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ORIGINAL PAPER

Maintenance and enhancement of forest ecosystem services: a non-industrial private forest owner perspective

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Abstract

The transition to a fossil-free society in Sweden is expected to cause an increased demand for forest-derived products which may intensify existing conflicts between forest ecosystem services. This study investigated the preferences among non-industrial private forest owners for maintaining multiple forest ecosystem services and their preferences for future forest development. The findings were related to their prioritizations for and knowledge of forest management. The study results were generated through the means of a survey which revealed a consistent high valuation among all respondents of ecosystem services relating to water quality, timber quality, recreation, and biodiversity. A majority of the respondents desired increasing proportions of mixed species and broadleaved stands within the future forest landscape. Certified forest owners who were members of a forest owner association (CMs) prioritized achieving high economic income through roundwood production with strong preferences for the ecosystem services high stand growth and high timber quality. For CMs, carbon substitution was the preferred means of mitigating climate change. Forest owners lacking both certification and membership in a forest owner association ranked the ecosystem services recreation and biodiversity significantly higher, and also preferred retaining more old forest within the landscape. The survey results revealed a higher management activity among CMs, resulting in a more frequent establishment of mixed and broadleaved stands. Forest owners with medium to large scale properties were well-represented within the CM category. The results indicated that while the CMs have stronger preferences for roundwood production compared to owners of small properties, they are also more likely to have taken adaptive measures favoring risk management and biodiversity.

Keywords Forest ecosystem services · Non-industrial private forest owners · Mixed species stands · Certification

Introduction

The concept of ecosystem services (ES) has highlighted the interactions between society and nature, and the values and benefits humans derive from natural goods and processes (IPBES 2019). Emphasizing the importance of long-term ecosystem stability, the concept has been widely applied in research to quantify both material and immaterial values derived from ecosystems, as well as potential synergistic linkages and trade-offs between services (Potschin and Haines-Young 2011). ES include regulating services such as drought and disease regulation, provisioning services relating to food, fiber and fuel, cultural services such as aesthetic and recreational, and supporting services such as the cycling of nutrients, provisioning of habitat and pollination (Millennium Ecosystem Assessment 2005).

In Sweden, assessments of the status of the Swedish Environmental Quality Objective (EQO) "*Sustainable forests*" show that the environmental targets will not be met because of an increasing loss of vulnerable species, biodiversity and important habitats (SFA 2022a). Assessments by the Swedish Forest Agency show that several of the regulating and supporting forest ecosystem services have an insufficient status. These forest ES relates to the provisioning of habitat,

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regulation of pests and diseases, prevention of erosion and landslides, and prevention of storm and weather-related damage (SFA 2018). Simultaneous ambitions to mitigate the ongoing climate crisis have increased expectations on forests to contribute with renewable resources through the production of sawn wood, pulp and biofuels (SNFP 2018). Concerns have been raised that increased extraction of biomass could further exacerbate existing conflicts between ecosystem services, with additional negative outcomes for forest biodiversity as a result (Kraxner et al. 2013; Felton et al. 2016a). On the other hand, the use of less intensive forest management strategies has been suggested to increase the potential for higher ecosystem multifunctionality at the landscape scale (van der Plas et al. 2016), which implies an acceptance of the trade-off between timber production and other forest ES (Pohjanmies et al. 2017a).

Sweden has a long tradition of forest management, which is foremost regulated through the Swedish Forestry Act (SFS 1979), but also through the Swedish Environmental Code (SFS 1998) within the Environmental Quality Objective "*Sustainable Forests*" (Lindahl et al. 2017). The Swedish Forestry Act was revised in 1993, causing a shift from production-oriented forest management toward an equal balancing of two objectives: to preserve the environment and to produce biomass for the welfare of Sweden. Known as "the Swedish Forestry Model," this mode of governing has put an increased emphasis on "freedom under responsibility," where forest owners are assumed to follow legal guidelines, but are also encouraged to go beyond these and take further voluntary initiatives to meet the targets of the Environmental Quality Objective 'Sustainable Forests' (Lindahl et al. 2017; Lidskog and Löfmarck 2016). For this, the systems of certification, the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC) serve a guiding standard for meeting environmental objectives (SFA 2019a). Voluntary set-asides have an important role in this regard. The Swedish certification schemes require landowners to exempt a minimum of 5% of the productive forest land (annual mean growth of stem biomass greater than 1 m^{-3} ha^{-1}) from conventional timber production to create voluntary set-asides (FSC 2020; PEFC 2017). The latest mapping indicates that 1.2 million ha of forests in Sweden (5.2% of the total Swedish forest land) are designated as voluntary set-asides (Claesson and Eriksson 2017). This also means that while there are legal requirements within the Swedish Forestry Act, the government (through the Swedish Forest Agency) mainly influence the forest owner through dialogue, using information, advice and recommendations (Appelstrand 2012).

The Swedish Forestry Act is considered to have a strong orientation toward production when considered in relation to other countries in Europe (McDermott et al. 2010). The emphasis on production in Swedish forestry is likely to be further reinforced by an increasing demand for forest-based products within a future of ambitious climate change mitigation, a development which can adversely affect the outcome for supporting, regulating and cultural forest ES (Bennett et al. 2009; Eggers et al. 2018; Eriksson and Klapwijk 2019; Lodin et al. 2020; Nordén et al. 2017). The development in Sweden with more responsibility shifted toward forest owners to meet an increasingly complex set of national objectives follows the same trajectory in forestry regulation as in many other European countries (Keskitalo and Pettersson 2012; Löfmarck et al. 2017; Uggla 2018). The Swedish approach to forest management share most similarities with neighboring countries Finland and Norway in terms of private property rights and planning (Bergstén et al. 2018).

About half of the productive forest land in Sweden is owned by 310 000 non-industrial private forest (NIPF) owners (SFA 2022b). The share of private ownership is rather high when compared to countries both in- and outside Europe (Lidskog and Löfmarck 2016). NIPF owners are more common in the southern parts of Sweden. About one third of all owners are part of forest owner associations (FOAs) (Kronholm 2015). Similarly, to the Swedish Forest Agency (SFA), the FOAs provide forest owners with advice regarding forestry-related matters, but also offer aid in harvesting, extraction of timber, and additional silvicultural operations. During the last decades, the SFA has had to operate with fewer resources (Lidskog and Sjödin 2015) but with higher demands on active governance due to the more complex set of goals and objectives that steer Swedish forestry (Lindahl et al. 2017) which has increased the role of FOAs in giving advice to NIPF owners (Jönsson and Gerger Swartling 2014). NIPF owners generally favor a traditional approach to forest management, which in Sweden is characterized by clear-felling and even-aged management (Löfmarck et al. 2017; Nordén et al. 2017). Biodiversity values are often maintained through practices such as retaining deadwood and coarse woody debris, but preservation of biodiversity is often of secondary interest to timber production (Eriksson and Klapwijk 2019). However, future uncertainties regarding local impacts of climate change on forest estates present novel challenges and increasingly require forest owners to consider alternative approaches to forest management to increase the resilience of production forests (Hallberg-Sramek et al. 2022; Pohjanmies et al. 2017b).

The preferences, attitudes and management decisions of NIPF owners will have a major influence on the possibility for progress toward the stated targets of the Environmental Quality Objectives "*Reduced Climate Impact*" and "*Sustainable Forests*" posited by Swedish government (SFA 2019b). Numerous studies have focused on NIPF owners and their motives for favoring single ES and choosing specific management strategies (Lodin et al. 2017; Grönlund et al. 2019; Eriksson and Klapwijk 2019; Bjärstig and Sténs 2018), but

few studies have focused on how NIPF owners simultaneously rank multiple ES. Here we investigate the perceived importance of a set of 10 forest ecosystem services, representing a range of provisioning, regulating, supporting and cultural forest ES, among a sample of NIPF owners in Sweden. We also analyze what kind of adaptive management actions the forest owners have implemented, and what kind of forest stands that should be promoted to meet future demands. We reflect on causes for different prioritizations of maintaining multiple ES and forest management practices, and relate our findings to a set of explaining factors, including sociodemographic characteristics.

