the connection between the forest owner's home consumption and practical experience and the use of small-diameter wood. Compared to sawlogs and pulpwood, the handling of small-diameter trees requires less skills and technology, and those owners who, regardless of their ownership motivations or management objectives, are self-active small-diameter tree managers may require special attention from service providers due to their practical knowledge and sensitivity to prices. More generally, this study has shown that forest owners can be grouped into different segments with respect to their perception of small-diameter wood. The constructed segments differ from each other with respect to how forestry knowledge, economic and socio-cultural motivations, and sensitivity to service offerings influence forest owner perceptions. The segments range from forest owners who are lacking in forestry-related skills and are likely to abandon forest management in the future (e.g. *Weakly-engaged traders*) to those who are professionally involved and whose willingness for forest management is affected to a greater extent by the situation in the wood market (e.g. *Self-active profit-seekers*). This shows that it is necessary to adapt communication approaches for each group, which corresponds well with earlier

forest owner typology studies that have suggested varying communication or service strategies for different forest owner groups (Wilkes-Allemann et al., 2021). The study has in particular identified the diversity of factors affecting small-diameter stand management motivation. We may find opportunities for successful communication and advisory services within the factors that positively affect the supply of SDS biomass to markets.

The present results have shown that the probability of supplying biomass from SDS to the market increases with (i) age, employment, and home consumption in the group of *Weakly-engaged traders*; (ii) education, lower social class, and home consumption in the group of *Well-being seekers*; (iii) home consumption in the group of *Self-active profit-seekers*; and (iv) age, employment, and home consumption in the group of *Well-informed service users*. In contrast to the above, the barriers that need to be considered in the future to enhance the market supply of SDS wood may be found in the factors that decrease the probability of market participation among the identified forest owner segments. To this end, the study has shown that the probability of supplying biomass from SDS to the market decreases with (i) the forest estate size in the group of *Weakly-engaged traders*; (ii) the share of SDS, and forest owners' association membership in the group of *Well-being seekers*; (iii) forest estate size and forest owners' association membership in the group of *Self-active profit-seekers*; and (iv) years of ownership, forest owners' association membership, available machinery, and the minimum diameter of harvested wood in the group of *Well-informed service users*. Several of the above owner or estate characteristics are associated with the small-diameter wood supply in a manner that is logical and in accordance with earlier wood mobilisation studies, but it is worth noting that between the identified owner segments, the associations have opposite directions. This observation suggests that the identified latent factors behind the owner segments are rather powerful in characterising forest owner perception and expected behaviour. With the present results, rather than stating that the owner's age or holding size increases or decreases the probability of small-diameter wood supply, we may now say that the small-diameter wood supply depends to a greater extent on the owner's knowledge, various motivations, and sensitivity to service offerings. The result that the smaller size of the forest estate increases the probability of supplying small-diameter wood is in line with previous studies (Kronholm et al., 2020; Mynttinen et al., 2014; Rämö et al., 2009) and is not surprising since forest size is a critical factor for the general forest management strategies of forest owners (Eggers et al., 2014). However, in some groups, forest owners with larger properties were less likely to supply biomass from SDS, which contradicts the results of Mynttinen et al. (2014), who identified forest owners with large properties as the most active suppliers. The mixed results may be related to contextual and methodological differences between the studies, but there may also be other factors involved. Nevertheless, from an industry and policy perspective, it is important to take into account that a fragmented holding structure makes it important to develop services that fit several types of forest owners if the full potential of SDS management is to be achieved. Potential strategies for this are all-inclusive services in which matters other than SDS are also served as well as cross-boundary collaboration services that could make the services more economical and persuade some of the less active owners to join the effort. Developing policy instruments and services that target broad groups of forest owners may also be better than focusing different measures towards specific types of owners (Danley, 2019).

