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Altamash Bashir

Non-industrial private forest owners' attitudes and forest management decisions

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PhD thesis

2021

Faculty of Applied Ecology, Agricultural Sciences and Biotechnology

Inland Norway University of Applied Sciences

Printed by: Flisa Trykkeri A/S

Place of publication: Elverum

PhD Thesis in Applied Ecology and Biotechnology no. 7 - 2021

ISBN printed version: 978-82-8380-308-2

ISBN digital version: 978-82-8380-309-9

ISSN printed version: 2703-819X

ISSN digital version: 2703-8181

Author details

Altamash Bashir

Inland Norway University of Applied Sciences, Faculty of Applied Ecology, Agricultural Sciences and Biotechnology, 2480 Koppang, Norway

Email: altamash.bashir@inn.no

Main supervisor

Hanne K Sjølie

Inland Norway University of Applied Sciences, Faculty of Applied Ecology, Agricultural Sciences and Biotechnology, 2480 Koppang, Norway

Email: hanne.sjolie@inn.no

Co-supervisor

Birger Solberg

Norwegian University of Life Sciences, Faculty of Environmental Sciences and Natural Resource Management (MINA)

Birger.solberg@nmbu.no

Co-Author

Dennis Becker,

University of Idaho, College of Natural Resources, USA

Email: drbecker@uidaho.edu

Sammendrag

Skogeieres holdninger til sin skog har store konsekvenser for bærekraften i skogforvaltningen. Med det som bakgrunn forsøker forskningen min å bidra til en dypere forståelse av hvordan den store variasjonen i skogeieres sosio-demografiske egenskaper, eiendomsvariabler, holdninger og adferd påvirker deres beslutninger om forvaltning, som tømmerhogst, bevaring av biodiversitet, besittelse av skogbruksplan og oppsøking av informasjon. For å nå dette målet brukte jeg et datasett basert på en nasjonalt dekkende spørreundersøkelse av personlige skogeiere, altså enkeltpersoner som eier skog. Undersøkelsen ble utviklet av Norges miljø- og biovitenskapelige universitet i nært samarbeid med Statistisk Sentralbyrå og distribuert i hele Norge. Resultatene viser at de fleste skogeierne har flere målsetninger for skogforvaltningen, fra ivaretakelse av sosiale verdier og biodiversitet til tømmerproduksjon. Et hovedfunn i avhandlingen er at det multifunksjonelle skogbruket som forvaltningsstrategi har en sterk posisjon blant personlige skogeiere i Norge. Skogeiere som forvalter skogen ut fra økonomiske målsetninger ser på skogeiendommen som en viktig ressurs for sin økonomiske trygghet og velferd. Informasjon fra offentlig forvaltning kan øke kunnskapen om skogforvaltning, som støtte til skjøtselstiltak, miljøverdier og bruk av skogbruksplan. Forskningen gir et viktig bidrag ved å peke på grupper av skogeiere som trenger spesiell oppmerksomhet når makthavere innenfor skogbruket jobber med politikkutforming og rådgivere gjennomfører informasjonskampanjer. Studien kan hjelpe det skogpolitiske apparatet til å formulere og utføre politikk og strategier som oppfordrer skogeierne til å skjøtte og ta skogressursene ytterligere i bruk, på en økonomisk, økologisk og sosial bærekraftig måte.

Abstract

Forest owners' attitudes towards their forests have large impacts on the sustainability of forest management. In this context, my research strives to provide greater depth of understanding of how the diverse socio-demographic and property characteristics of forest owners, their attitudes and behavior ultimately affects their management decisions, such as timber harvesting, biodiversity conservation, possessing a forest management plan or seeking information. To achieve this research goal, I utilized a questionnaire dataset originated from a national survey of non-industrial private forest (NIPF) owners, developed and distributed across Norway by the Norwegian University of Life Sciences in close collaboration with Statistics Norway. The results signify that most owners manage their forests for multiple objectives; ranging from ensuring social values and biodiversity to timber production. A main finding in this thesis is that the multifunctional forestry as a management strategy has a strong position among the NIPF owners in Norway. Forest owners managing their property for economic objectives consider their forest property as an important asset to attain financial security and well-being. Information from public management authorities may increase knowledge about forest management like timber harvest incentives, schemes for forest activities, environmental knowledge, and use of forest plans. This research study provides important contribution by pointing to specific groups of forest owners that demand special attention from forest policymakers and extension services while drafting different policies and executing various information campaigns. This study also provides valuable insights that can guide forest policy makers to formulate and execute policies and strategies that encourage forest owners to further manage and utilize forest resources while adhering to the principles of economic, ecological and social sustainability.

Keywords: Forest ecosystem services, Survey, Timber, Forest plan, Environmental conservation, Information needs

Dedication

To my lovely parents

Bashir Ahmad and Rafiqa Banu

List of papers

Paper I

Bashir, A., Sjølie, H.K., Solberg, B. Determinants of Nonindustrial Private Forest Owners' Willingness to Harvest Timber in Norway. Forests 2020, 11, 60. https://doi.org/10.3390/f11010060

Paper II

Bashir A., Sjølie, H.K., Becker, D., Solberg, B. (2021). Non-industrial private forest owners' knowledge of environmental values in their forest and their attitudes towards environmental conservation (In review: Scandinavian Journal of Forest Research)

Paper III

Bashir A., Sjølie, H.K., Solberg, B. (2021). Forest plan pathways among non-industrial private forest owners in Norway: from acquisition to implementation of forest plans (Manuscript)

Paper IV

Bashir A., Sjølie, H.K., Solberg, B. (2021). Information needs of Norwegian non-industrial private forest owners for improved forest management and environmental considerations (Manuscript)

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Synopsis

1. Introduction

1.1 Forest Ecosystem Services

Forest are complex and dynamic ecosystems providing important flow of various ecosystem services that are critical for the welfare of the society (Haines-Young and Potschin 2018, Jenkins and Schaap, 2018; MEA, 2005). These forest ecosystem services (FES) are classified into three broad types: provisioning, regulation and maintenance, and cultural (Gatto et al., 2019; Haines-Young and Potschin-Young, 2018). The provisioning benefits include ecosystem service (outputs/products) that are obtained directly from the forests (timber, wood fuel, game, berries and mushrooms) (de Groot et al., 2002; Haines-Young and Potschin-Young, 2018; MEA, 2005). Regulation and maintenance services include functions of forest ecosystem that improves the environment (for e.g. carbon sequestration and storage, erosion reduction, and prevention of floods (Haines-Young and Potschin-Young, 2018). Furthermore, cultural FES include non-material services such as recreation opportunities, aesthetic enjoyment, spiritual enrichment, and biodiversity (Haines-Young and Potschin-Young, 2018). A Detailed description of main three ES classification system is well discussed in Forest Europe (Forest Europe, 2014).

Forests contribute significantly to climate change mitigation by acting as carbon sinks, sequestering carbon in trees and forest soils (Bashir et al., 2019; IPCC, 2018), regulating water flow, and surface cooling (Bright et al., 2017). In addition, forests house a significant proportion of global terrestrial biodiversity and provide habitats for many species (Gustafsson et al., 2020; MEA, 2005; FAO and UNEP, 2020). Overall, forest ecosystems are vital for the provisions they provide and regulate. Therefore, the proper functioning of forest ecosystem is highly emphasized in various national and international policies to maintain the provision of these services (Forest Europe, 2015; MEA, 2005). However, to great extent it depends on how we interact and use the forest ecosystem (FAO and UNEP, 2020).

The societal need for FES is constantly increasing, and further increase is estimated by the experts in the near future (FAO and UNEP, 2020). The reasons are continuously expanding resource needs for an increasing population, forests contribution in mitigation of climate change and awareness of environmental benefits of forest ecosystem, especially biodiversity conservation (FAO and UNEP, 2020). To cater to these growing demands from forest ecosystems, the societies have shifted to more diverse use of forests (Brockerhoff et al., 2017; Górriz-Mifsud et al., 2016). This led to the paradigm shift from the idea of sustained timber yield to multifunctional objective forestry (Blanco et al., 2015; Gatto et al., 2019). The multifunctional characteristics of forest landscapes are attained by adhering to the principles of sustainable forest management (SFM) (Gatto et al., 2019; Nagaike, 2020). SFM has been a globally accepted approach by most governments and forestry organizations within the forestry sector (Živojinović et al., 2015).

1.2 Diverse structure and objectives of NIPF owners

An Assessment of forest cover of 234 countries showed that forests constitute approximately 3,999 million ha of the earth's surface. Furthermore, 76% of the world's forest is under public ownership, privately owned forest account for 20%, and the remainder is categorized as either "unknown" or "other" (FAO, 2015; FAO and UNECE, 2020) (Figure 1a). Of the total private forest, individuals own 56%, 29% is owned by private enterprises and local communities and indigenous people manage 15% of the private forest (Figure 1b). For the period of 1990-2010, private forests have increased by 3% in comparison to pre1990 levels. The increase in private forests is mainly observed in upper to middle-income countries (FAO, 2018; FAO and UNECE, 2020).

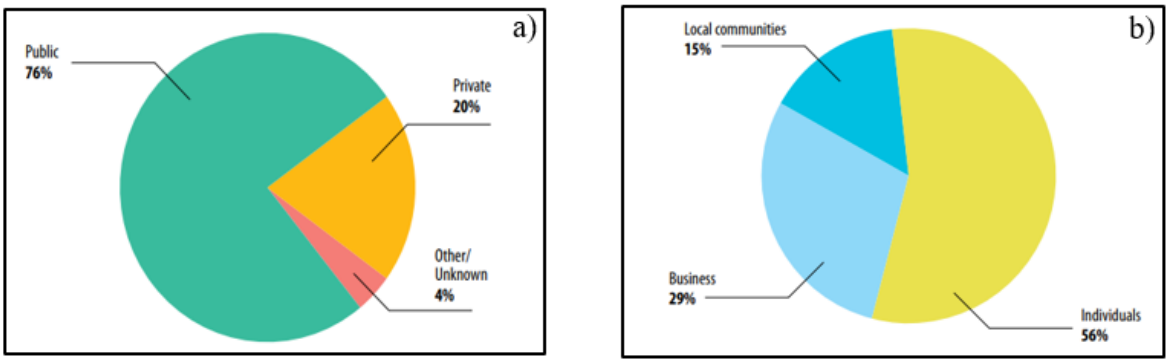

Figure 1. Global forest ownership (a) and breakdown of private holders (b) (Source: FAO 2015)

The other category of private forest ownership includes the individuals or group of owners referred to as non-industrial private forest (NIPF) owners (Follo et al., 2015; Živojinović et al., 2015). These owners are a diversified and dynamic group controlling about 14% of the global forests (FAO, 2018; Zhang et al., 2005). According to Confederation of European Forest Owners 60% of forests in Europe are owned privately by almost 16 million private forest owners (CEPF, 2021; Kang et al., 2020). In many European countries (France, Austria, Portugal, Spain and Slovenia) including Nordic countries (Norway, Sweden, Finland) NIPF owners own more than 50% of the forests (Halder et al., 2014; Lindstad, 2002; Valente et al., 2003; Zivojinovic et al., 2014; Forest Europe, 2015) (Figure 2). According to the assessment of 55 countries constituting mainly temperate and boreal forest resources. The NIPF owners account for 40% of the total forests available for wood supply (UNECE and FAO, 2000). In USA, 63 % of forestland is managed by 11 million private owners, of which 10 million are considered family forest owners. In addition, NIPF owners possess 252 million acres of forestland (USDA, 2008).