Methods

The survey

In late autumn 2021, postcards were sent to 3000 NIPF owners in Sweden with an invitation to participate in a study. The postcards contained a link to an online questionnaire. The first set of questions within the questionnaire aimed to determine the forest owner preferences for maintaining provisioning, regulating, supporting or cultural ES in their forests (Table 1). Biodiversity was presented as a final ecosystem service classified as supporting, rather than as an underlying component of ecosystem function. This implies that the potential value of biodiversity lies in maintaining genetic or species diversity within forests which, for example, could positively affect pollination capacity or regulation of diseases (Mace et al. 2012). For each alternative, the respondent could indicate their effort to maintain or increase/decrease the status of one ecosystem service on a Likert scale from 1 to 5, where 1 represented a view of the ES as "completely unimportant" and a 5 as "very important." We refer to this set of questions as the theme *Ecosystem services*. In the second theme, *Forest management*, the NIPF owners were asked to specify whether they had undertaken a specific forest management activity on their property from a given set of alternatives during their period of ownership (Table 1). The third set of multiple-choice questions prompted the respondents to indicate their opinion on what kind of forest that should be promoted to meet future demands (Theme: *Future outlook*). Owners were asked to provide their opinion on what they considered important on a scale from 1 to 5, as mentioned above (Table 1).

Recipients of the survey were also asked to specify some sociodemographic characteristics relating to their gender, age, education, the size of their estate, property location, whether their property was certified or not, and if they were members of a forest owner association. The survey did not distinguish between the two market-based certification schemes PEFC (Programme for the Endorsement of Forest Certification) and FSC (Forest Stewardship Council) which co-exist in Sweden. The two voluntary standards are largely similar in aim and scope, and forest owners may be certified according to one of the standards or to both. Furthermore, private forest owners in Sweden may also be certified through a FOA or through other umbrella organizations that the forest owner is a member of, which is known as group certification. In that case, the umbrella organization holds responsibility for the FSC or PEFC certificate and carries out a large part of the administrative work as well as internal audits to check compliance with certification requirements (FSC n.d.; PEFC n.d.). Previous studies have found no statistically significant differences between PEFC and FSC concerning environmental outcomes after felling or for the area of set-asides within productive forests on NIPF properties in Sweden, which further indicates a similarity between the two standards (Villalobos et al. 2018).

Table 1 Questions/statements presented to respondents of the survey for theme (A) *Ecosystem services*, (B) *Forest management*, (C) *Future outlook*. Respondents were asked to specify a given response option for each alternative one-at-a-time

	Question/statement	Alternative	Response option
A	Which ecosystem service do you strive to promote when managing your forest?	Timber quality, timber growth, berries & mushrooms, hunting, water quality, biodiversity, carbon sequestration in standing stock, carbon substitution through timber production, recreation, preservation of cultural heritage	1 (completely unimportant) to 5 (very important)
B	Which of the following forest management activities have you undertaken?	Has insured estate, prolonged rotation, shortened rotation, established continuous cover forestry, established mixed forest, established broadleaves, retained deadwood, retained forest edges, retained set-asides	Yes/No
C	For the future more… is needed:	Coniferous forest, fast-growing forest, mixed forest, broadleaf forest, continuous cover forestry, old forest, retention forestry, set-asides, recreational forest	1 (completely disagree) to 5 (completely agree)

Sample population characteristics

The sample population of non-industrial private forest owners which received the survey were selected based on the location of their forest estate, so that 750 individuals were drawn randomly from each of four specified bioclimatic zones of Sweden (nemoral, boreonemoral, southern boreal, northern boreal) according to the proportionate stratified sampling method (Frayer and Furnival 1999). The data on forest owners were supplied by the real estate tax assessment register of Statistics Sweden for the year 2020.

In total, 3000 individuals owning more than 2 ha of productive forest, with or without felling restrictions, received an invitation to participate. The survey consisted of 67 questions and received 232 answers, presenting a response rate of 7.7%. Males aged 61 years or older were slightly over-represented within the sample compared to the national average (Table 2). Half of all respondents were residing on their properties, and most were actively managing their own forests in some way. 45.5% of all NIPF owners were certified, and 52.7% were members of forest owner associations (FOAs).

Statistical analysis

The survey responses for the three themes *Ecosystem services, Forest management* and *Future outlook* were analyzed to determine if diverging opinions existed among NIPF owners which could be explained by specific sociodemographic characteristics and factors within the sample. We analyzed if differences among NIPF owners depended on the following factors: property location, age, education level, gender, certification, membership within an FOA or on estate size (Table 3).

Table 2 Sociodemographic characteristics of survey respondents and for comparison, NIPF owner characteristics at the national scale

Sociodemographic characteristics of owners	Respondents (%)	National scale (%)
Certified	45.5	
		10.0 (FSC certificate 2022)[a]
		16.8 (PEFC certificate 2022)[b]
Member in a forest owner association	52.7	33.7 (2014)[c]
Gender		
Female	29.4	39.0 (2021)[d]
Male	68.8	61.0 (2021)[d]
Property location		
Northern Sweden	36.7	32.1 (2021)[d]
Central Sweden	15.3	26.8 (2021)[d]
Southern Sweden	48	42.0 (2021)[d]
Age (years)		
Below 30	0.9	1.5 (2021)[d]
30 to 60	38.4	43.4 (2021)[d]
Over 60	60.7	55.1 (2021)[d]
Higher (tertiary) education	66.8	30.3 (2010)[e]
Mean estate size		
2–5 ha	9.6	34.6 (2021)[d]
6–20 ha	18.7	28.5 (2021)[d]
21–50 ha	23.5	19.2 (2021)[d]
51–100 ha	21.7	10.0 (2021)[d]
101–200 ha	14.3	5.0 (2021)[d]
201–400 ha	7.0	1.9 (2021)[d]
401–1000 ha	3.5	0.6 (2021)[d]
> 1000 ha	1.7	0.1 (2021)[d]
Residing on the estate	49.1	67.7 (2021)[d]
Actively managing the forest	60.5	
Has adapted some part of the forest estate to climate change	61.9	

Proportion of certified members on national scale according to FSC and PEFC respectively should not be regarded as additive, since many NIPF owners are certified according to both standards. Sources: [a]Personal communication from Henrik Von Stedingk, FSC (2022), [b]Personal communication from Christina Lundgren, PEFC (2022), [c]Kronholm (2015), [d]Statistics Sweden (2023), [e]Haugen et al. (2016)

Table 3 Choice of statistical analysis for each theme

Theme	Number of dependent variables included	Statistical analysis
Ecosystem services	10	Kruskal–Wallis test + Dunn's post-hoc test, Principal component analysis
Future outlook	9	Kruskal–Wallis test + Dunn's post-hoc test, Principal component analysis
Forest management	9	Chi-square test
Factors (Independent variables)		Levels of each variable
Certification status + Membership within an FOA		Certified member (CM), non-certified member (NCM), certified non-member (CNM), non-certified non-member (NCNM)
Educational level		Has higher education/lacks higher education
Estate size		2–20 ha, 21–100 ha, 101–1000 ha
Age		Below 30 years, 30 to 60 years, 61 years or older
Gender		Male, female
Property location		Southern Sweden, central Sweden, northern Sweden

The responses for each theme were used as dependent variables for each statistical test. Tests for significant differences between levels of each independent variable were carried out for all three themes utilizing both the Kruskal–Wallis test with Dunn's post-hoc test and Chi-square tests

Forest owners were classified within four categories based on their responses regarding their membership status within an owner association and the certification status of their forest estate in the statistical analysis (Table 3). The categorization was as follows: CM = certified owners who are members of an association ($n = 80$), CNM = certified owners who are not members of an association ($n = 22$), NCM = owners without certification who are members of an association ($n = 38$), NCNM = owners without certification who are not members of an association ($n = 84$). Previous studies have shown that non-certified NIPF owners are less oriented toward timber production compared to certified (Nordén et al. 2017; Lidestav and Lejon 2011) and that fellings and extractions of timber from non-certified properties are less frequent (Lidestav and Lejon 2011). For a forest owner, the decision to join an FOA is often an indication of a willingness to produce and sell wood within the coming decade, and is often strongly associated with a decision to certify the estate. Economic motives for joining a certification scheme may be as prevalent as environmental motives, and a majority of forest owners regard certification as something that favors profitability rather than consider it to restrict economic yield (Johansson and Lidestav 2011). While it is possible to sell roundwood from non-certified forestry, all FOAs in Sweden offer a price premium for certified wood which varies with geographical location and assortment. The statistical analysis aimed to determine if these factors could distinguish NIPF owners with respect to preferences and perceptions of both the theme *Ecosystem services* and *Future outlook,* as well as for the set of questions in *Forest management* (Table 3).