Members of forest owners' associations are typically more focused on forestry income than non-members (Berlin et al., 2006), and the share of self-employment in forestry work has historically been higher in this group (Lindroos et al., 2005). Given that Kronholm et al. (2020) have shown that self-employed forest owners tend to be less favourable than others towards early thinnings in SDS, this could potentially explain, to some extent, the negative correlation between forest owners' association membership and the willingness to supply biomass from SDS. This interpretation is also supported by Mynttinen et al. (2014), who showed that forestry entrepreneurs were one of the least active groups and least willing to supply energy wood. Forest owners' associations have traditionally played an important role in educating and supporting members in forest management, improving market conditions for the timber trade, and representing forest owners' political interests at the national level. Therefore, they could also be influential in their members' decision to engage in SDS management and biomass harvesting. However, in Sweden and other Nordic countries, the focus of forest owners' associations has primarily been on the production of roundwood for sawmills and paper mills, and the services offered and education have been designed to meet this objective (Aurenhammer et al., 2017; Kronholm, 2016). In Central and Eastern Europe, many forest owners' associations primarily focus on representing forest owner interests, and less on management support (Aurenhammer et al., 2017; Sarvašová et al., 2014). The objectives and nature of forest owners' associations will of course also affect the type of forest owners that are members of these organizations. Thus, since SDS management and the supply of biomass has not been an important part of the business of forest owners' associations, it may be that forest owners with such an interest have had fewer incentives to become a member. The SDS wood market has a low market price compared to sawlogs and pulpwood, and therefore in countries with well-developed wood markets such as Sweden and Finland, SDS wood may go as additional assortments in a larger sale. In such situations, the prices of the other assortments indirectly affect the supply of SDS wood. In other types of markets, the presence of particular SDS demand (such as local mid-sized biomass power plants) may influence the supply. Home consumption may increase activeness in the SDS market because of the general activeness of the owner and higher skills needed to enter the market. Market participation is less likely if there is no associated home consumption.

Since forest owner forest management strategies are strongly influenced by factors such as the size of the forest property, the importance of income from forestry, and the knowledge and interest of the forest owner in forestry (Eggers et al., 2014), it is natural that some groups are more interested than others in specific management activities.

4.1. Methodological reflections

The studied sample represents a heterogeneous group of forest owners. One should note that due to contextual differences in cadastral and forest owner information and polling agency service availability, data collection and sample size differed from country to country, and the studied sample may not describe all forest owners in the involved countries with similar representativeness. For example, the minimum size of forest holdings included in the sample differed between the countries. Comparison between countries is still feasible, but due to the low number of respondents, the Spanish within-country results contain higher uncertainties than those of the other countries. Data weighting before the regression model was performed in order to overcome the different sample sizes. Country differences can be observed in Table 7, which includes an independent variable to help the reader understand the effect of the country.

The data from Finland are geographically rather well representative; however, there is a slight over-representation of male forest owners, and the average size of the forest estate among the respondents is lower than that within the population. The mean age of the Swedish respondents was in line with that of forest owners in general, and the distribution between age categories corresponded fairly well. Males were more prone to answer than females and were thus over-represented among the respondents, which is a familiar pattern from other surveys that have targeted forest owners. Furthermore, the response rate of 33% was relatively low compared to previous studies with similar data collection methods (Kronholm et al., 2020). The mean age of Slovenian respondents was in the line with national reports on forest owners, and the geographical distribution is well represented. Similar to the Finnish data, there is a slight over-representation of male forest owners, and the

Table 7
Parameter estimates of explanatory variables from the logistic regression model on the market activeness of forest owners. Statistically significant variables are bolded and marked with stars (where: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