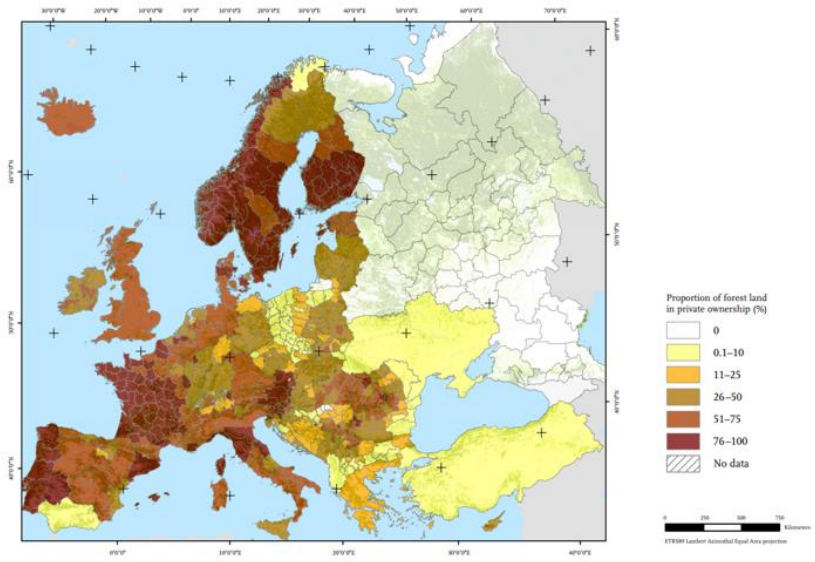

Figure 2. Distribution of private and public ownership across Europe (red-strong private, yellow-strong public) (Pulla et al., 2013; Mauser, 2021)

About 26% of the land area in Norway is covered by productive forest, totaling about 7.0 million hectares (Statistics Norway, 2021). The forest ownership in Norway is dominated by small-scale private, non-industrial owners or so-called family forests. The NIPF owners own approximately 78% of the productive forestland, divided into 118 000 properties (Statistics Norway, 2021a) (Figure 3). 60% of the properties have 50 hectares or less of productive forestland, and these together add up to 22% of the productive forest landbase. More than half of the NIPF properties have not harvested timber for sale during the last fifteen years (Statistics Norway, 2020). However, during the growing harvest volumes since 2009, removals have grown on all size classes and relatively considerably more on smaller than larger properties (Statistic Norway, 2021a).

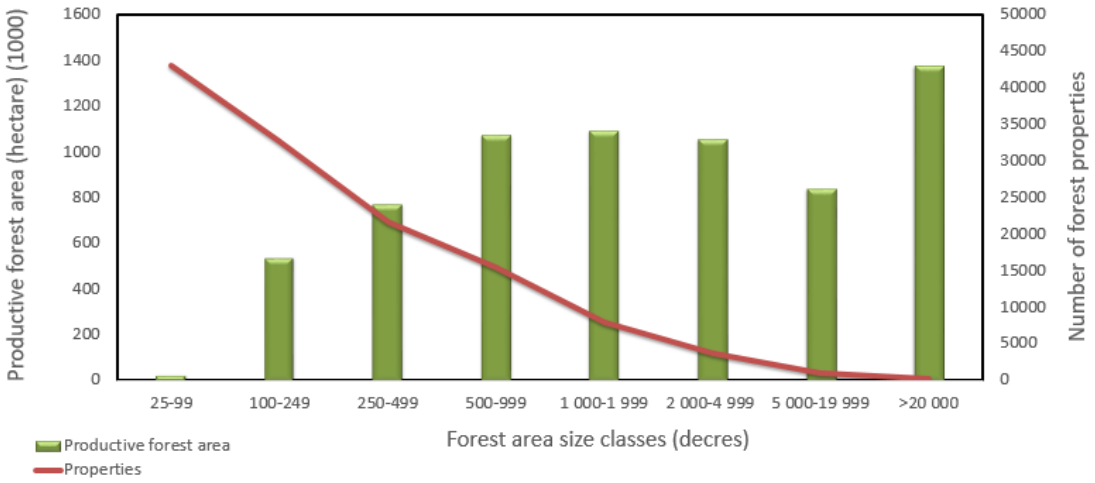

Figure 3. Productive forest area (left axis) and number of properties (right axis) by forest area size classes in Norway (Statistic Norway, 2021a)

Privately owned forests dominate industrial timber supply, contributing to 89% of harvest volumes (Rognstad et al., 2011; Statistic Norway, 2021a). Due to the large base of small-scale properties, only about 15% of the NIPF owners have positive forestry earnings in a given year with the incomes constituting a minor share of the total earnings for the vast majority of owners. For the owners with positive entrepreneurial incomes, the forestry's shares of total earning ranged in 2019 from about 3% (NOK 22 000) for properties smaller than 10 hectares to 21% (NOK 729 000) for the owners with more than 2 000 hectares of productive forest. The average forestry's share of total incomes was 7% (NOK 57 000) (Statistics Norway, 2021b).

The regional forestry cooperatives (member organizations) cover together the whole forest area of Norway and represent about 35 000 family forest owners, with a market share of approximately 80 percent of the domestic timber market (Norwegian Forest Owners' Federation, s.a.). These organizations are important sources of information and practical advices for forest planning and operations for the forest owners that are members. The Ministry of Agriculture and Food has the responsibility for the Forestry Act and forest policy while the county governor supervises the local and regional execution of policies. The first-

line in the forest policy is the municipality's staff, which are the bureaucrats that keep the regular dialogue with the forest owners.

Globally, prominent variations are recorded in ownership, control, and management of forests (FAO 2015, 2020). The social- economic changes and historical and cultural traditions across nations resulted in the substantial diversity for forest owner characteristics, ownership structure and management of forests (Weiss et al., 2019; Wiersum et al., 2005; Forest Europe, 2015; Keskitalo et al., 2017). In addition, many studies stated urbanizations, other avenues of income, and ageing forest owners as certain specific reasons for diversity among forest owners (Schmithüsen and Hirsch, 2010; Živojinović et al., 2015; Bashir et al., 2020). The consequences of these changes are reflected in diverse attitude and behavior of forest owners towards managing their forests (Živojinovic et al., 2015). The increase in the diversity of private forest owners has been recognized globally by policy makers and the forestry sector (Ficko et al., 2019). This diversity of forest owners may present obstacles to lay out proper and efficient strategies or policies for their management but creates mosaic landscapes due to cluster of different management strategies (FAO and UNECE, 2020). The implementation of wide set of forest management approaches improves the forest structure and composition, increases the resilience of forests and provides a more diverse set of FES, including favorable habitat for biodiversity compared to large and homogenous landscapes (Moore and Allen, 1999; Nagaike, 2020).

The NIPF owners are grouped into different categories based on their objectives of managing forests (Majumdar et al., 2007, Häyrinen et al., 2014; Ficko et al., 2019; Ní Dhubháin et al., 2007; Howley, 2013; Feliciano et al., 2017, Bashir et al., 2020). Kuuluvainen et al (1996) used K-means cluster analysis to categorized owners as multiobjective owner, self-employed owners, recreationists, and investors. Karpinnen (1998) and Favada et al (2009) studied management behavior of small-scale forest owners in Finland with similar

classification. A study in USA by Majumdar et al (2007) characterizes family forest owners into three types, multiple-objective, non-timber, and timber oriented, based on their stated reasons for owning forestland. Many studies attempted to modify this classification, such as Trubins et al (2017) and Kline et al (2000) which added terms passive and timber produce owners to this grouping list, respectively. In this PhD study, I also grouped NIPF owners into different classes based on forest owner's objectives for e.g. economists, environmentalist, recreationist and multi-objective oriented.

Overall, NIPF owners constitute a complex, diverse and changing community and control a significant amount of forest area in many countries, including Norway (Weiss et al., 2019, Forest Europe, 2015). These owners also act as the important interface between society and the FES. However, this association gets more complicated due to wide heterogeneity and diverse objectives among NIPF owners. Forest policies place paramount importance to the inclusion of SFM principles in their forest management planning and forests owners are encouraged to adhere to SFM principles to maintain the balance between proper functioning of forests and catering to the growing demands of society. However, implementing this approach is complex and requires proper understanding of the decision-making pathways of forest owners (Gatto et al., 2019; Matta et al., 2009; Serbruyns and Luyssaert, 2006). Therefore, in order to facilitate SFM principles, forest owners' modes of decision-making and attitudes and behavior towards managing their forestland needs to be monitored and better understood for well designing policy formulation and implementation (FAO and UNECE, 2018). In this context, my research strives to provide a greater depth of understanding of how socio-demographic and property characteristics of forest owners and their attitudes affect management decisions as well as the role of multi-objective attitudes and strategies among NIPF owners.

1.3 Research aim and objectives

The overall aim of the PhD project was to achieve better understanding of management decisions of Norwegian NIPF owners. The NIPF owners present a wide diversity in ownership characteristics, personal attributes and motivations and socio-economic status, which strongly influence forest management decisions such as timber harvesting, biodiversity conservation, possessing a forest management plan or seeking information (Bashir et al., 2020; Joshi and Arano, 2009; Kärhä et al., 2020; Kline et al., 2000; Koskela and Karppinen, 2020). *Therefore, in paper I, we analyzed socio-economic factors, owner attitudes and other variables that influence timber-harvesting behavior (decision-making modes) using tobit and two-step probit and linear modelling.* Although timber is the most important FES, however, it is very crucial to give full importance to the biodiversity conservation service of forests as well, because the gradual reduction of biodiversity has profound impact on the ability of forests to produce timber and non-timber benefits for the society (Benz et al., 2020; Kurttila et al., 2001; EEA, 2006; Uliczka et al., 2004). *Therefore, In Paper II, we analysed NIPF owner's questionnaire database to understand their stated knowledge of environmental values in their forests and their attitudes towards nature protection and conservation*. To further improve the flow of FES, more knowledge about the forest resources is a key. To this context, forest plans can be a very important policy instrument for efficient forest management and planning. *In Paper III, we categorised NIPF owners based on their statements of having acquired FP, knowing the content very well and implementing the proposals of the plan.* The forest owners' information level is an important factor in forestry activity and forestry authorities and extension services have implemented several information strategies. However, there is little knowledge about which groups of owners are interesting in more information. A better understanding of the interest among subgroups of owners for more information regarding forest management can aid in tailoring dissemination. *Thus, in paper IV, we*

recognized and categorized NIPF owners based on their information needs regarding management of their forests.