The data from the survey were analyzed with the software *R* (R Core Team 2022), and figures were created using *R, Excel* (Microsoft 2019) and *MATLAB (*R2020b MathWorks Inc.). The non-parametric Kruskal–Wallis test was applied to the survey data for the theme *Ecosystem services* and *Future outlook* to test for statistically significant differences between levels of all factors (Table 3) (Kruskal and Wallis 1952). Dunn's Multiple Comparison test was used to distinguish the specific levels which significantly differed for each given independent variable (Dunn 1964).

We used chi-square tests for the statistical analysis of the questions concerning the theme *Forest management* (Table 3). The respondents were given the choice of answering either "yes" or "no" for a set of 9 different forest management activities. The registered response count of "yes" and "no" for the total sample for each forest management activity was used to determine the expected frequency within the chi-square test. Significant differences were determined by testing for differences between the observed frequencies of each level for a given independent variable in the analysis and the expected frequency based on the responses for the total sample (Table 3).

We also applied principal component analysis (PCA) to the responses for the themes *Ecosystem services* and *Future outlook* in order to visualize the different prioritizations among forest owners within the sample. Drawing upon the original data, a principal component analysis reduces the dimensionality of the data by creating a set of new variables (principal components) which captures varying amounts of the total variation within the data (Jolliffe and Cadima 2016). The first principal component captures the greatest amount of variation in the dataset followed by the second, and so on. Factor loadings produced within the analysis indicate the extent to which any given input variable correlates with the PC axis (Jolliffe and Cadima 2016).

10 input variables were used for the *Ecosystem service* theme corresponding to the number of assessed ES (Table 1). Similarly, nine input variables were used for the *Future outlook* theme. We used Cattell's scree test to determine the appropriate number of principal components to retain within the analysis (Cattell 1966). The test indicated retaining 3 principal components for the theme *Ecosystem services* and 2 principal components for the theme *Future outlook*.

Following the exclusion of n/a-values, a total of 186 samples were included in the PCA analysis for *Future outlook* and 169 samples for *Ecosystem services*. The filtering of n/a-values and outliers was performed within the statistical program R so that only completed sections of each theme with values within the assigned range were used within the PCA. The number of samples available for statistical testing with the Kruskal–Wallis test ranged from 214 to 225 for the theme *Ecosystem services*, and between 216 and 223 for the theme *Future outlook*. The principal component scores for each theme were used as dependent variables within an analysis of variance (ANOVA) to determine if the alignment of NIPF owners with each PC axis differed between owners based on the assessed factors (Table 3). Analysis of variance tests were applied with a significance level of 5%.

Results

Theme: Ecosystem services

Analysis of individual services

Among all respondents, the ES which were perceived as important to promote when managing the forest were those relating to water quality, timber quality, recreation, and biodiversity (Fig. 1). NIPF owners who had certified the property generally gave higher ratings for timber quality and forest growth. Respondents who were both certified and members within a FOA (CMs) gave significantly higher ratings for timber quality compared to those who were neither certified nor members of an owner association (NCNMs) ($p < 0.05$). The latter owner category also considered sustaining the growth of the forest less important compared to the other three categories of forest owners ($p < 0.05$) (Fig. 1). Respondents with very small estates (2–20 ha), across all groups/owner categories, considered timber quality and forest growth less important ($p < 0.05$). ES relating to the mitigation of climate change were perceived as important to all categories of owners, both through carbon sequestration in standing stock, and through carbon substitution by harvesting and producing forest products. NIPF owners aged 61 years or older had stronger preferences for retaining forest for carbon sequestration within the stands ($p < 0.05$). CMs considered carbon substitution to be significantly more important than NCNMs ($p < 0.05$) (Fig. 6). Similarly, respondents with medium to large property sizes (101 – 1000 ha) indicated higher ratings of carbon substitution compared to the small-scale owners (21–100 ha). The ES biodiversity was perceived as important among all owner categories, with no significant differences among the four groups CM, CNM, NCNM and NCM. However, biodiversity received significantly higher ratings from forest owners with college or university educational background ($p < 0.05$).

Women rated recreation higher than males ($p < 0.05$). Although the cultural ES recreation received high ratings, these were not followed up with similar high ratings of either berries & mushrooms or of hunting. However, NIPF owners with medium to large property sizes (101–1000 ha) had stronger preferences for hunting compared to those with small properties (2–20 ha) ($p < 0.05$).

Varying prioritizations for multiple ecosystem services among NIPF owners

All ES correlated positively with the first principal component (PC), which explained 31% of the variation within the data (Table 4). The highest correlations with PC 1 were found for the ES water quality, biodiversity, and carbon sequestration followed by carbon substitution (Fig. 2). In other words, PC 1 most strongly represented regulating and supporting ES, and to a lesser extent cultural and provisioning ES (Table 4). The forest owners within the sample showed a large spread regarding their preferences to maintain or enhance the ES (Fig. 2). An analysis of variance found no statistically significant differences in alignment among the four categories of NIPF owners to PC 1, which indicated that the factors certification and membership within an FOA were not important for explaining differences between consistently low preferences for all services compared to consistently high preferences for all ES among the NIPF owners.

PC 2 explained 19.5% of the total variation in the dataset, and represented differing preferences for either provisioning services (timber quality, growth) or cultural/supporting services (recreation, berries & mushrooms, biodiversity). The two variables growth and timber quality had the strongest positive correlation to the second principal component, followed by carbon substitution, whereas carbon sequestration correlated weakly with PC 2 (Table 4). The ES recreation, biodiversity and berries & mushrooms had the strongest negative correlation with PC 2 with weaker negative correlation for cultural heritage (Table 4). Varying priorities in maintaining these different ES among the forest owners were explained by their certification status and membership within an owner association (Fig. 2). The NCNM forest owners differed significantly from the other three groups and were more aligned with negative values for PC 2 compared to the other