	1 Weakly-engaged traders			2 Well-being seekers			3 Self-active profit-seekers			4 Well-informed service users		
	Coefficients	Std. Errors	Marginal effects	Coefficients	Std. Errors	Marginal effects	Coefficients	Std. Errors	Marginal effects	Coefficients	Std. Errors	Marginal effects
Gender	0.315	0.600	0.0396	0.149	0.452	0.0233	−0.588	0.577	−0.0924	−0.048	0.411	−0.0065
Age	**0.060***	0.032	0.0075	0.015	0.017	0.0024	−0.025	0.025	−0.0039	**0.081*****	0.022	0.0110
Education	−0.406	0.361	−0.0510	**0.402***	0.216	0.0629	−0.228	0.248	−0.0358	−0.023	0.191	−0.0032
Employment	**1.285***	0.776	0.1614	−0.513	0.405	−0.0802	−0.158	0.551	−0.0248	**0.858****	0.437	0.1168
Social class (Lower)	0.615	0.680	0.0740	**0.801***	0.410	0.1168	−0.327	0.463	−0.0518	0.761	0.467	0.0949
Social class (Upper)	0.493	1.240	0.0604	−0.340	0.715	−0.0586	−0.225	0.811	−0.0352	0.118	0.906	0.0166
Inherited forest	0.396	1.519	0.0498	0.414	0.816	0.0648	−0.155	0.719	−0.0244	0.114	1.388	0.0155
Years of ownership	−0.007	−0.022	−0.0009	0.003	0.012	0.0005	0.013	0.018	0.0021	**−0.043*****	0.016	−0.0059
Forest estate size	**−0.028*****	−0.010	−0.0036	0.003	0.012	0.0004	**−0.026*****	0.007	−0.0041	−0.003	0.003	−0.0005
Harvesting intensity	−0.0000	0.0004	0.0000	−0.0003	0.0002	0.0000	0.0003	0.0002	0.0000	0.00004	0.0001	0.0000
Share of SDS	−0.577	1.446	−0.0725	**−1.793****	0.769	−0.2805	0.148	1.205	0.0233	0.613	0.853	0.0834
FOA membership	0.076	0.630	0.0095	**−0.882****	0.343	−0.1379	**−1.319*****	0.496	−0.2075	**−0.841****	0.369	−0.1146
Closeness	0.815	0.549	0.1024	−0.079	0.358	−0.0124	0.108	0.459	0.0171	0.513	0.369	0.0698
Available machinery	−0.379	0.265	−0.0476	−0.078	0.358	−0.0121	0.011	0.210	0.0018	**−0.409*****	0.158	−0.0557
Extract biomass from SDS	0.046	0.687	0.0057	−0.027	0.382	−0.0043	0.331	0.475	0.0520	0.628	0.497	0.0855
Min. assortment	0.069	0.043	0.0086	−0.013	0.017	−0.0021	−0.041	0.044	−0.0065	**−0.052****	0.021	−0.0071
Home consumption	**3.027*****	0.706	0.3803	**2.046*****	0.405	0.3200	**2.465*****	0.615	0.3877	**2.038*****	0.485	0.2774
Finland	**2.173*****	−0.85	0.2745	**−0.988*****	−0.449	−0.1638	**1.928*****	0.627	0.3024	−0.167	0.525	−0.0223
Spain	17.234	1455.398	0.4822	x	x	x	x	x	x	16.872	708.803	0.2382
Sweden	**2.687*****	0.958	0.3187	**−0.766***	−0.460	−0.1228	**2.583*****	0.626	0.3799	−0.405	0.516	−0.0563
Constant	**−5.452****	2.271		−0.627	1.376		0.324	−2055		**−3.228***	1.663	
Number of observations		143			291			186			305	
Akaike Inf. Crit.		154.051			318.854			218.186			302.934	
Log-likelihood		−56.025			−139.427			−89.093			−130.467	
Pseudo R2 (McFadden)		0.3314			0.2068			0.2823			0.25222	

X – excluded due to insufficient sample size or due to the exclusion of cases with missing data.

average size of the forest estate among the respondents is higher than that within the population. With these discrepancies, the data may be viewed to be of sufficient quality to meet the objectives of the study and present perceptive and attitudinal patterns among forest owners to guide communication and advisory services.