The outline of the thesis synopsis is the following. Section 2 provides a literature review about NIPF owners management decisions, reflecting the themes of my four thesis papers. It reviews some previous empirical studies relevant in this work. Section 3 gives a brief introduction to my study area, survey data sets and the statistical approaches I used in the separate studies, and Section 4 summarizes these results. Lastly, section 5 presents an overall thesis discussion and Chapter 6 enlist the points for future work or directions.

2. Literature review: Factors influencing NIPF owners management decisions

NIPF owners follow multiple decision-making pathways for better management and planning of their forests. The decisions making process includes timber harvesting, timing of harvest and intensity (Bashir et al., 2020; Joshi and Arano, 2009; Lidestav and Ekström, 2000; Petucco et al., 2015), biodiversity and conservation measures (Kline et al., 2000; Koskela and Karppinen, 2020; Selvik, 2004) and their needs for forestry related information (Kärhä et al., 2020; Measells et al., 2005). These decisions taken by NIPF owners will influence the quality and quantity of delivery of FESs to the society. Below, I provide a detailed literature overview of different forest management decisions as influenced by forest owner personal and property characteristics and objectives and reasons for owning forests. This section is sub-divided into four sections, which reflect the themes of my four thesis papers.

2.1 Timber harvesting decision-making

Globally, the management of forests for timber production is one of the most important economic activities performed by NIPF owners. The factors shaping decisions to harvest and supply timber are a result of various forest owners socio-demographic, property and

management characteristics (Bashir et al., 2020; Favada et al., 2009; Joshi and Arano, 2009; Zhang et al., 2005).

Due to higher economic benefits (economies of scale), a positive relationship is evident between timber harvest intensions (supply) and size of the forest holding (Beach et al., 2005; Eggers et al., 2014; Kuuluvainen et al., 1996; Kuuluvainen and Salo, 1991). However, some studies (Bashir et al., 2020; Vokoun et al., 2006) stated that timber harvesting intensity reduced with increasing forest property area. Studies suggest that owners living farther from their properties were negatively correlated with harvest activities (Amacher et al., 2003; Beach et al., 2005) and an increasing share of these owners may result in more decreased forest activities in future (Haugen et al., 2016). Age of the landowner was negatively correlated with timber harvesting (Beach et al., 2005; Kuuluvainen and Salo, 1991) and total volume harvested (Kuuluvainen and Salo, 1991; Lidestav and Berg Lejon, 2013). Conway et al (2003) stated that due to fewer financial limitations (e.g., debts or loans) older forest owners harvest less timber than younger ones. General education was positively associated with harvesting of timber (Beach et al., 2005; Silver et al., 2015) but more weakly to harvesting intensity (Størdal et al., 2008). Farmers with relatively lower income levels are more likely to harvest (Hyberg and Holthausen, 1989; Kuuluvainen et al., 1996), but a study observed that farmers are less inclined towards harvesting of timber (Kuuluvainen and Salo, 1991). In many studies, harvesting and silvicultural activities were less common on properties owned by women (Côté et al., 2017; Lidestav and Berg Lejon, 2013). However, we found that female forest owners in Norway harvested more timber than male forest owners from a period of 2003 to 2012 (Paper I) and Kuuluvainen et al (2014) observed that female owners harvested timber less frequently, but at larger quantities, compared to male owners. The probability of timber harvest was positively correlated with present timber prices (Kuuluvainen et al., 1996; Zhao et al., 2020) but negatively correlated with future (predicted) timber prices (Prestemon and Wear, 2000; Zhang et al., 2005).

Favada et al (2009) observed forest owners with interests in recreational activities harvest less timber. Whereas, Howley (2013) and Jennings and van Putten (2006) found forest owners actively harvesting timber when valuing forests solely for economic objectives. In addition, the forest owners in the United States (Oregon) with primarily economic motivations required more incentives to forgo timber harvesting in comparison to multi-objective oriented owners (Kline et al., 2000).

2.2 Environmental knowledge and conservation attitudes of NIPF owners

An increase in the heterogeneity of NIPF owners resulted in the diversification of management goals in which environmental conservation was considered an important objective (Gustafsson et al., 2020; Joa and Schraml, 2020; Matta et al., 2009; Weiss et al., 2019). Many studies highlighted that forest owner's socioeconomic situation, property characteristics, objectives of owning forests, knowledge and level of education influenced their environmental conservation attitude and behaviour (Joa and Schraml, 2020; Koskela and Karppinen, 2021; Langpap and Wu, 2004; Mitani and Lindhjem, 2015).

Forest owners's age was positively correlated with participation in conservation programs (Langpap and Wu, 2004; Mitani and Lindhjem, 2015). Young forest owners were observed to be more biocentric (Uliczka et al., 2004) and willing to participate in pro-environmental and conservation activities (Chen et al., 2011). Gender differences were evident in attitudes towards nature and environmental values of forests (Hayrinen et al., 2015; Nordlund and Westin, 2011). Female forest owners possessed higher intentions for environmental sustainability (Chekima et al., 2016; Pradhan et al., 2019) and encouraged protection of forest biodiversity than male owners. Participation in forest conservation programs increased with size of forest (Langpap, 2006), however, (Uliczka et al., 2004) observed no effect of this and (Langpap and Wu, 2004; Mitani and Lindhjem, 2015) found

negative correlation. Forest owners living far from their forest were willing to perform additional activities for environmental conservation (Danley et al., 2021; Hayrinen et al., 2015; Mitani and Lindhjem, 2015; Nordlund and Westin, 2011). Whereas, observed onsite forest owners possess higher probability of delegating area for conservation. Forest owners with high general education or environmental knowledge assign greater importance to environmental considerations (Beach et al., 2005; Danley et al., 2021; Drescher et al., 2017; Hayrinen et al., 2015; Koskela and Karppinen, 2020; Uliczka et al., 2004). Overall, environmental motives and attitude encourage forest owners to participate in forest conservation programs demanding minimal compensation claims for biodiversity protection (Gren and Carlsson, 2012; Koskela and Karppinen, 2020).

2.3 Forest plans as management tool

Forest plan (FP) ensure sustainable forest management through effective participation of forest owners in strategic and operational decisions making processes (Brukas and Sallnäs, 2012; Ficko and Boncina, 2015; Nagaike, 2020; Stojanovska et al., 2014). FPs also provide an efficient course of action for implementation of various local and national forest management regulations and policies to meet specific environmental, economic and social objectives (Ficko 2019; Stojanovska et al., 2014). Therefore, FPs serves as an essential instrument to balance these multiple but competing services of the forest ecosystem landscape (Brukas and Sallnäs, 2012). As stated by Brukas and Sallnäs (2012), FPs operate as a combined approach consisting of carrot or stick and sermon system. The stick approach will follow more of a regulatory or compulsory system, which can be supplemented with a carrot approach of including subsidies, tax deductions or financial assistance. Furthermore, FP (as sermons) can be useful tool to encourage forest owners towards desirable forest management practices by providing necessary information to forest owners. Thus, a well-defined FP is very

important but works in conjunction with a forest owner's willingness to acquire the plan, and being well versed with the content of the FP and lastly, their willingness to implement the proposal of the plan effectively on their property (Paper III).

According to many studies, because of the economies of scale the owners with larger property are keen to perform forest management activities on their land base (Beach et al., 2005; Ficko, 2019; Pan et al., 2007). Research has found that female forest owners were less likely to manage their property (Butler et al., 2018). However many studies stated that educated, urban female forest owners are keen on improving their forest management decision making. (Kilgore et al., 2015) in the USA found that owners with some form of assistance, or advice are more active in managing their forestland. However, while FPs are considered important informational instruments by Swedish forest owners, they are considered as regulatory tool in Lithuania (Brukas and Sallnas 2012). However, FPs were associated with higher costs and institutionalized corruption in Lithuania. In Eastern and Central European countries FPs are considered as an essential tool for forest planning (Bouriaud et al., 2013). Similarly, in Slovenia 55 % of private forest owners think of FPs as an important decision-support instrument (Ficko and Boncina, 2015). In Spain, 89% of participants were in favor of the having a FP for better management of forest resources (Bruña-García and Marey-Pérez, 2017). However, a number of studies have observed that private forest owners lack information and awareness about management and planning for forest sustainability (Erickson et al., 2002; Eyvindson et al., 2019). The studies in USA and France suggest that only 3-6% of forest owners possess written FPs or other official document specifically dedicated to forest management (Agreste, 2013; Butler, 2008).

2.4 Information needs of NIPF owners

The magnitude and quality of information needs vary widely across the cohorts of NIPF owners (Schubert and Mayer, 2012). The personal, property, and sociodemographic characteristics of NIPF owners and their objectives of managing forest strongly influence the impact, source and need of information among NIPF owners (Rouleau et al., 2016). The approach to cater the information needs should be dynamic because of the diversity among forest owners is increasing for forest values, reason of owning forests and pathway of forest management (Blanco et al., 2015; Eriksson and Fries, 2020).

Many studies (Butler et al., 2018; Côté et al., 2017; Karppinen, 2012; Nordlund and Westin, 2011) concluded that female forest owners are hesitant to be enrolled in any information dissemination programs. However, other studies mentioned that female forest owners are keen to receive more information to support their decision-making in managing forestlands. Butler et al (2018) observed that forest owners with higher education participate in educational and information programs. Additionally, owners with smaller forest areas and those living far from their property properties were inclined to participate in the outreach initiative (McCuen et al., 2013). Butler et al (2017) recommended that older forest owners might need more information because they are more likely to sell the land. Whereas, (McGrath et al., 2020) suggested that older owners are usually members of forest organization and keen to enroll in forestry programmes. Forestry extension activities were deemed important channels of fulfilling information needs among forest owners (Kittredge, 2004; Kueper et al., 2014; Measells et al., 2005). Dhubháin et al., (2010) suggest that forest owners who attend extension activities are more likely to thin their forest. Several studies suggest that peer networks can be utilized efficiently as a source for information dissemination to influence proper forest management strategies by NIPF (Kueper et al., 2014; Lind-Riehl et al., 2015; Schubert and Mayer, 2012)

Social networks signified a useful medium to improve information dispersal among NIPF owners for better management of forests (Kueper et al., 2014). Ruseva et al., (2014) suggested that forest owners with higher social ties were more actively managing forestland. A number of studies considered personal contacts with trusted professional advisors, print media from forest organizations, as well as courses and excursions as the most important sources for information about forestry (Hannerz et al., 2010; Hujala and Tikkanen, 2008).