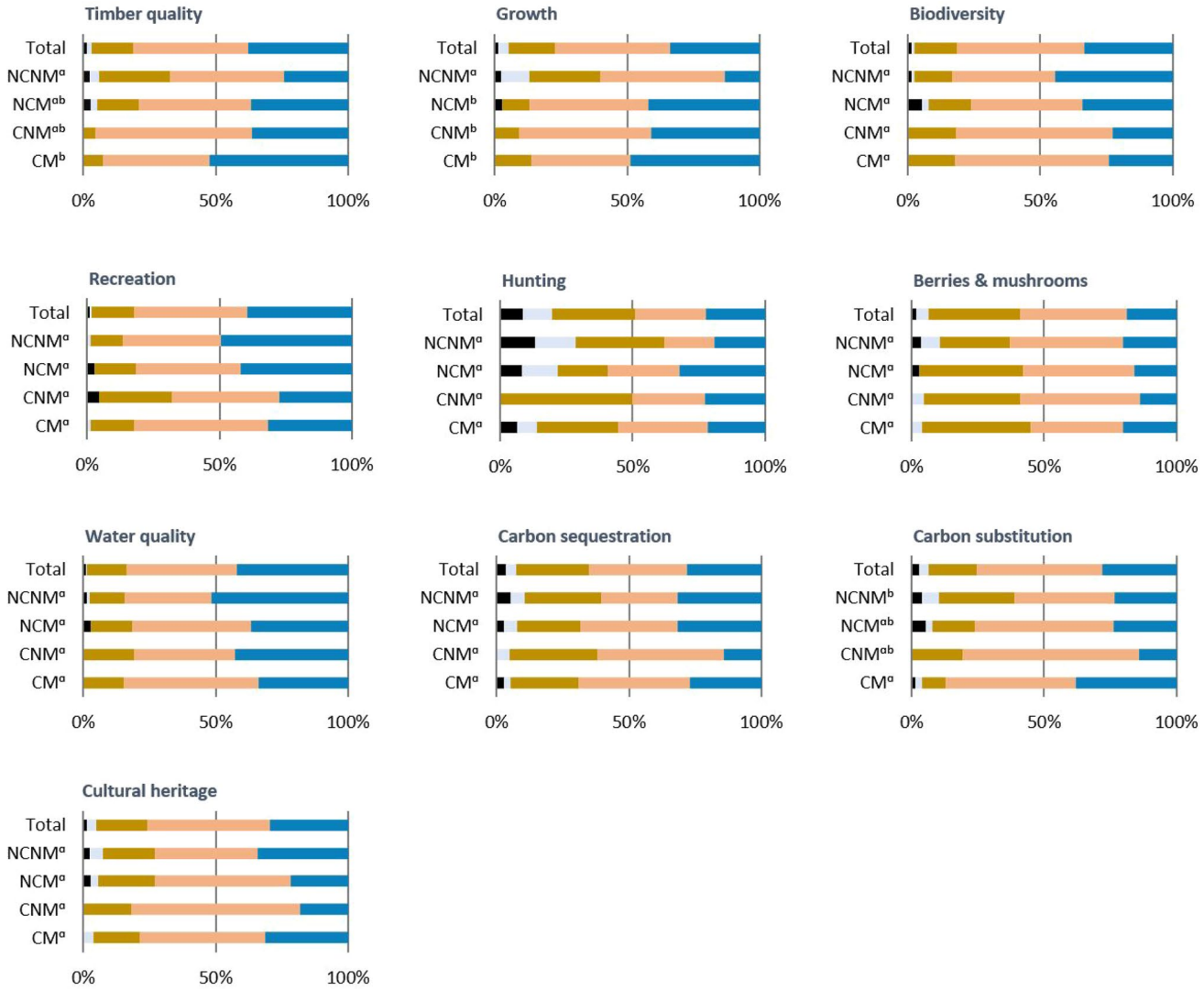

Fig. 1 The proportions of ratings in percent given by respondents regarding perceived importance of maintaining or enhancing forest ecosystem services on the property. Total = total sample, NCNM = non-certified non-members, NCM = non-certified members, CNM = certified non-members, CM = certified members. Black = completely unimportant, light gray = unimportant, brown = neutral preference, pink = important, blue = very important. Letters signify significant differences in ratings between groups at the 5% level

categories ($p < 0.01$). In other words, the NCNM category contained more respondents who gave higher ratings for ES which correlated negatively with PC 2: recreation, biodiversity, berries & mushrooms, cultural heritage & water quality. This category also gave consistently lower ratings for ES which correlated positively with PC 2: growth, timber quality, carbon substitution and carbon sequestration. These preferences of NCNMs explain the significant difference between the NCNM category and the other groups with respect to PC 2. The lack of significant difference with respect to PC 1 indicates that the NCNM category also contained respondents who gave consistently high ratings of all ES (Fig. 2). Forest owners represented within the groups NCMs, CNMs and CMs prioritized growth and timber quality and carbon substitution to a greater extent. PC 3 most strongly represented preferences for cultural ES related to hunting and picking of berries & mushrooms (Table 4). An analysis of variance indicated no significant differences among the 4 forest owner categories in their alignment with PC 3.

Theme: Forest management

Totally 68% of all respondents had taken measures to insure their property, and among those, CMs were over-represented ($p < 0.000$) while significantly fewer of the NCNMs had taken an insurance ($p < 0.000$) (Fig. 3). Insuring the property was

Table 4 Principal component loadings for the themes *Ecosystem services* and *Future outlook*. A positive value indicates a higher correlation between the given variable and PC axis 1 or 2, whereas a negative value implies a negative correlation. Only positive or negative correlations of 0.1 or greater are included

Ecosystem services				Future outlook		
Factor loadings	PC 1	PC 2	PC 3		PC 1	PC 2
TimberQuality	0.269	0.485		MoreConiferous	0.195	0.551
Growth	0.234	0.512	0.115	MoreBroadleaf	−0.249	0.413
Berries.Mushrooms	0.302	−0.286	0.367	MoreMixed	−0.290	0.438
Hunting	0.116		0.774	MoreFastGrowing	0.172	0.556
Biodiversity	0.400	−0.312	−0.206	MoreOld	−0.400	
WaterQuality	0.405		−0.182	MoreCCF	−0.377	−0.142
CarbonSequestration	0.359	0.122	−0.353	MoreRF	−0.401	
CarbonSubstitution	0.348	0.329	−0.101	MoreSetAsides	−0.417	
Recreation	0.313	−0.400	0.188	MoreRecreational	−0.386	
CulturalHeritage	0.310	−0.151				
Variation explained	31.0%	19.5%	12.1%		37.9%	16.2%

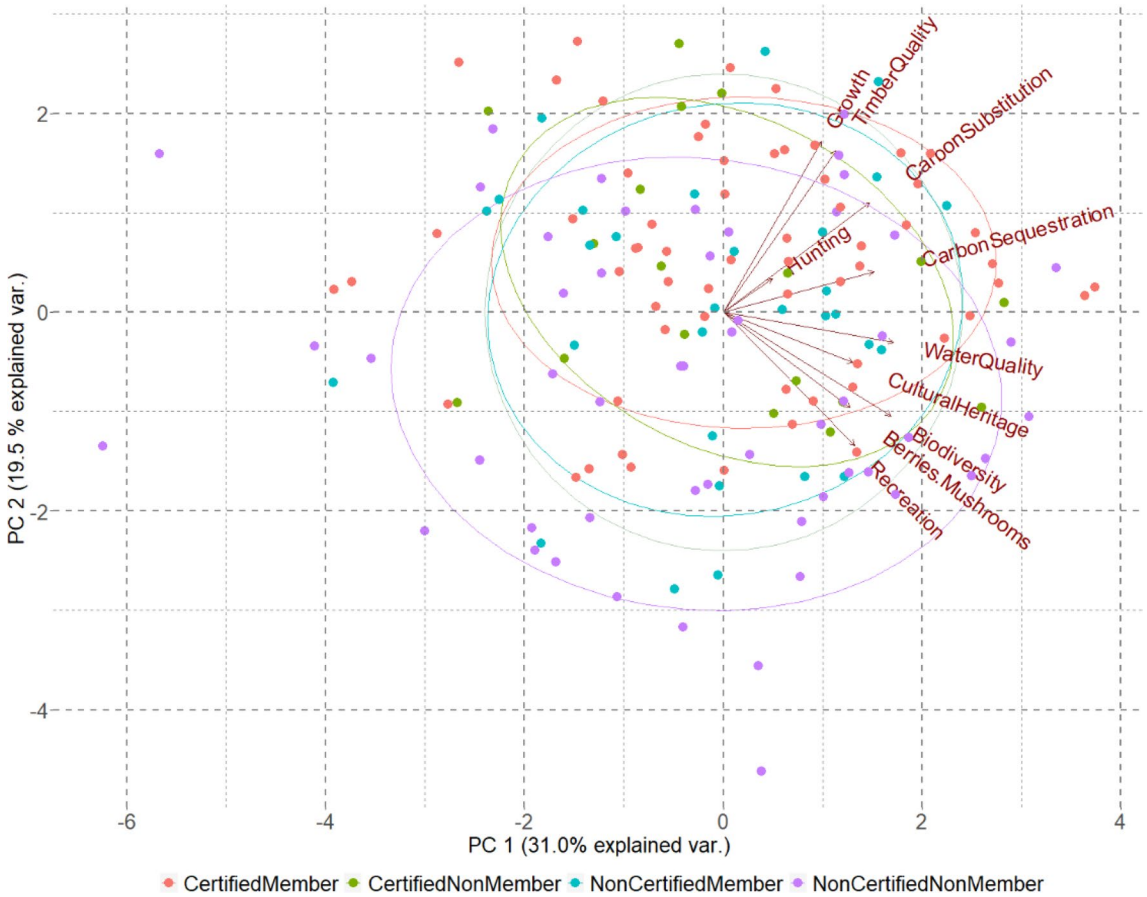

Fig. 2 Biplot of principal component 1 (x-axis) and principal component 2 (y-axis) for the theme *Ecosystem services*. Arrows indicate the correlation between each ES and the principal component axes. The alignment of each forest owner included in the sample to PC 1 and PC 2 is indicated by a dot. A principal component value of 0 for both PC 1 and PC 2 indicates a neutral preference to maintain ES. Dots are color-coded according to the classification of forest owners within four different categories. Superimposed ellipses indicate the captured range of 68% of the variation for each color-coded category of forest owners. The gray ellipse indicates the overall 68% range of variation in the data