5. Conclusion

This study contributes to the literature by covering selected countries in Northern Europe, East-Central Europe, and Southwestern Europe to better understand the factors motivating forest owners to mobilise small-diameter biomass. Characteristic of small-diameter biomass supply is its association with home consumption and related self-active forestry work, which is absent with pulpwood and much less frequent with sawn wood. It is recommended to take into account personal small-diameter wood experiences when serving, advising, and communicating with forest owners. The study has discerned different forest owner segments with diverse motivations and commitment levels, indicating that the further implementation of SDS management should be approached in several ways. Each segment's needs and expectations are different, which indicates the limited possibilities of implementing a "one-size-fits-all" policy. We learned from this study that although barriers and obstacles do exist, they can be overcome (i) by combining SDS management with other services that may drive service needs to a greater extent than SDS management alone, which produces economic pay-offs in the relatively distant future; (ii) by cross-boundary collaboration services, which tackle the profitability challenge that is particularly relevant to SDS management; and (iii) by supporting self-active decision-making and management in forest ownership in general, which suits the needs of many decisive owners who use SDS wood for home consumption. Supporting self-activeness may also induce forest owners to take responsibility for SDS management on their land.

SDS management may not be attractive as a stand-alone activity if it involves a single forest owner with a single small-diameter stand, but it could be attractive and more acceptable if it is combined with other activities that together are attractive to owners (e.g. as a "forest care service").

Cross-boundary collaboration services that perform such forest management activities in an economically- and cost-efficient manner is another approach. Several owners can be approached to jointly perform activity at the same time, especially in a fragmented landscape. Individual forest owners would not be responsible as a sole client and would therefore benefit from the lower responsibility and lower commitment level associated with being part of a larger endeavour. This could also be interesting from the point of view of the service providers, as some inactive owners who are not interested in SDS management would be more easily persuaded and motived to join the group if there is a larger effort.

Finally, policy makers should also keep in mind the forest owner segment that involves a group of individuals who are not particularly keen to interact, cooperate, or engage. They are likely to perform services by themselves and therefore be recognized as self-active. To keep them active it is necessary to provide them with access to supportive services such as (i) quality information delivery, (ii) access to the market so that they can focus on forest management, and (ii) enhanced decision-making power to represent their needs at the policy level. This is something that the self-active segment of forest owners values most, and this is also an important and relevant result for the further development of forest owners' association policy. Forest owners' associations are advised to consider their role in supporting the awareness different owner types and their agency in SDS management.

Further qualitative research aimed at more deeply understanding the drivers and barriers than what was possible with the present quantitative survey would be of high interest and would further support the findings of this study. Another possibility is to further investigate operative business models including SDS management, including the research question on the possible ways to deliver SDS management services in a manner that supports various circular bioeconomy, biodiversity, and climate policies.

CRediT authorship contribution statement

Matevž Triplat: Conceptualization, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Satu Helenius:** Data curation, Investigation, Writing – original draft, Writing – review & editing. **Ruben Laina:** Data curation, Writing – original draft, Writing – review & editing. **Nike Krajnc:** Funding acquisition, Project administration, Resources, Supervision, Writing – review & editing. **Thomas Kronholm:** Data curation, Investigation, Writing – original draft, Writing – review & editing. **Zdenka Ženko:** Data curation, Funding acquisition, Project administration, Resources, Writing – original draft, Writing – review & editing. **Teppo Hujala:** Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

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

Data availability

These data are not publicly available due to anonymity requirements. Interested readers are directed to contact the author to request an anonymised version of the data.