Digital modes of communication may speed up the information dissemination among NIPF owners, particularly young, educated owners (Pynnönen et al., 2021) but older ones may struggle to connect because of their age (Kueper et al., 2014) and the internet still ranks lower than traditional channels for the spread of information (VanBrakle, 2015).

3. Methodology for the study

3.1 Study area

Norway has a large forested area covering 122,000 km^2 and constituting 38 percent of the land area (Fig 3). Approximately 86,600 km^2 of this is productive forestland, representing 26% of the total land area (NMCE, 2020; Ministry of Agriculture and Food, 2018).

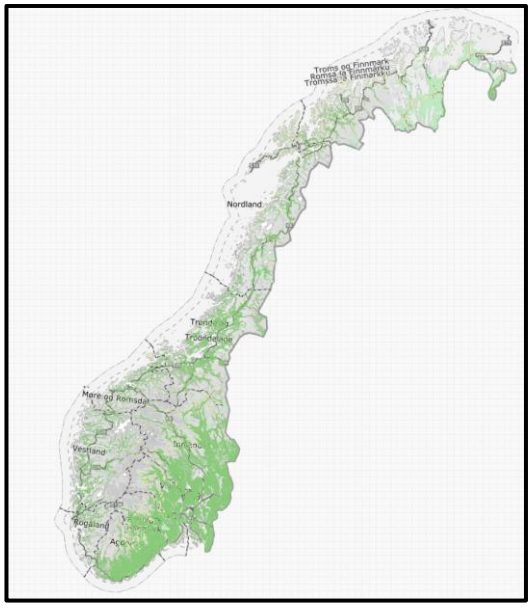

Figure 4. Map of counties with forest resources in Norway (kilden.nibio.no)

The forests of Norway possess a significant variation in topography and productivity (NMCE, 2020). The most predominant and important tree species found in Norway are the Norway Spruce (*Picea abies*) (47%), Scots Pine (*Pinus sylvestris*) (33%) and birch (*Betulaceae*) (18%). These three species comprise about 92% of the total forest area (Statistics Norway, 2021; Larsson and Hylen, 2007; NMCE 2020). The rest 8% of the forest species mainly comprises of other broad-leaved (NMCE, 2020).

Norwegian forests provide different services such as timber, protection functions, recreation and aesthetics. The forest industry plays an important role in the rural economy by providing jobs and export earnings, accounting for about 25,000 people working in the forest-based value chain (Ministry of Agriculture and Food, 2018; NMCE, 2020). Norwegian forests capture (net growth) annually about 30 million tons CO_2, which correspond to 45-50% of the anthropogenic greenhouse gas emissions in the country (NMCE, 2020; Statistics Norway, 2021; Statistics Norway, 2018), and there is potentials for carbon sequestration to be increased substantially. According to an estimate for the next 100 years, forest management measures could increase sequestration of CO_2 by up to 12.3 million tons per year compared to a reference scenario (Norwegian Climate and Pollution Agency, 2010).

The active forest management policy in Norway over the last 60-70 years has resulted in a steady increase in the growing stock of trees by around 30 per cent (since 1990) (NMCE, 2020). This resulted a net annual forest growth of about 24 million cubic meters (2015-2019) while removals averaged 11.1 million cubic meters in the years (1996-2019) (NMCE, 2020; Statistics Norway, 2021; Figure 3).

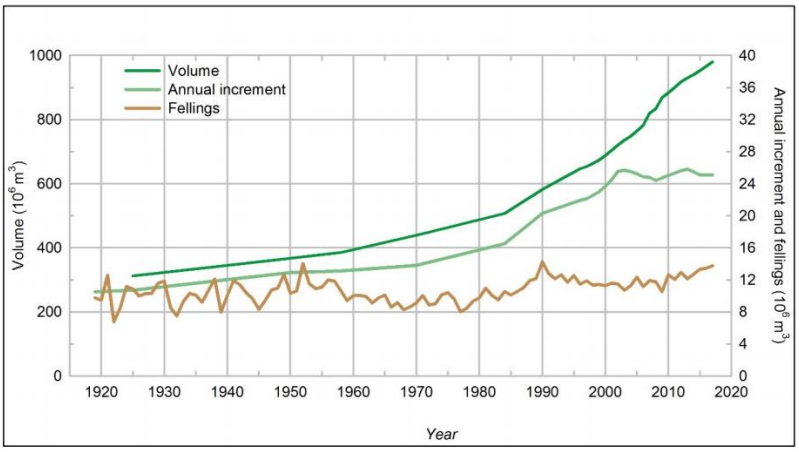

Figure 5. Forest fellings, annual increment and volume, 1919–2016 (Source: NIR 2018, Norwegian Institute of Bioeconomy Research and Statistics Norway)

3.2 Survey questionnaire (database)

The main questionnaire based dataset utilized in the study originates from a national survey of NIPF owners. The survey questionnaire is developed and distributed across Norway by Statistic Norway in close collaboration with the Norwegian University of Life Sciences. The survey instrument was developed with the aim of collecting comprehensive country-wide information on NIPF landowners' socioeconomic, personal and property characteristics, in addition to questions related to attitudes, reasons for owning forests and the owner's own judgement of their knowledge of environmental values in their forests. In this survey, two populations of private individual forest owners were created: *Active owners* and *Inactive owners*. The NIPF owners were divided into two groups based on quantity of timber harvested during the period 1998-2012. Active owners had harvested at least 5 m^3 of timber for sale during this period whereas Inactive had harvested less than that summed over those fifteen years. The Statistic Norway categorizes private forest owners into different size classes based on forest area, and the minimum cut off required is more than 2.49 hectares of forest property size. Therefore, only owners having more than 2.49 hectares of forest property were included in the study (Sjølie et al., 2019). Out of the population of 55 965 active forest

owners, a gross sample of 1500 was drawn. A gross sample of 1650 was drawn from the population of the 72 147 inactive owners.

The questionnaire in collaboration with Statistics Norway was developed first for active forest owners and thereafter altered to accommodate inactive NIPF owners by excluding irrelevant questions and adapting others (Sjølie et al., 2019). The questionnaire included about 60 questions divided over 5 sections covering: 1) general information about the property and the owner, used for grouping the respondents; 2) attitudes to the forest and motives for the ownership; 3) information strategy, i.e. whom to turn to for advices on forestry issues, and which channels are used to obtain information. Three strata dimensions were used to create the samples i.e., activity (Active/Inactive), county (18) and size class (seven). Statistics Norway additionally added owner and property-level register data for each of the last fifteen years, including income, asset value and annual harvest, as well as forest area. In addition, the survey data for each forest owner were supplemented by annual data on taxable income, taxable wealth and timber harvest volume, as provided by the Norwegian Statistical Bureau. The county Finnmark was not included in the study because of very limited amount of private forest land. All returned questionnaires were scanned and digitally read and open questions manually read. The Total Design Method developed by Dillman (1978) as a general framework was employed for developing and implementing the survey effectively. The survey questionnaire was distributed by surface mail in February 2014 to the randomly selected sample of NIPF owners. Two reminders with the questionnaire enclosed were mailed after one and two months, respectively. Data collection ended in June 2014. To improve the setup of the survey a pre-testing was done and the questions were altered based on the feedback. For the Paper I, a panel data set for the years 2003-2012 of forest area, harvest and incomes figures from the nationwide property and tax registers was appended with data from the questionnaires.

3.3 Theoretical and modelling framework

In paper I, we modelled the decisions of NIPF owners' as a utility-maximizing behaviour explained by a set of observable owner specific factors (Amacher et al., 2003; Conway et al., 2003). The factors that influence timber harvesting were grouped as set of four vectors: forest owner and property characteristics, management characteristics, and timber.

Table 1. Provides detailed description about theoretical, modelling framework and statistical approach adopted for each paper in the thesis

Study	Theoretical framework	Statistical approach	Dependent Variable
Paper I*	Utility maximization $(U_{it} = f(O, P, M, \mathrm{T}) + e_{it})$	**Step 1** = Probit analysis $P(Y_{it} = 1) = \Phi(X_{it}\beta + \varepsilon_{it})$ + Linear model $Y'_{it} = X_{it}\gamma + \varepsilon_{it}$ **Step 2** = Tobit model $T_{it} = T_{it}^{*} = \beta' x_{it} + \varepsilon_{it}$	Probit model: Binary variable, indicate that if timber harvested for sale = 1; Has not = 0 Linear model: Continuous variable includes only the forest owners' harvested timber for sale. Tobit model: Censored variable includes all forest owners, where 0 values imply forest owners not harvested any timber in a particular given year.
Paper II**	Social cognitive hierarchy model Knowledge of environmental values $KE_i = f(S, I,) + e_i$ Protecting and conserving nature's diversity $ND_i = f(KE, S, I, EF) + e_i$ Nature preservation $NP_i = f(KE, S, I, EF) + e_i$	Probit analysis $P(Y_i = 1) = \Phi(\beta_0 + \beta_1 X) + \epsilon_i$	KE: 1 if the respondent answer "correspond rather well" or "correspond very well" to the statement: "I know the environmental values of my forest"; 0 if the respondent answer "doesn't correspond at all" or "correspond slightly" ND: 1 if the respondent answer "of relatively great importance" to "very important" to the statement "My forest provides me the opportunity to protect and preserve nature's diversity" ; 0 if the respondent answer "not important at all" or "slightly important" NP: 1 if the respondent answer "of relatively great importance" to "very important" to the statement "My forest is first and foremost a nature preservation object for me" ; 0 if the respondent answer "not important at all" or "slightly important"
Paper III	Combination of decision tress and regression modeling Two-stage procedures. Stage 1: In the first step, the respondents' answers on the question of having a FP were analyzed.	Two step process Step 1: classification decision trees Step 2: Probit analysis $P(Y_i = 1) = \Phi(\beta_0 + \beta_1 X) + \epsilon_i$	FP: 1 if the respondent answer "Yes" to the statement: "Do you have a forest plan for your property"; 0 if the respondent answer "No" or "Don't know" ContentFP: 1 if the respondent answer "correspond rather well" or "correspond very well" to the statement: "I know the content of the forest plan well"; 0 if the respondent answer "doesn't correspond at all" or "correspond slightly"

	Stage 2: self-reported knowledge of the content and implementation of the FP was analyzed (sample consisted of only forest owners indicated having FP)		ImplementFP: 1 if the respondent answer "correspond rather well" or "correspond very well" to the statement: "I implement the proposals from the forest plan"; 0 if the respondent answer "doesn't correspond at all" or "correspond slightly"
Paper IV	Two separate empirical models, were developed to examine willingness of NIPF owners to receive more information for improving 1) environmental value of forest 2) forest activity	Probit analysis $P(Y_i = 1) = \Phi(\beta_0 + \beta_1 X) + \epsilon_i$	Environmental value of forest: it equals 1 if a landowner associates "correspond rather well to corresponds very well" to the statement "I need more information about the environmental values in my forestland" 0 otherwise. Information to increase forest activity: it equals 1 if a landowner "Agree a little to Agree completely" to the statement "With more/better information, I could have increased the activity level in my forest" and 0 otherwise.