much less important to small-scale forest owners compared to the average owner ($p < 0.001$), and more important to those with larger estates (101–1000 ha) ($p < 0.001$). Prolonging the rotation period was more common than shortening it.

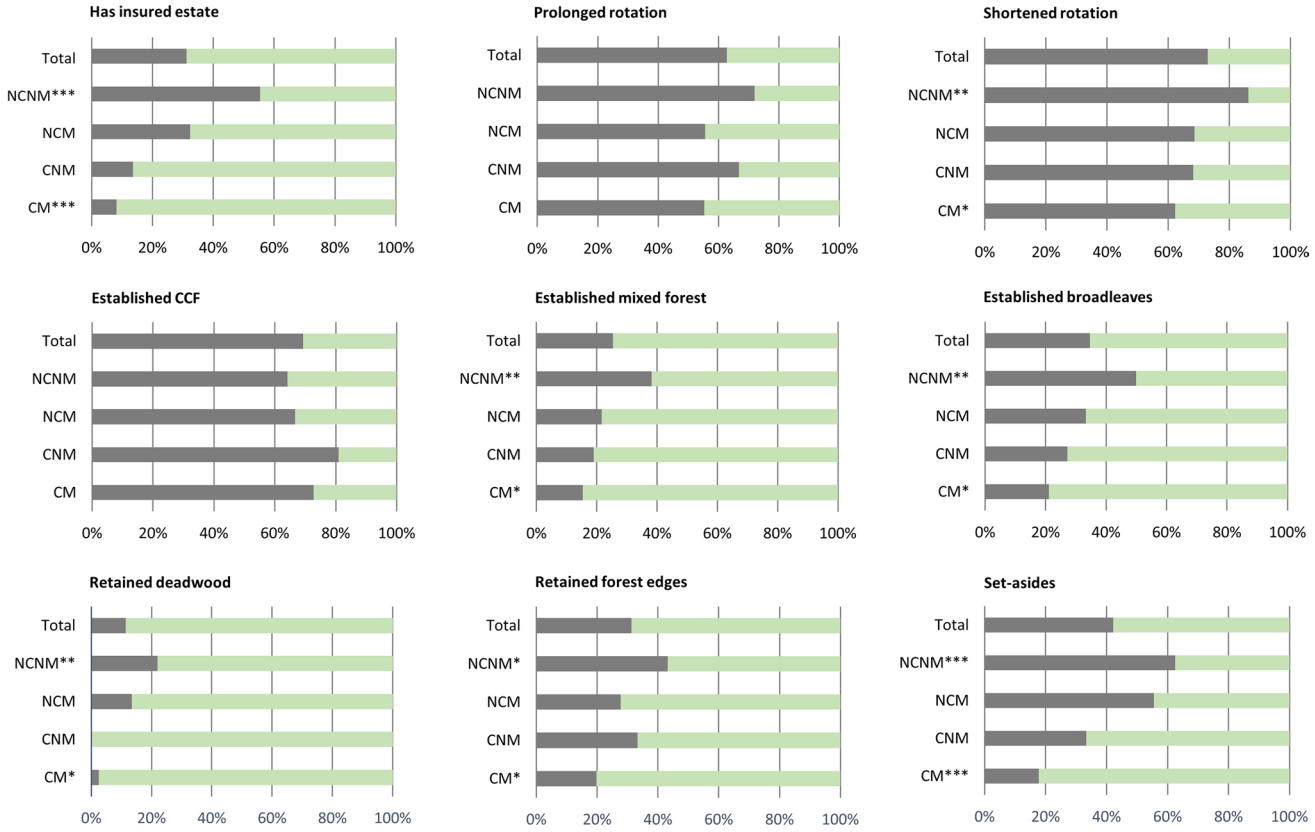

Fig. 3 Forest management treatments or measures taken by respondents on their properties. Yes = light green, no = gray. Total = overall sample responses, NCNM = non-certified non-members, NCM = non-certified members, CNM = certified non-members, CM = certified members. Significant differences between the group and the overall sample frequency (Total) are indicated with (* = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$)

Significantly more of the CMs ($p < 0.05$) and significantly fewer of the NCNMs ($p < 0.01$) had shortened rotations compared to the expected frequency. Shortening the rotation was also more frequent among owners who lacked college or university education ($p < 0.05$) and among those with properties in southern Sweden ($p < 0.01$). There were no statistical differences among groups of owners regarding the choice to prolong the rotation period. Three out of four NIPF owners had established mixed forest whereas 65% had favored the establishment of broadleaves on their properties (Fig. 3). The CMs displayed greater positivity toward establishing both mixed forest ($p < 0.05$) and broadleaf forest ($p < 0.05$) compared to the expected frequencies of the total sample (Fig. 6). Although the interest was relatively high for both forest types among all owners, the NCNMs had established significantly less mixed forest ($p < 0.01$) and broadleaf forest during their period of ownership ($p < 0.01$). NIPF owners with properties in southern Sweden had more frequently established broadleaves ($p < 0.001$) and mixed forest ($p < 0.05$) compared to NIPF owners in other parts of the country.

Few of the respondents had established continuous cover forestry (CCF) and the data revealed no statistically significant differences between groups regarding the choice to convert forest to CCF (Fig. 3). Although the preservation of environmental values was important to all NIPF owners, fewer respondents with estates in southern Sweden left set-asides compared to the average sample ($p < 0.05$). CMs stood out as significantly more positive toward retaining deadwood ($p < 0.05$), and more frequently engaged in creating voluntary set-asides ($p < 0.000$) (Fig. 6). Furthermore, 80% of the CMs had retained forest edges compared to 69% of the total sample of owners, resulting in a significant difference ($p < 0.05$).

Forest owners with properties in southern Sweden more frequently retained forest edges compared to the average ($p < 0.05$). Because of a low sample size, it was not possible to ascertain if the results for CNMs were significant regarding retaining deadwood on the property. Fewer of the NCNMs had retained forest edges ($p < 0.05$) and set-asides ($p < 0.000$) compared to the expected frequency of the sample. Respondents with medium to large properties (101–1000 ha) more frequently retained forest edges and set-asides ($p < 0.01$) whereas fewer of the small-scale forest owners (2–20 ha) left forest edges and set-asides ($p < 0.001$). A separate analysis with only the two categories certified and non-certified

indicated that certified forest owners differed significantly from non-certified owners by more frequently undertaking 6 out of the 9 management activities (*data not shown*).

Theme: Future outlook

Analysis of individual alternatives

Of the included alternatives, mixed forest received the highest ratings, indicating a strong interest among all NIPF owners to increase the extent of this forest type in the future (Fig. 4). The preservation of physical structures vital for biodiversity after clear-felling through retention forestry (RF) was also perceived as important to sustain and increase in future among all respondents. Increasing the proportion of broadleaf forest received high ratings overall with no significant differences in rating among owner categories (Fig. 6). Respondents with properties in southern Sweden expressed a greater willingness to expand the area of broadleaf forest compared to those with properties in northern Sweden ($p < 0.001$). NCNMs showed a greater preference for more old forest in the future compared to CMs ($p < 0.05$) (Fig. 4). NIPF owners with college or university education also significantly differed from those without, desiring more old forest within the future landscape.