Acknowledgement

This study was primarily supported by the European Union's Horizon 2020 Research and Innovation Programme, which has funded the Smallwood project (http://www.smallwood.eu/) through the ERA-NET Cofund action "ForestValue – Innovating the forest-based bioeconomy", under grant agreement number 773324. The national financers of the Smallwood project are also acknowledged: the Finnish Ministry of Agriculture and Forestry (MMM) with decision number 262873; the Academy of Finland (AKA) with decision number 326614; the Slovenian Ministry of Education, Science and Sport (MIZS); the Swedish Energy Agency; Sweden's Innovation Agency (Vinnova); and the Swedish Research Council for the Environment, Agricultural Sciences and Spatial Planning (Formas). The authors wish to thank the respondents in Finland, Slovenia, Spain, and Sweden for their time and willingness to share their views about small-diameter stand management. The authors wish to thank the reviewers for their valuable contribution to the completion of this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.forpol.2022.102901.

References

Ahnlund Ulvcrona, K., Bergström, D., Bergsten, U., 2017. Stand structure after thinning in 1–2 m wide corridors in young dense stands. Silva Fennica 51. https://doi.org/10.14214/sf.1563.

Aurenhammer, P.K., Ščap, Š., Triplat, M., Krajnc, N., Breznikar, A., 2017. Actors' potential for change in Slovenian forest owner associations. Small-Scale For. 17, 165–189. https://doi.org/10.1007/s11842-017-9381-2.

Bergström, D., 2009. Techniques and Systems for Boom Corridor Thinning in Young Dense Forests. Sveriges lantbruksuniv. Acta Universitatis Agriculturae Sueciae, p. 87.