* For utility model; where U_i is owner i's utility in period t of harvesting or not and O, P, M, and T are vectors of factors influencing the decision to harvest or not: of forest owner characteristics (O), property characteristics (P), management characteristics (M), and timber price (T), and e is a random error term. For probit model; where X_{it} and β represent vectors of independent variables and coefficients, respectively, Φ denotes the cumulative normal distribution, and ε_{it} is the error term. For linear regression model; where Y' it is the dependent variable harvest (m^3 ha^{-1} $year^{-1}$) supplied by owner i in period t, X_{it} is a vector of explanatory variables, and ε_{it} is the error varying over i and t. For Tobit model; where T_{it}* is the latent potential timber supply, T_{it} is the observed timber supply (non-negative) of owner i in year t. x_{it} and β are corresponding vectors of independent variables and coefficients, respectively. The error term ε_{it} is normally and independently distributed with a mean zero and a common variance.

** where Φ denote the cumulative normal distribution, β_0 and β1 are coefficients of the probit regression models and ε_{it} is the error term. where KE_i is the level of knowledge of the forest environmental values stated by forest owner i, S_i the social factors influencing forest owner i, I_i the information sources used by forest owner i, EF_i the economic factors characterizing forest owner i, ND_i and NP_i the attitudes of forest owner i towards nature diversity and nature preservation, respectively, and e_i is error term.

Two statistical pathways were carried out: first the two-stage regression analysis with a binary probit and linear regression, and followed by a tobit (censored) regression analysis. The tobit and probit models are structurally identical but tobit model has more information associated with it compared to probit model. In our sample, nearly 85% of the observations on timber harvest were recorded zero. As the dependent variable was regarded as censored, therefore, tobit model was applied for the analysis (Favada et al., 2009).

For paper II, we utilized a conceptual framework of the knowledge-attitudes relationships to draw the social cognitive hierarchy model (Fig. 6) (McFarlane and Boxall, 2003). The model specified that knowledge, information and socialization influences are important predictors for attitudes. The first objective of ownership presented to the forest owners in the survey was '*My forest provides me the opportunity to protect and preserve nature's diversity*' which is a strategy compatible with other ownership objectives. The second

objective, '*the forest is first and foremost a nature preservation object*,' puts nature preservation as a primary objective.

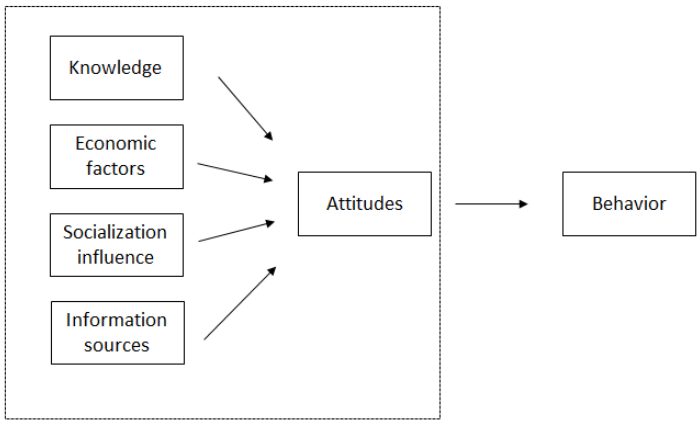

Figure 6. Conceptual framework of the knowledge-attitude modelled relationship. Dotted line presents the analyzed part the framework in this work

In this study, firstly, we hypotheses that socialization and information factors influence the level of knowledge of environmental values among individual NIPF owners. Secondly, the knowledge of environmental factors, together with information, socialization and economic factors explain forest owner's attitudes towards environmental conservation (the two objectives protecting and conserving nature's diversity and nature preservation). The model was expanded to include social and economic factors as predictors. For the statistical estimation, we used probit regression models due to the binary nature of the three dependent variables (Table 1).

In paper III, each of the decision tree (DT) and regression models were analyzed in two-stages representing the pathway for the FP for managing forests. In the first step, the respondents that answered the question of having a FP in the survey were analyzed. In the second stage, only owners that indicated having FP in the first stage were included and analyzed for two outcomes: self-reported knowledge of the content of their FP and implementation of the FP. For this study, we assumed that the role of FP for the individual forest owner is steered by owner and property characteristics as well as the social context. For

the DT, we examined a wide set of variables related to the property, demographic and socio-economic factors and attitudes, sources of information, future plans for the property to understand which groups of owners acquire FP, know the content well and implement the plans. The significant variables from DT were used to build the regression models.

In paper IV, we used probit regression to examine the relationship between the dependent variable and a set of independent variables in two models. The willingness of NIPF owners to receive more information on knowledge about environmental value of their forest and increasing forest activity were examined by using two separate probit models. The first dependent variable represents NIPF owners' willingness to receive more information on environmental value of their forests, it equals 1 if a landowner associates "correspond rather well to very well" to the statement "I need more information about the environmental value in my forests" and 0 otherwise (does not correspond at all to correspond slightly). Likewise, the second dependent variable also had two levels in terms of NIPF landowners' interests to receive better information to increase forest activity on their forest land. It equals 1 if a landowner "agree a little to agree completely" to the statement "with more/better information, I could have increased the activity level in my forest" and 0 otherwise (disagree completely to disagree a little). The empirical models also include a number of explanatory variables measuring socio-demographics and property characteristics, ownership characteristics, past management decisions and information sources. In binary regression, probabilities are assigned to each of the two possible outcomes. To obtain a valid explanation of explanatory variables, marginal effects were computed for each explanatory variable.

The survey (questionnaire) dataset utilized for the study contained missing values, as several of the NIPF owners' responses were incomplete. The issue of receiving incomplete surveys leads to a database with missing information. The missing values in our survey database varied from 5 to 20% across all the variables. As the deletion of an entire respondent due to

incomplete information will lead to loss of information and may cause biased results (King et al., 2001). We employed a multiple imputation procedure to fill the missing values in our dataset (King et al., 2001; Schafer and Graham, 2002). In the imputation method, the value for missing observation is calculated based on the estimates of observed values (King et al., 2001) Schafer and Graham, 2002). We created multiple datasets using the R package mice and combined the results of the imputed datasets (van Buuren and Groothuis-Oudshoorn, 2011). The imputed datasets were then used to perform regression analysis in probit, linear, and tobit model. In the following, all results refer to the imputed datasets. All statistical analysis employed in the study were performed using the R software (R Core Team, 2018).

For each study, we initiated data analysis by evaluating all pairwise correlations in order to exclude or group highly correlated variables based on a correlation coefficient value > 0.4. We log-transformed several independent and dependent variables to achieve symmetry in the central distribution of data (Cohen, 2013; Pek et al., 2018) and regression models were tested for multicollinearity using a variance inflation factor (Allison, 1999). Before statistical analyses were initiated for each study, all observations were weighted according to county and property sizes. Table 2 provides a list of statistical approaches carried out in each separate study.

Table 2. List of statistical methods employed in each separate study

Statistical approaches	**Paper I**	**Paper II**	**Paper III**	**Paper IV**
Correlation matrix	✓	✓	✓	✓
Linear regression	✓	×	×	×
Probit model regression	✓	✓	✓	✓
Tobit model regression	✓	×	×	×
T-test	×	×	✓	×
Principal component analysis	×	×	✓	×
Classification tree analysis	×	×	✓	×

4. Summary of study results

4.1 Descriptive statistics of survey dataset

From a total of 1500 and 1650 questionnaires sent to active and inactive forest owners, 842 and 795 questionnaires were returned, respectively. The adjusted response rates were 56% and 49% for the Active and Inactive owner samples respectively, and 52 % for all owners after accounting for non-deliverables and non-responses. The presented figures are based on weighted responses. The mean age was 58.3 years for all forest owners. However, the mean age was 53 years using the panel data in Paper I, as the age of forest owners for these analyses were calculated year-by-year from 2003 to 2012. In the survey dataset, 25% of the respondents were female and 75% male. The mean forest holding size was 49.6 ha for NIPF owners, with average distance of 56.7 km between residence and the forest property. During the years 1998-2012, 44% of the respondents had harvested (at least once) more than $5m^3$ of timber for sale. Furthermore, 59% of the respondents visited the forest more than once per year. Almost 40 % of the respondents had a bachelor degree or higher, while almost a quarter of the owners (23%) had forestry or agricultural-related education. In addition, 22% had registered environmental values on their forest property. For advice and suggestions related to forestry issues on their property, approximately half of the NIPF owners had direct contact with the forestry section in their municipality. The respondents that agreed media and peers as important sources of information for the management of their forests were 15% and 23%, respectively.

4.2 Paper I: Timber harvesting decision and intensity

In this study, we provided a better understanding of Norwegian non-industrial private forest owners' timber harvesting decisions by analyzing survey outcomes and comparing the answers using two different statistical approaches i.e., a combination of probit-linear models

with tobit model.

Table 3. Parameter estimates and marginal effects of the Probit model in the period 2003-2012 (N = 16370 over 10 year)

Factor	Estimate	Marginal effects
Age	-0.002	-0.0002
Gender	0.108**	0.0136
General education	0.071*	0.0091
Size of forest property	0.266***	0.0343
Distance from the property	-0.040***	-0.0052
Gross income	0.017	-0.0024
Taxable net wealth	-0.001	-0.0100
Real timber prices	0.024	0.0035
Knowledge of the forest fund	0.830***	0.1149
Visits to forest land for activity	0.341***	0.0455
Interest in buying more forests	0.100**	0.0127
Plan to sell/transfer	0.143***	0.0187
Social objectives	0.040***	0.0050
Financial objectives	0.099***	0.1243
Conservation objectives	-0.062***	-0.0076
Recreation objectives	-0.020***	-0.0023
Constant	-3.539***	
Pseudo R^2	0.45	

*Significant at 10% level, **Significant at 5% level, ***Significant at 1% level

The study results revealed that age, income, wealth, and timber price were the only non-significant (*p*-value > 0.10) variables included in the probit model. Highly educated forest owners with good knowledge of the Forest Fund and with an interest in buying more forest property were more inclined towards harvesting. Knowledge of the Forest Fund and

financial objectives had the most significant impacts on the willingness to harvest in the probit model, with marginal effects of 11 and 12 %, respectively.