About 35% of all NIPF owners rated an increased proportion of fast-growing forest as unimportant, and 45% had no preference either way. NCNMs were more reluctant than the CMs toward more fast-growing forest ($p < 0.05$). Furthermore, respondents aged above 60 indicated significantly lower ratings for this alternative compared to younger owners ($p < 0.05$). CMs considered CCF significantly less important and NCNMs more important to increase in future ($p < 0.05$) (Fig. 6). The preference for more set-asides of forest land was higher among owners who had a college or university background.

Varying opinions among NIPF owners regarding future landscape composition

Similar to the principal component analysis for *Ecosystem services*, the PCA analysis for *Future outlook* indicated a large spread in opinions among the NIPF owners. The analysis revealed three main directions of opinions among the

Fig. 4 The proportions of respondent ratings in percent of important aspects to retain or increase within a future forest landscape. Total = total sample, NCNM = non-certified non-members, NCM = non-certified members, CNM = certified non-members, CM = certified members. Dark gray = completely unimportant, light blue = unimportant, green = neutral, yellow = important, red = very important. Letters signify significant differences among groups at the 5% level

respondents regarding the forest types and management alternatives which were perceived as most needed for the future (Fig. 5). The first direction concerned more coniferous forest and more fast-growing forest which had a positive but weak correlation with PC 1 (Table 4). About 55% of the respondents were associated with positive values for PC 1. The second direction of opinions concerned more mixed forest and more broadleaf forest, and the third more old forest, more set-asides, more RF, more recreational values, and more CCF.

In general, negative values for PC 1 indicated an orientation among the NIPF owners toward retaining natural characteristics of the forest, whereas positive values indicated preferences for increasing the area of forest designated for production (Table 4). An ANOVA showed that CMs were more associated with positive values along PC 1 compared to the other groups and therefore associated more strongly with more coniferous forest and more fast-growing forest ($p < 0.05$). Respondents who had stronger preferences for more mixed forest and more broadleaf forest were also more likely to have positive perceptions of more old forest, more set-asides, more RF, more CCF and more recreational values (Fig. 5). The NCNMs were to a greater extent aligned with negative values along PC 1, perceiving the environmental and social values associated with more old forest, more recreational forest, more set-asides, more retention forestry, more broadleaf forest, more mixed forest and more CCF as more important to sustain or increase in future ($p < 0.01$). PC 1 explained 37.9% of the variation within the data (Table 4).

Several variables correlated strongly with PC 2 (Table 4). An association with positive values for PC 2 among the NIPF owners revealed preferences for further increasing provisioning ES from forests. The results also indicated that respondents who gave high ratings to more mixed forest, more broadleaf forest, more coniferous forest and more

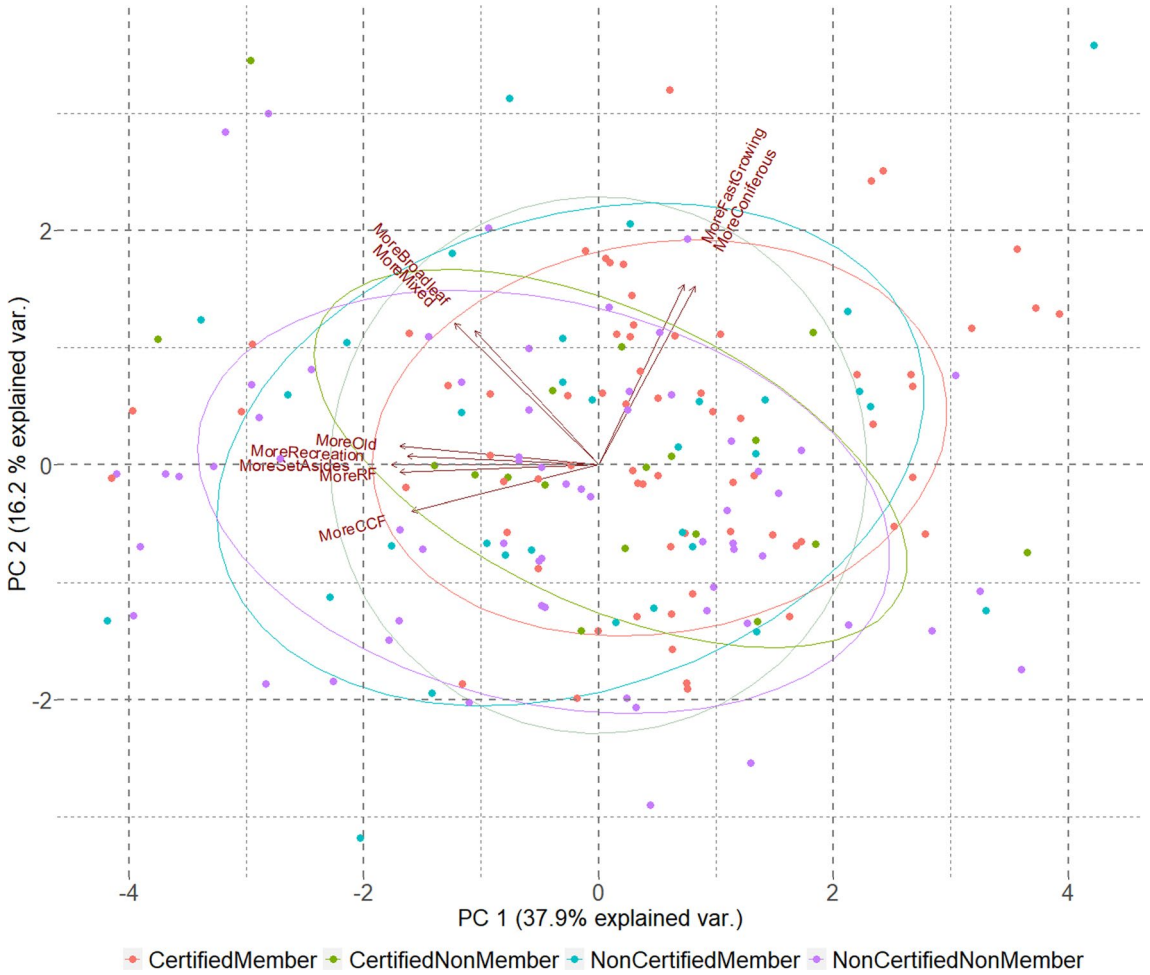

Fig. 5 Biplot of principal component 1 (x-axis) and principal component 2 (y-axis) for the theme *Future outlook*. Arrows indicate the correlation between each forest type/management alternative and the principal component axes. Dots represent individual owner alignment with PC axis 1 and 2 and are color-coded according to the classification of forest owners within four different categories. Superimposed ellipses capture 68% of all data points for each color-coded category of forest owners. The gray ellipse indicates the overall 68% range of variation in the data. More RF = more retention forestry, more CCF = more continuous cover forestry