Bergström, D., Di Fulvio, F., 2014. Comparison of the cost and energy efficiencies of present and future biomass supply systems for young dense forests. Scand. J. For. Res. 29, 793–812. https://doi.org/10.1080/02827581.2014.976590.
Bergström, D., Fernandez-Lacruz, R., de la Fuente, T., Höök, C., Krajnc, N., Malinen, J., Nuutinen, Y., Triplat, M., Nordfjell, T., 2022. Effects of boom-corridor thinning on harvester productivity and residual stand structure. Int. J. For. Eng. 1-17 https://doi.org/10.1080/14942119.2022.2058258.
Berlin, C., Lidestav, G., Holm, S., 2006. Values placed on forest property benefits by Swedish NIPF owners: differences between members in forest owner associations and non-members. Small Scale For. Econ. Manag. Policy 5, 83–96. https://doi.org/10.1007/s11842-006-0005-5.
Cheng, H., Youn-Jeng, C., Quingzhou, S., 2021. Companion to BER 642: Advanced Regression Methods. https://www.bookdown.org/chua/ber642_advanced_regression/.
Danley, B., 2019. Forest owner objectives typologies: instruments for each owner type or instruments for most owner types? Forest Policy Econ. 105, 72–82. https://doi.org/10.1016/j.forpol.2019.05.018.
Eggers, J., Lämås, T., Lind, T., Öhman, K., 2014. Factors influencing the choice of management strategy among small-scale private forest owners in Sweden. Forests 5, 1695–1716. https://doi.org/10.3390/f5071695.
European Commision, 2018. In: Directorate General for Research and Innovation (Ed.), A Sustainable Bioeconomy for Europe - Strengthening the Connection between Economy, Society and the Environment : Updated Bioeconomy Strategy. https://doi.org/10.2777/792130.
Eurostat, 2020. Agriculture, forestry and fishery statistics — 2020 edition. Products Statistical Books - Eurostat (europa.eu).
Favada, I.M., Karppinen, H., Kuuluvainen, J., Mikkola, J., Stavness, C., 2009. Effects of timber prices, ownership objectives, and owner characteristics on timber supply. For. Sci. 55, 512–523. https://doi.org/10.1093/forestscience/55.6.512.
Ficko, A., Lidestav, G., Ní Dhubháin, Á., Karppinen, H., Zivojinovic, I., Westin, K., 2019. European private forest owner typologies: a review of methods and use. Forest Policy Econ. 99, 21–31. https://doi.org/10.1016/j.forpol.2017.09.010.
FOREST, EUROPE, 2020. State of Europe's Forests. https://foresteurope.org/wp-content/uploads/2016/08/SoEF_2020.pdf.
Häyrinen, L., 2019. Finnish forest owner objectives as indicators for a diversifying use of forests on the road to a bioeconomy. Dissertationes Forestales 2019. https://doi.org/10.14214/df.280.
Häyrinen, L., Mattila, O., Berghäll, S., Toppinen, A., 2014. Forest owners' socio-demographic characteristics as predictors of customer value: evidence from Finland. Small-Scale For. 14, 19–37. https://doi.org/10.1007/s11842-014-9271-9.
Hujala, T., Kurttila, M., Karppinen, H., 2012. Customer segments among family forest owners: combining ownership objectives and decision-making styles. Small-Scale For. 12, 335–351. https://doi.org/10.1007/s11842-012-9215-1.
ISO, 2019. Market, opinion and social research, including insights and data analytics — Vocabulary and service requirements. In: ISO/DIS Standard No. 20252, p. 66. https://www.iso.org/standard/73671.html.
Juutinen, A., Kurttila, M., Pohjanmies, T., Tolvanen, A., Kuhlmey, K., Skudnik, M., Triplat, M., Westin, K., Mäkipää, R., 2021. Forest owners' preferences for contract-based management to enhance environmental values versus timber production. Forest Policy Econ. 132 https://doi.org/10.1016/j.forpol.2021.102587.
Juutinen, A., Haeler, E., Jandl, R., Kuhlmey, K., Kurttila, M., Mäkipää, R., Pohjanmies, T., Rosenkranz, L., Skudnik, M., Triplat, M., Tolvanen, A., Vilhar, U., Westin, K., Schueler, S., 2022. Common preferences of European small-scale forest owners towards contract-based management. Forest Policy Econ. 144 https://doi.org/10.1016/j.forpol.2022.102839.
Karppinen, H., 1998. Values and objectives of non-industrial private forest owners in Finland. Silva Fennica 32, 43–59. https://doi.org/10.14214/sf.699.
Kronholm, T., 2016. How are Swedish forest owners' associations adapting to the needs of current and future members and their organizations? Small-Scale For. 15, 413–432. https://doi.org/10.1007/s11842-016-9330-5.
Kronholm, T., Bengtsson, D., Bergström, D., 2020. Family forest owners' perception of management and thinning operations in young dense forests: a survey from Sweden. Forests 11. https://doi.org/10.3390/f11111151.