Once owners decided to harvest, age and timber price had an impact on the harvest levels, with age inversely influencing harvest volume, whereas higher timber prices elevated the quantity of harvest. In addition, gender factors tended to remain significant in determining harvest volumes even after the owner had decided to harvest according to the probit model.

7 out of the 16 explanatory variables significantly influenced the timber harvesting behavior of NIPF owners in the tobit model. Being a female forest owner and owning forests for financial objectives increased the supply of timber by 1.85 m^3 ha^{-1} $year^{-1}$ and 1.25 m^3 ha^{-1} $year^{-1}$, respectively. The timber price was significant with an elasticity of 1.18, indicating that 1% increase in timber price elevated timber harvest by 1.18%.

Knowledge of the Forest Fund and frequent visits to their forest inclined forest owners towards timber harvest. These results were similar to the probit but contrary to the linear model. Gender and owning forest for financial benefits significantly influenced harvesting behavior of forest owner across all three statistical models. Valuing forests for conservation objectives by forest owners restricted timber harvesting to 1.23 m^3 ha^{-1} less than other owners. With a 1% increase in forest owner income, the supply of timber was raised by 1.35 m^3 ha^{-1}. The variables forest area, distance to forest property, and education were not significant in the tobit model, contrary to the probit and linear model. In the linear model (elasticity 1.18) and tobit model (elasticity 0.66) timber prices were significant, whereas they were non-significant in the probit model. In this paper, we constructed and presented the tobit and two-step logit/probit and linear modeling statistical approaches. Both models present a different decision-making scenario for forest owner. Furthermore, these decision-making platforms could be performed in specific context and that needs more research and analysis.

Table 4. Parameter estimates of the linear model and tobit model in the period 2003-2012

	linear model (N = 2682)		Tobit model (N = 16370)	
Factor	Estimate	Std. Error	Estimate	Std. Error
Age	-0.007**	0.002	-0.009	0.005
Gender	0.392***	0.064	0.618**	0.196
General education	0.255***	0.566	0.153	0.147
Size of forest property	-0.739***	0.022	0.106	0.089
Distance from the property	0.062***	0.017	-0.071	0.043
Gross income	0.224***	0.065	0.288***	0.069
Taxable net wealth	0.020***	0.003	-0.197	0.709
Real timber prices	1.176***	0.128	0.658***	0.199
Knowledge of the forest fund	0.133	0.130	2.512***	0.258
Visits to forest land for activity	0.065	0.099	0.804***	0.222
Interest in buying more forests	-0.079	0.067	0.192	0.198
Plan to sell/transfer	0.151**	0.054	0.212	0.139
Social objectives	-0.029	0.019	0.110	0.062
Financial objectives	0.104***	0.015	0.229***	0.042
Conservation objectives	-0.023	0.022	-0.179***	0.046
Recreation objectives	0.016	0.011	-0.040	0.031
R^2	0.38		0.09	2.986
Constant			-12.098***	
Log-likelihood			-6999.85	

*Significant at 10% level, **Significant at 5% level, ***Significant at 1% level

4.3 Paper II: Environmental knowledge and conservation

Here, I was interested in obtaining a better understanding of NIPF owners' knowledge of environmental values and their attitudes towards environmental conservation. To the statement, "I know the environmental values of my forest" 35% of forest owners, replied,

"Correspond rather well" to "very well". 53% of the respondents stated that "Protect and conserve nature's diversity" as an important reason for owning forest, while only 19% stated "The forest being first and foremost a nature preservation object".

The results of the probit model for environmental knowledge shows that the variable 'Registered environment values' has the marginal effect of 0.276. This indicates that if the owner had registered the environmental values in their forests, the probability of the forest owner to possess knowledge of environmental values increased by 27.6 %, all other factors being equal. The results of the probit model also suggest that variables such as Forest harvest activity, Size of forest property, Visits to forest, Environmental knowledge, Media and professional journals, Centrality (according to the municipality of residence of the forest owner) and Direct contact with municipality significantly affected the attitude of forest owners towards nature diversity. The marginal effects indicated that Environmental knowledge (11%) and Media and professional journals (13.5%) stood out as the variables affecting the attitudes of forest owners towards nature diversity the most. In contrast, active forest owners were negatively correlated, with 9.1 % lower probability of owning forest for diversity objectives than inactive owners.

The three variables significant towards nature preservation in the probit model were Age, Forest harvest activity, and Environmental knowledge. The results show that older forest owners prefer owning forest for nature preservation, and if the age increases by 1 year, the probability of having nature preservation as a main objective increased by 0.36%. Also, forest owners possessing knowledge of environmental values in their forest have a 6.1% increased chance to own forest for nature preservation. However, being an active forest owner reduced this probability by 6.8%.

Table 5. Marginal effects of variables used in the probit models that analyze variables influencing private forest owner's stated level of knowledge of environmental values in their forest and attitude towards owning forests for nature diversity and nature preservation

Variables	Knowledge of environmental value of forests	Nature diversity	Nature preservation
	Marg. eff	Marg. eff	Marg. eff
Age (Years)	-0.0001	0.0004	0.0036***
Gender	-0.0654*	0.0359	-0.0032
Education	0.0131	-	-
Forest harvest activity	0.0798***	-0.0912***	-0.0685**
Gross income (M NOK)+	-	-0.0700	-0.0312
Taxable net wealth (M NOK)+	-	-0.0036	-0.0003
Size of forest property (ha)	-	0.0400***	0.0009
Distance from the property to residence (km)	-	-0.0099	-0.0061
Visits to forest land for activity	0.1199***	0.0550*	0.0013
Registered environment values	0.2762***	-	-
Media and professional journals	0.0553	0.1350***	0.0433
Direct contact with municipality	0.0699***	0.0378*	-0.0079
Forestry or agricultural education	0.1018***	0.0016	-0.0389
Environmental knowledge	-	0.1102***	0.0610**
Farming	0.0156	-0.0341	-0.0450
Centrality	-	0.0218*	0.0111

+ In 2017 the exchange rate were 9.33 NOK per euro, and 8.26 NOK per USD
*Significant at 10% level, **Significant at 5% level, ***Significant at 1% level

4.4 Paper III: Forest plan: acquisition, knowledge and implementation

The survey data collected in 2014 was utilized to quantify the impact of non-industrial private forest owner's attitudes, sociodemographic characteristics, objectives and motivations for managing forests on a pathway towards a FP i.e. acquisition of a FP, awareness of its content, and finally its implementation on the property. The results of the study indicate that 37 % of NIPF owners answered "Yes" to having a FP. Among the owners with a FP, 66 % of forest owners corresponded 'rather well' to 'very well' for having knowledge about the FP contents. However, a lesser number of forest owners (40 %) that possessed a FP agreed to implement the proposals of the FP on their property. All variables except for taxable net wealth were significantly different between the sample of owners with a FP and without a FP. We also employed a dimensionality reduction procedure principal component analysis to merge 12 correlated statements into three principal components accounting for 65% of the variance in the data (Fig 6).

Table 6. Principal component analysis summary statistics for reasons for owning forests

	Rotated principal component loading		
Variable	PC1 (Multiobjective) (MO)	PC2 (Economic) ECON)	PC3 (Environmentalist) (ENV)
LEISURE	**0.757**	-0.207	-0.025
HUNT	**0.590**	-0.018	0.119
NATURE	**0.806**	-0.267	0.117
DIVERSITY	**0.722**	-0.294	**0.306**
PRESERVE	**0.441**	-0.411	**0.433**
INCOME	**0.463**	**0.768**	0.092
ECON_SEC	**0.493**	**0.747**	0.169
INVEST	**0.488**	**0.622**	0.206
INTRINSIC	**0.670**	0.086	-0.567
INHERITANCE	**0.627**	-0.016	-0.562
RELAX	**0.785**	-0.275	0.012
NATIVE	**0.604**	-0.136	-0.102
Variance	4.827	2.009	1.020
% of Variance	40.223	16.738	8.500
Cumulative % of variance	40.223	56.962	65.461

The three selected PCs had an eigenvalue greater than one and are interpreted as three groups of NIPF owners, labelled as Multi-objective, Economist and Environmentalist. These three groups of forest owners were then included in the DT and probit models for analysis. We utilized a combined approach of conditional classification decision tree and logistic regression analysis to visualize and quantify variables explaining forest owners' behavior towards FP. The variables harvest activity, productive area, contact with forest section of municipality, knowledge of public schemes for forestry, county group and agreeing that a FP accommodates

their objectives strongly influenced the FP acquisition, knowledge of its content and its implementation in both DTs (Fig 7-9) and regression models.

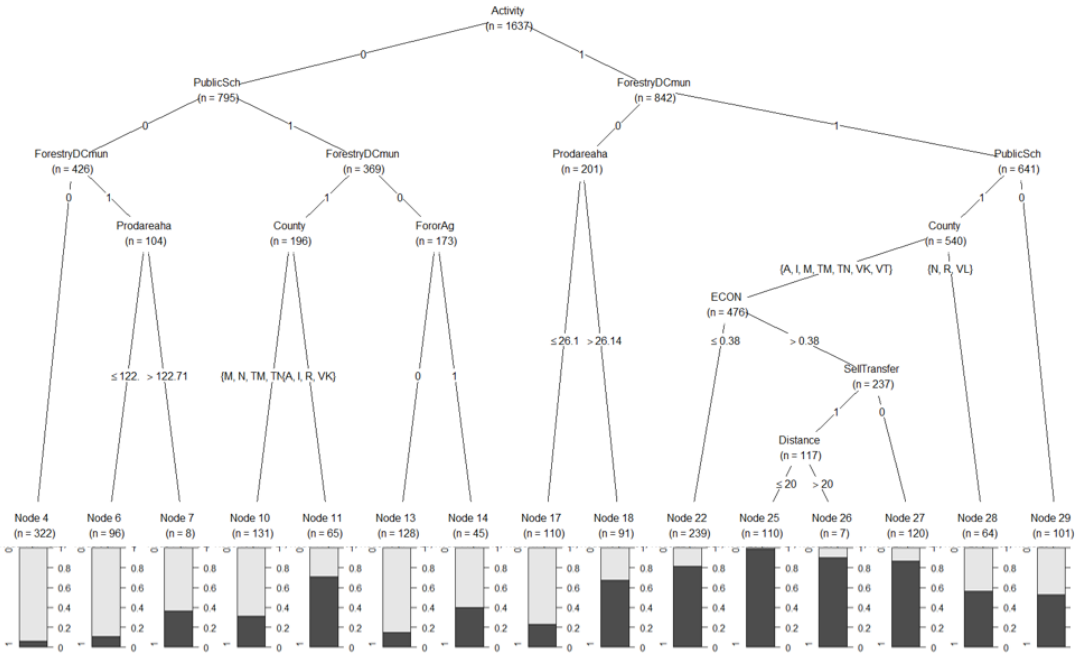

Figure 7. Conditional classification tree showing the variables' influence on NIPF owners' acquisition of Forest plan (AcquireFP). Each oval in the tree contains a particular variable. The n values at the leaves display the total number of observations that fall in the terminal nodes. For visibility, the counties were denoted with codes in the tree: Agder (A), Innlandet (I), Møre og Romsdal (M), Rogaland (R), Troms (TM), Trøndelag (TN), Vestfold og Telemark (VT).