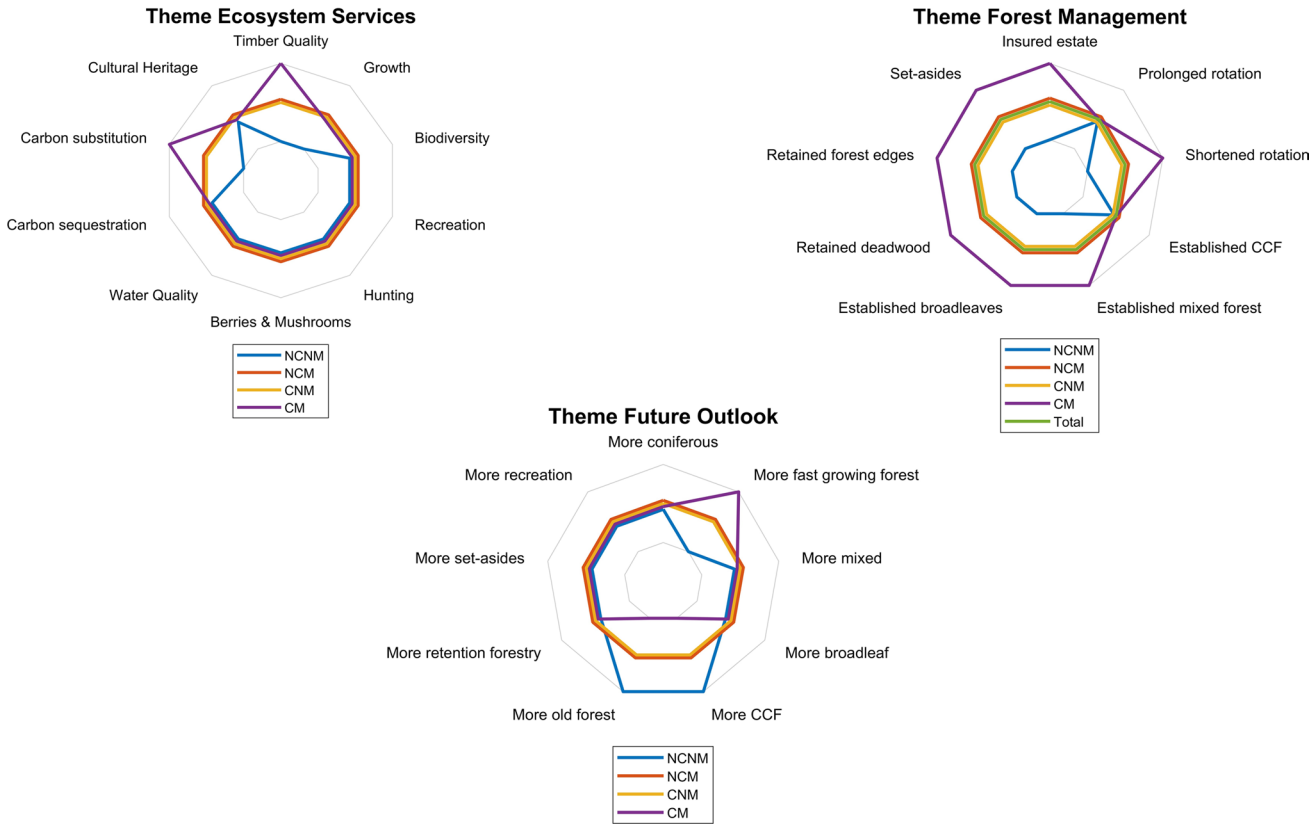

Fig. 6 **A** Theme *Ecosystem services*: Significant differences between four classifications of forest owners. A one step deviation toward the center indicates a significant lower rating of the ES, whereas a one-step deviation toward the edge indicates a significant higher rating. **B** Theme *Forest management*: significant differences between the total sample frequency and four classifications of forest owners regarding performing management activities. A one step deviation from the green line indicates a significant difference between the group compared to the total sample. A deviation one step toward the edge indicates significantly more of the NIPF owners within the groups had taken the activity, and a deviation one step toward the center indicates that significantly fewer of the respondents had taken such an action. **C** Theme *Future outlook*: significant differences are visualized as in **A**

fast-growing forest generally ranked the option of more CCF lower. An analysis of variance showed that NCNMs significantly differed from the other groups with respect to alignment with PC 2 ($p < 0.05$), and that this group was more strongly associated with higher ratings of CCF as a silvicultural management strategy. PC 2 explained 16.2% of the variation in the data.

Discussion

General overview

This study aimed to provide insight into the perceived importance of forest ecosystem services, forest management practices, and desires for future change in forest composition among NIPF owners in Sweden. The sample data indicated positive perceptions of all included ES, but also reflected an existing broad and diverse set of opinions among all respondents regarding which ES should be prioritized (Fig. 2). Our analysis found that differences among owners regarding their priorities largely depended on two factors: the certification status and/or membership status within a forest owner association (Fig. 6). Certified forest owners who were members of an association (CMs) differed most from non-certified owners who were not members of any owner association (NCNMs), both concerning their rating of ES and regarding their preferred future forest composition.

Our results reveal divergent rationales among owners promoting differing uses of the forest as a resource with varying implications for mitigation and biodiversity conservation. CMs were more oriented toward values relating to forest production, including sustaining continuous high stand growth and securing high timber quality with stronger preferences for carbon substitution as a means of mitigating climate change compared to the other groups. Contrasting these results, the NCNMs rated the ecosystem service carbon substitution significantly lower, primarily favoring values relating to recreation and biodiversity, with stronger preferences for retaining increased proportions of old forest.

Emotional motivations and ties to old forest on the estate have been considered one underlying reason for prolonging rotations beyond what is considered optimal from a pure profitability perspective (Lodin and Brukas 2021).

Our findings also underline that there is no simple connection between the perceived importance of ES among non-certified NIPF owners and the kind of forest management they have chosen. As has been shown in earlier research, membership in a FOA and certification are factors which seem to largely influence the choice of applied management strategies. Members of FOAs value timber production higher (Johansson and Lidestav 2011) while they simultaneously retain more voluntary set-asides compared to other groups, probably because they are certified to a higher degree (Danley 2018).

Societal challenge # 1: Climate change

The results of this study indicate that a majority of the respondents envision the need of a shift from the current conifer-dominated monocultural landscape toward an increased proportion of mixed species stands and broadleaf forest. This desire for change is consistent across all assessed categories of owners (Fig. 4). Establishment of mixed forest has been promoted by the SFA as a risk-spreading strategy to reduce the harmful effects of climate change, and constitutes the most common adaptation measure taken among forest owners in Sweden (Blennow 2012). Adaptation to climate change among forest owners is increasing which may partly explain the greater interest in these forest types among the respondents (Eriksson and Sandström 2022; Blennow 2012).

The individual effort toward achieving a more diversified landscape varied among the groups of NIPF owners. Based on the given responses for undertaken forest management activities, our study revealed a more active approach to forest management among CMs compared to the other categories, resulting in a more frequent establishment of broadleaved stands and mixed forest (Fig. 3). Increased social interaction among owners can contribute to a greater openness and connectedness, which may motivate them to become more active forest owners (Eriksson and Fries 2020). CMs more frequently took part in meetings arranged by the SFA (Appendix A). Direct access to promotions and information regarding the beneficial aspects of establishing mixed and broadleaved stands could have contributed to their approach to forest management. Forest owners with medium to large scale properties were well-represented within the CM category (*data not shown*). Owners with larger property sizes have in previous studies been shown to have more objective knowledge of forest management and of adaptation to climate change (Eriksson and Fries 2020).

Despite the high rating of more CCF, more old forest, more set-asides, more RF and more recreational values of NCNMs (Fig. 5), overall initiatives to undertake forest management activities which develop their preferences for recreation and biodiversity were lower among this category of owners (Fig. 6). The contrast between the stated preferences of NCNMS regarding desired future outcomes and their lack of activity in promoting them implies a prevalent passive approach to forest management among them. This also indicates that underlying ideals and stated future preferences are not sufficiently strong motivators for undertaking management treatments to achieve the desired change compared to the act of certifying or becoming a member within a forest owner association. Our findings are corroborated by Danley (2018) who found that forest owners who were members of an FOA were also more frequently certified, and therefore also retained more set-asides.

In 2018, the National Forest Programme was launched in Sweden to promote an increased use of the forest as a renewable resource in the transition toward net-zero carbon emissions (SNFP 2018). A trajectory representative of ambitious climate mitigation through the extraction of biomass will cause a need for shortening of the rotation periods compared to the contemporary practice in southern Sweden in order to meet increased demands (Lodin et al. 2020). CMs had stronger preferences for earlier harvests compared to the other categories which may further indicate a greater risk awareness among this production-oriented category of owners (Fig. 3). Shortening the rotation in Norway spruce forests reduces the susceptibility to storm damage by lowering overall height and size of individual trees (Roberge et al. 2016). Furthermore, the risk of extensive damage from the spruce bark beetle (*Ips typographus*) decreases with an earlier harvest as older stands are at greater risk of damage from the pest (Overbeck and Schmidt 2012). Potential economic losses associated with root rot (*Heterobasidion spp.*) is also lowered by shortening the rotation (Roberge et al. 2016).