Kumer, P., Štrumbelj, E., 2017. Clustering-based typology and analysis of private small-scale forest owners in Slovenia. Forest Policy Econ. 80, 116–124. https://doi.org/10.1016/j.forpol.2017.03.014.
Kuuluvainen, J., Karppinen, H., Hänninen, H., Uusivuori, J., 2014. Effects of gender and length of land tenure on timber supply in Finland. J. For. Econ. 20, 363–379. https://doi.org/10.1016/j.jfe.2014.10.002.
Lähdesmäki, M., Matilainen, A., 2013. Born to be a forest owner? An empirical study of the aspects of psychological ownership in the context of inherited forests in Finland. Scand. J. For. Res. 29, 101–110. https://doi.org/10.1080/02827581.2013.869348.
Laitila, J., Heikkilä, J., Anttila, P., 2010. Harvesting alternatives, accumulation and procurement cost of small-diameter thinning wood for fuel. Silva Fennica 44, 465–480. https://doi.org/10.14214/sf.143.
Lindroos, O., Lidestav, G., Nordfjell, T., 2005. Swedish non-industrial private forest owners: a survey of self-employment and equipment investments. Small Scale For. Econ. Manag. Policy 4, 409–425. https://doi.org/10.1007/s11842-005-0025-6.
Metsämaski, 2020. Finnish Forest Centre. https://www.metsakeskus.fi/fi/avoin-metsa-ja-luontotieto/tietoa-metsien-omistuksesta.
Mynttinen, S., Karttunen, K., Ranta, T., 2014. Non-industrial private forest owners' willingness to supply forest-based energy wood in the South Savo region in Finland. Scand. J. For. Res. 29, 41–50. https://doi.org/10.1080/02827581.2013.856935.
Ní Dhubháin, Á., Cobanova, R., Karppinen, H., Mizaraite, D., Ritter, E., Slee, B., Wall, S., 2007. The values and objectives of private forest owners and their influence on forestry behaviour: the implications for entrepreneurship. Small-Scale For. 6, 347–357. https://doi.org/10.1007/s11842-007-9030-2.
Osborne, J.W., 2015. What Is Rotating in Exploratory Factor Analysis? https://doi.org/10.7275/hb2g-m060.
R Core Team, 2021. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.
Raiche, G., Magis, D., 2022. nFactors: Parallel Analysis and Other Non Graphical Solutions to the Cattell Scree Test. R package version 2.4.1.1.
Rämö, A.K., Järvinen, E., Latvala, T., Toivonen, R., Silvennoinen, H., 2009. Interest in energy wood and energy crop production among Finnish non-industrial private forest owners. Biomass Bioenergy 33, 1251–1257. https://doi.org/10.1016/j.biombioe.2009.05.013.
Sarvašová, Z., Zivojinovic, I., Weiss, G., Dobšinská, Z., Drăgoi, M., Gál, J., Jarský, V., Mizaraite, D., Põllumäe, P., Šálka, J., Schiberna, E., Šišák, L., Wolfslehner, B., Zalite, Z., Zalitis, T., 2014. Forest owners associations in the central and eastern European region. Small-Scale For. 14, 217–232. https://doi.org/10.1007/s11842-014-9283-5.
Stekhoven, D.J., Buhlmann, P., 2012. MissForest–non-parametric missing value imputation for mixed-type data. Bioinformatics 28, 112–118. https://doi.org/10.1093/bioinformatics/btr597.
Tolosana, E., Bados, R., Laina, R., Bacescu, N.M., de la Fuente, T., 2021. Forest biomass collection from systematic mulching on post-fire pine regeneration with BioBaler WB55: productivity, cost and comparison with a conventional treatment. Forests 12. https://doi.org/10.3390/f12080979.
Weiss, G., Lawrence, A., Hujala, T., Lidestav, G., Nichiforel, L., Nybakk, E., Quiroga, S., Sarvašová, Z., Suarez, C., Živojinović, I., 2019. Forest ownership changes in Europe: state of knowledge and conceptual foundations. Forest Policy Econ. 99, 9–20. https://doi.org/10.1016/j.forpol.2018.03.003.
Wiersum, K.F., Elands, B.H.M., Hoogstra, M.A., 2005. Small-scale ForestOwnership across Europe: characteristics and future potential. Small Scale For. Econ. Manag. Policy 4, 1–19. https://doi.org/10.1007/s11842-005-0001-1.
Wilkes-Allemann, J., Deuffic, P., Jandl, R., Westin, K., Lieberherr, E., Foldal, C., Lidestav, G., Weiss, G., Zabel, A., Živojinović, I., Pecurul-Botines, M., Koller, N., Haltia, E., Sarvašová, Z., Sarvaš, M., Curman, M., Riedl, M., Jarský, V., 2021. Communication campaigns to engage (non-traditional) forest owners: a European perspective. Forest Policy Econ. 133 https://doi.org/10.1016/j.forpol.2021.102621.
Witzell, J., Bergström, D., Bergsten, U., 2019. Variable corridor thinning – a cost-effective key to provision of multiple ecosystem services from young boreal conifer forests? Scand. J. For. Res. 34, 497–507. https://doi.org/10.1080/02827581.2019.1596304.