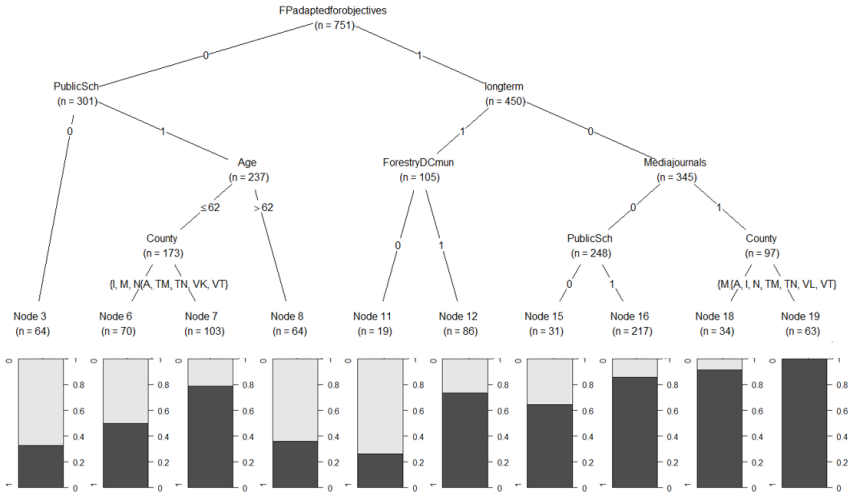

Figure 8. Conditional classification tree showing the variables' influence on NIPF owners having good knowledge of the content of the FP (ContentFP). Each oval in the tree contains a particular variable. The n values at the leaves display the total number of observations that fall in the terminal nodes. For visibility, the counties were denoted with codes in the tree: Agder (A), Innlandet (I), Møre og Romsdal (M), Rogaland (R), Troms (TM), Trøndelag (TN), Vestfold og Telemark (VT)

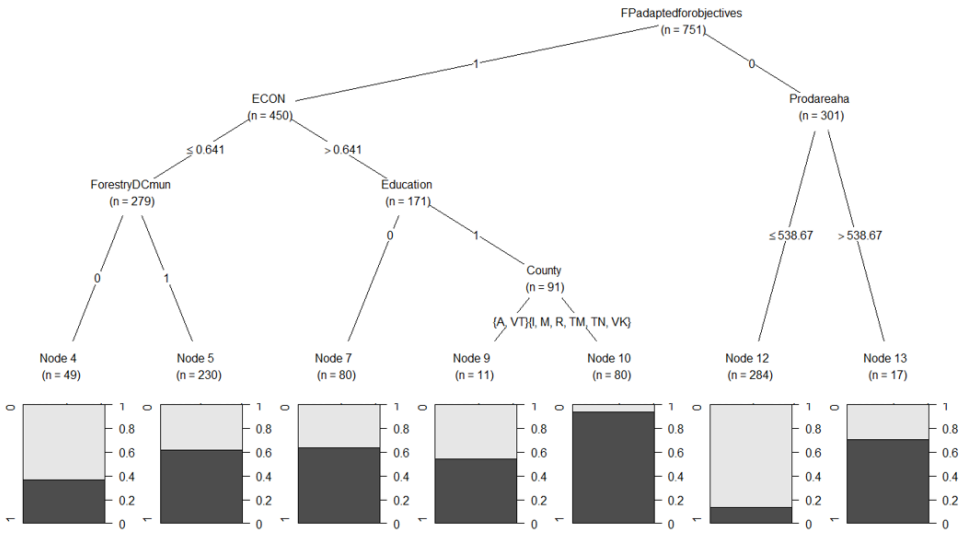

Figure 9. Conditional classification tree showing the variables' influence on NIPF owners implementing the proposals in the FP (ImplementFP). Each oval in the tree contains a particular variable. The n values at the leaves display the total number of observations that fall in the terminal nodes. For visibility, the counties were denoted with codes in the tree: Agder (A), Innlandet (I), Møre og Romsdal (M), Rogaland (R), Troms (TM), Trøndelag (TN), Vestfold og Telemark (VT)

4.5 Paper IV: Information needs for improved forest management

In this study, we categorized the cohort of NIPF owners that are willing to improve forest management activity on their land base. About, 31% stated that they are interested to know more about the environmental value of their forest. Similarly, 45% of forest owners are interested to increase forest activity on their forest property, as they "agree little to agree completely" to the statement that "with more/better information, I could have increased the activity level in my forest".

The variables gender, education, farming, public authority and knowledge of environmental value were significant variables in encouraging NIPF owners towards receiving more information about environmental value of their forests. The female respondents and owners with higher education opted to have more information on role of their forests for environment. However, owners who already possess environmental knowledge and are farmers were less keen towards possessing more information in the environmental model. Respondents who had public authority (municipality or forest organization) as a source of information for managing forests are likely to be highly interested to gain more information about environmental sustainability. The increase of 13% was noted among NIPF owners who stated public authority as source of information for managing forests.

In probit model for increased forest activity, the economic oriented respondents who have utilized peers and public authority as a source of managing forests will increase forest activity, if provided with more or better information about managing forests. On the contrary, older respondents who are involved in farming activities and possess forestry or agricultural education are less likely to increase forest activity when supplied with more information. The respondents in contact with public authority in combination with peer group possess 19 % higher chances to increase forest activity on their forest property.

Table 7. Estimated coefficients and marginal effects of variables used in the probit models that analyze variables influencing private forest owner's need of more information about environmental value of their forest and increasing forest activity on their forest

Variables	More information about environmental value of forests	More information to increase forest activity
	Marg. eff	Marg. eff
Age	-0.0007	-0.0047***
Gender	0.0559*	0.0101
Education	0.0635**	-0.0265
Size of forest property ha, (LN_ha)	-0.0003	0.0072
Farming	-0.0744**	-0.0589*
Media and professional journals	-0.0241	0.0218
(Peers) Other forest owners/family/neighbors/friends	0.0113	0.0581*
Public authority	0.1257***	0.1316***
Environmental knowledge	-0.1353***	-0.0871**
Forestry or agricultural education	-0.0519	-0.0927**
Economic	-0.0002	0.0322*
Nature diversity	0.0433	0.0311
Nature preservation	0.0406	0.0238

*Significant at 10% level, **Significant at 5% level, ***Significant at 1% level

5. Discussion

Forest owners' reasons for owning forests contain certain attitudes that steer their management decisions, including timber harvesting (Bashir et al., 2020; Beach et al., 2005; Joshi and Arano, 2009), biodiversity conservation (Doremus, 2003; Langpap, 2006; Mitani and Lindhjem, 2015; Uliczka et al., 2004), acceptance of public forest schemes (Bashir et al., 2020; Horne, 2006; Matta et al., 2009), and information programs (Andrejczyk et al., 2016; Eyvindson et al., 2019; Kärhä et al., 2020; McGrath et al., 2020). In addition, the forest owner's socio-demographic and property characteristics and the access to information influence their attitudes towards management of their forests. The decisions opted by forest owners plays a significant role in determining forest utilization, provision and delivery of FES (Pukkala, 2016; Tian et al., 2015).

The study was able to fill critical gaps to the literature base of NIPF owners internationally, and for Norway in particular. The study provided important insight on NIPF owners, especially owners that do not harvest as relatively little attention has been paid to this growing owner group. Our study adds to the relatively limited research based on longitudinal surveys. This research also contributed with valuable information about NIPF owners' stated knowledge of environmental values in their forests and their attitudes towards nature protection and conservation outside the conservation programmes. This study increased the understanding of the mind-set of NIPF owners towards environmental consideration and provide important foundation for drafting any polices and extension programmes towards environmental sustainability. With this research, the literature on empirical studies addressing different aspects associated with FPs among NIPF owners is enriched. The complexity of pathway of the FP among owners is addressed in this study and new insights about the difference of possessing FP and implementing FP is highlighted. Lastly, this study is vital as it attempted to fills the gaps about information needs of NIPF owners in order to enhance the

forest management activity and environmental consideration on their land base. This research effort contributed towards providing an important literature resource base for policy makers to understand Norwegian NIPF owners better and, accordingly draft policies or strategies that could motivate owners towards sustainable forest management. Many researchers and policy makers of various countries with private forests can relate to the outcomes of our study, and this can be a step forward for more research and analysis in future. Over all, the thesis contributed valuable insights by examining the impact of wide set of factors as a means towards predicting management approaches among Norwegian NIPF owners (Howley, 2013). With this context, this research work enhances knowledge about NIPF owners' forest management decision-making processes that was warranted to formulate efficient policies to encourages multidimensional forestry through sustainable management of forests (Benz et al., 2020; Nagaike, 2020; Urquhart et al., 2017).