CMs indicated significantly higher ratings for the ES carbon substitution as a means of mitigating climate change compared to the other owners. Lower preferences of NCNMs for shortening rotations were consistent with their desire for more old forest (Fig. 6). Altogether, the forest owners generally preferred prolonging the rotation rather than shortening it. Previous studies have indicated that small-scale private forest owners generally prefer less intensive forest management compared to large-scale owners or enterprises (Eggers et al. 2014). In general, all respondents indicated a lukewarm interest toward a development where the proportion of highly productive forest further increases, but NIPF owners within the CM category were more likely to favor such a development (Fig. 4).

Societal challenge # 2: Biodiversity

The principal component analysis for *Ecosystem services* indicated differing prioritizations among the respondents between

preferences related to production and economy (timber quality, growth) and to biodiversity and recreation (Fig. 2), in line with the "eternal" conflict between biodiversity protection and forest production (Jakobsson et al. 2021). NIPF owners who more strongly favored either of these contrasting ES could be found within all four owner categories. However, NIPF owners within the category of NCNM had stronger preferences for maintaining the ES biodiversity, recreation, cultural heritage, berries & mushrooms and water quality compared to the other groups (Fig. 2). The proportion of NIPF owners with reduced interest in economic gain from producing timber, pulp or biofuels increased from 1990 to 2010 in Sweden (Haugen et al. 2016). Furthermore, non-certified forest owners constitute the majority in Sweden (Table 2). Our findings imply that the CMs more frequently retained set-asides, deadwood and forest edges compared to the NCNMs (Fig. 6). However, these results should be interpreted with caution, as the CMs also owned larger properties, indicating an overall increased likelihood of undertaking any type of forest management measure during their period of ownership. The average area of set-aside property for certified NIPF owners has been shown to be similar to that of non-certified forest owners (Villalobos et al. 2018). The volume of deadwood per hectare, area of old forest and of old broadleaved forest have increased on small-scale certified properties in southern Sweden between 2000 and 2005, with no change in trend on larger certified properties (Johansson and Lidestav 2011). However, thinning and harvesting activities have also become more frequent on small-scale certified estates, which could in practice adversely affect biodiversity (Johansson and Lidestav 2011). In southern Sweden, the inherent forest growth rate and the potential for timber production is more than two times larger when compared to northern Sweden (SNFI 2022). Our study found a lower willingness to leave set-asides among forest owners in southern Sweden compared to in other parts of the country, which may be explained by the associated higher costs of setting aside forest land in southern Sweden.

The respondents expressed broad agreement regarding a future desired expansion of the area of mixed species and broadleaf stands (Fig. 4). An expansion of mixtures of either Norway spruce-birch or Norway spruce-Scots pine at the expense of monocultural stands of Norway spruce would benefit biodiversity, water quality, aesthetic and recreational values in forest ecosystems (Felton et al. 2016b). Moreover, the above-mentioned ES were among those considered most important to maintain among all respondents (Fig. 1). The area of young conifer-dominated mixed forest and broadleaf-dominated mixed forest stands have increased in Sweden (Ara et al. 2022). It is unclear whether these mixtures will retain their species composition over time or revert to monocultures. The proportion of birch in Norway spruce-birch mixtures has shown to decrease with increasing stand age in southern Sweden both due to a competitive advantage of Norway spruce, and due to more frequent removal of birch during thinning treatments, especially in stands designated for timber production (Holmström et al. 2021). An active management approach, including the removal of Norway spruce individuals in mixed stands, is therefore likely required of forest owners to maintain a landscape development toward an increased proportion of mixed forest over time. Management objectives toward sustaining biodiversity values in forest stands have shown to be more prevalent among NIPF owners with college or university education (Eriksson and Fries 2020). Our findings imply that respondents with higher education significantly differed from other respondents by rating the ES biodiversity as more important. NIPF owners with higher education have increased in Sweden during recent decades, which may partly explain this development (Haugen et al. 2016).

Limitations of the study

The questionnaire which was sent out during autumn 2021 and the responses analyzed represent a sample of NIPF owners which differ in some ways from the larger national population. Males older than 60 years were slightly over-represented, and forest owners with estate sizes of < 20 ha were under-represented (Table 2). Previous studies have revealed that small-scale owners have a diverse set of aims with their forest management (Ingemarson et al. 2006). This suggests that their under-representation within the current study is not likely to have skewed the results, as our findings indicated heterogeneous opinions and preferences regarding the maintenance of ES and the preferred future forest composition (Figs. 2 & 5).

We applied a proportional stratified sampling method where 750 respondents in the nemoral, boreonemoral, southern boreal and northern boreal zones received the questionnaire. The relatively low sample size of this study ($n = 232$) was sufficiently large to perform a statistical analysis and draw valid conclusions based on the material. The two groups CM ($n = 80$, 35.7% of sample) and NCNM ($n = 84$, 37.5% of sample) represented categories with opposed opinions and values whereas NCM ($n = 38$, 17% of sample) and CNM ($n = 22$, 9.8% of sample) represented categories of owners which were positioned in between the other two groups. Since the factors certification and membership within a forest owner association were important for explaining sample differences, the results for NCM and CNM represented a spread of opinion in line with what could be expected, as these were positioned in between the other two more polarized categories regarding stated values for all three themes. However, clearer trends within the data would have likely emerged with a larger sample size, and the extent to which the findings of the current study represents the larger national population of forest owners can be questioned. The principal component analysis required a full set of values for all included variables in the analyzed theme from each respondent. The removal of n/a-values further reduced the effective sample size to 169 in the PCA analysis of *Ecosystem services* and to 186 in the PCA analysis of

Future outlook. The Kruskal–Wallis analysis required only one dependent variable at a time. The number of samples available in the Kruskal–Wallis test was therefore greater, and varied between 214 and 225 in the theme *Ecosystem services*, and between 216 and 223 in the theme *Future outlook*. However, the outcomes of the PC analyses were consistent when compared to the outcomes of the Kruskal–Wallis test. Because of the relatively few responses received from the questionnaire, the results of this study can only provide general indications of trends within the larger NIPF owner population in Sweden. Furthermore, a larger sample size could potentially have revealed clearer differences in motivations for maintaining different forest ES depending on the regional location of the estate. The questionnaire was carefully designed to elicit responses on valuable topics and was pre-tested in September 2021 to gauge its validity. However, NIPF owners with greater interest in the topic is more likely to have responded to the questionnaire, which may also be a cause of bias.

Conclusion

This study provided new insights into the perceived importance of a set of 10 forest ecosystem services among non-industrial private forest owners in Sweden. Differing views on the future forest composition and varying prioritizations for forest management were also studied. Our results revealed consistent preferences among the respondents for an increased proportion of mixed species and broadleaved stands within the future forest landscape and a simultaneous high valuation of ecosystem services relating to biodiversity, water quality, recreation and timber quality. The results of the study further suggest that the main cause for differences in opinion relates to whether the owners were certified and members of a forest owner association. However, the overall results of the analysis can only provide general indications of trends due to the relatively low sample size of the study ($n = 232$). Complementing future studies designed to elicit responses regarding forest owner knowledge of ES trade-offs or synergies could be a valuable area to explore further, to gain more understanding of conflicting interests and ways forward. Questionnaires or qualitative interviews where stakeholders such as NGOs, forest advisors and company representatives could share their views could also paint a fuller picture of how the forest should be utilized as a resource. Opinions are influenced by changing perceptions of risk, which could also determine the perceived benefits of forest ecosystem services and be valuable to consider in future research.

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Availability of data and material Data will be made available on request to the corresponding author.

Code availability Not applicable.

Declarations

Conflict of interest The authors declare that they have no competing interests.

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