As private forests constitute significant shares of forestland in many countries across the globe (Tian and Pelkki, 2021; FAO and UNEP 2020), the role of private forests to achieve and safeguard FES across the landscape is highly emphasized and prioritized in recent forest policies (Ficko, 2019; Howley, 2013; Schmithüsen and Hirsch, 2010). In addition, the societal paradigm shifts to harness multiple benefits from forest ecosystems have led to the evolution of multifunctional and sustainable forest management approaches (Blanco et al., 2015; Gatto et al., 2019; Gołos et al., 2021). In our study (Papers I and II), it was evident that a significant number of forest owners considered to manage their forests for multiple objectives; ranging from bequest values and to biodiversity to timber production. Similar results were recorded in various other studies in other countries (Boon et al., 2004; Dhubháin et al., 2010; Feliciano et al., 2017; Hayrinen et al., 2015; Howley, 2013; Kendra and Hull, 2005; Pynnönen et al., 2021; Serbruyns and Luyssaert, 2006). However, this study is unique as it is based on what is to our knowledge the first national-wide data that combined survey figures on attitudes and

information sources with tax-record panel data of samples that are representative of NIPF owners in Norway. The survey was based on stratified, random sampling ensuring the national representativeness. In addition, it included many important variables related to attitudes, demography, forest, income and wealth of NIPF owners. It thus addresses a wide set of factors that steer decision-making among NIPF owners of Norway and deals with various critical issues related to sustainable management of forests for economic and environmental sustainability. The study is relevant in many countries with private forest ownership. In this context, this work will be very beneficial for international researchers and policy makers.

Forest owners managing their property for economic objectives were positively inclined towards timber harvesting (Paper I). These owners consider their forest property as an important asset to attain financial security and well-being. This finding was also reflected in other studies (Aguilar et al., 2014; Dhubháin et al., 2010; Petucco et al., 2015). On the contrary, 40% of inactive NIPF owners did not recognize forests for financial security (Paper I). Rognstad and Steinset (2011) and Statistics Norway (2017) estimated that during the last twenty years there has been no timber harvesting from properties that together constitute 22% of the productive forest area in Norway. In addition, relatively low annual felling (approximately 40 per cent of the annual increment) on the national level has resulted in the accumulation of available timber resources (NMCE, 2020) (Figure 3). Due to the low timber harvest, more than 50% of productive forests are classified as close-to-mature and mature forests (developmental stages IV and V). In the near future, this may have consequences on the ability of Norwegian forest to act as carbon sink (NMCE, 2020) and increase tree susceptibility to diseases and pests, especially under climate change (Bashir et al., 2019).

Many studies have suggested that smaller properties account for a disproportional large growing stock due to the higher productivity and lower harvest levels on smaller than larger properties. These properties also possess the highest potential for increased timber

harvesting (Hobbelstad and Ørnelund Nilsen, 2006; Statistics Norway, 2021). In our study (Paper I), we also observed that forest area was inversely related to the area-based timber supply. This reflects the higher productivity and larger growing stock per area unit on smaller properties. Since owners of smaller properties to a lesser extent harvest the potentials. In paper I, we observed that awareness about the Forest Fund (Skogfund) had a strong influence in motivating NIPF owners towards timber harvesting in Norway. In contrast, forest owners without proper knowledge about the Forest Fund could not accurately estimate after-tax of timber harvest and the cost of stand establishment after harvesting (Bashir et al., 2020; Sjølie et al., 2019). Similarly, Sjølie et al (2019), using the same dataset, found that only 17% of inactive forest owners were members of the forest organizations as compared to 72% of active owners. This implies that forest organizations play an important role in raising awareness among forest owners and encouraging activity on the forestland. Forest owners not interested in forest management either do not know about forest organizations, or do not trust them (FAO and UNECE, 2020). For instance, a study done by (Rametsteiner and Kubeczko, 2003) in Austria, found that only 16 % of owners with forest property < 10 ha possess membership in forest organization. In addition, we also recognized that timber harvesting was a strong predictor for acquisition of a FP (Paper III). This implies that if we utilize advisory services such as advice from a forestry section of the municipality to familiarize forest owners with the forest fund, this might encourage them to avail membership in a forest organization. This is because direct contact with the municipality for forestry advice strongly encourages forest owners towards acquiring a FP (Paper III). In addition, similar means can be utilized to familiarize forest owners about the financial assistance that can be obtained from a forestry investment fund, such as Skogfond, for buying the FP. In our study, 37% of the Norwegian NIPF owners possess a FP, and among those 66% know the content of plan well and 40% implement the FP proposals on their property (Paper III). Therefore, information about the

role of Skogfond and its utilization in buying FP can be an important step towards increasing awareness among forest owners about active forest management.

Furthermore, it will contribute to fulfilling an important political objective of Norway to develop rural areas with proper population distribution or settlement patterns over the country (Follo, 2011), in same line with the EU adopted concept of rural development through diversification of economic activity in rural areas (European Commission, 2008). In addition, this will contribute to the European agenda of an increased role of forests in bioenergy production 2030 (Bogaert et al., 2017; De Schutter and Giljum, 2014). However, it might be because of economies of scale that smaller and inactive forest owners were less inclined to timber harvesting. Thus, co-management strategies can be a solution to activate passive or small forests owners towards active forest management (FAO and UNECE, 2020). Forest owners with smaller properties possess lower rates of FP enrollment due to a practical management constraints and complexity of forest area (Best, 2004; Best and Wayburn, 2001; Bruña-García and Marey-Pérez, 2017; Hirschnitz-Garbers and Stoll-Kleemann, 2010). The owners with large properties and more harvesting experience expect higher earnings and are more inclined to acquire a FP (Pan et al., 2007). Therefore, if smaller forest owners are convinced towards timber harvesting through exposure to different policy measures (i.e. a combination of regulations, information and incentives), they may also be motivated to have and implement a FP (Paper III).

The policy instruments employed were mainly classified into three broad classes i.e. regulation, incentives, advice and information. Some studies designated these approaches as carrot and stick strategy (Bruña-García and Marey-Pérez, 2017). The stick approach relates mainly to regulations and carrot infers information, advisory or incentives. In our study, the variables employed represent most of these approaches. For example, registered environmental values achieved through forest certification represents soft regulatory

measures, whereas forest funds and tax deductions are an incentives (carrot) approach. The other variable that represents an information and advisory approach is contact with the municipality. We observed that these policy instruments were effective if employed in a proper mix. A study suggest that countries characterized with a higher share and diversity of private forest ownership usually follow policy approaches that constitute a combination of different policy instruments (FAO and UNECE, 2020). Similarly, we observed that the combination of different policy tools could be more efficient to achieve policy goals (Paper I – IV). The use of information or advisory sources as a policy instrument was well evident as a very efficient tool to provide knowledge about forest management like timber harvest incentives, schemes for forest activities, environmental knowledge, and a FP pathway. The access to information or advisory sources encourages and educates forest owners to execute efficient forest management decisions and maximize the benefits from their forests (Paper I-IV).

In Paper II, we noted that private forestlands are a key resource for implementing environmental conservation policies and strategies, also reported in other studies (Drescher et al., 2017; Kamal et al., 2015; Norton, 2000). Most forest owners want to conserve nature's diversity (Paper I and II). 37% of owners state that they possess environmental knowledge of their forests. This implies forest owners possess a dedicated sense of responsibility towards the environment. This finding elucidate that Norwegian NIPF owners in general are affirmative to reconcile both economic and environmental values on their forestland (Paper I and II). In turn, this indicates that the multifunctional forestry concept has a strong position among the NIPF owners in Norway. On one hand, some of the forest owners relate financial objectives with forests (Paper I), while on other side, 19% of owners consider their forest as first and foremost a nature preservation object (Paper II). However, continuous efforts would help to raise more awareness of environmental amelioration from forests, especially among female forest owners

who to a larger extent than men state that they lack knowledge about the forests' environmental values. We found that the 19% of the owners who state that the forest is first and foremost a nature preservation object own in total 16% of the productive forest area. Thus, forest owners' attitudes do not seem to create a barrier to achieve the objective of protecting 10% of the forest area set by Norwegian parliament in 2016 (NMCE, 2019; Stortinget, 2015).

Among other policy measures, forest certification plays an important role in promoting sustainable forest management. The two main programs are the PEFC (Programme for the Endorsement of Forest Certification) and the FSC (Forest Stewardship Council) certification schemes. However, PEFC account for the vast majority of certified forestland in Norway (PEFC, 2015) and the most forest is group certified through the timber buyers. An important instrument for encouraging forest owners towards environmental conservation is forest certification. The certification includes certain set of measures such as officially registering and setting aside biological hot-spots, maintaining buffer zones (around lakes and rivers) and ensuring retention trees during forestry operations (PEFC, 2015). We believe that the environmental awareness of forest owners has most likely increased considerably as part of the process of environmental consideration that started in the 1990s with the first certification standard published in 1998 (Levende Skog). Furthermore, the attitudes towards nature conservation in the public has also shifted remarkably over the last decades. These factors may help to explain why a significant number of forest owners are positive to nature diversity and conservation. In addition, forestry education and information tools can be utilized to increase environmental awareness among forest owners and motivate them towards sustainable management of forests. The owners who had environmental values registered on their property possessed the highest knowledge about the environmental values of their land (Paper II). This study (Paper I and II), implies that educational and information tools are highly important to

incline forest owners towards combining timber production with biodiversity measures to reach the objective multifunctionality.

In Paper I-IV, we recognized particular groups of forest owners that demand special attention from forest policymakers and extension services when drafting different policies and executing various information campaigns. Similarly, female owners demonstrate less knowledge about the environmental values of their forest (Paper III) but have a desire towards increased information on environmental issues (Paper IV). Disseminating more awareness about the forestry related programs through the information and advisory tools will aid forest owners to take better decisions for managing forests.

Many studies across the globe have attempted to better understand NIPF owners and encourage forest policies that direct management actions towards sustainable forest management to achieve the objective of multifunctional forestry (Benz et al., 2020; Kilgore et al., 2007; Urquhart et al., 2017). However, there is a major challenge of accounting for varied owner characteristics, objectives and motivations expressed by private forest owners (Beach et al., 2005; Butler et al., 2017; Favada et al., 2009; Hayrinen et al., 2015). To ensure economic viability of forestry, in addition to social and environmental benefits, there is need to design effective policy instruments. For reaching that goal, policy makers should be well informed about forest management decisions, including timber harvesting (timing and magnitude; Paper I), how different nature diversity and conservation objectives are perceived by forest owners, pathway of FP, from acquisition to implementation of forest plan (Paper III) and information needs (Paper IV) of NIPF owners.

6. Future research directions

The thesis delved deeper into various aspects of NIPF owner's decision-making process for sustainable management of their forests. At the same time, there are many other important research questions. However, due to limited time and resources those questions remained untouched and, hence, some research prospects are listed for future considerations.

- The diversification in forest owners in increasing due to age, requirements, access to information and influence of peers (Butler et al., 2017). This results in more diversified approaches of managing forests (Weiss et al., 2019). Trends in incomes, occupation and attitudes among some owners may likewise create more diversity in the forest owner population. Therefore, more research is warranted to raise awareness of the impacts among policy-makers and stakeholders about the diversity of forest owners. Otherwise, limited knowledge on the diversity of forest owners would restrict the understanding of forest owner motives and behavior, and eventually impact the formulation and execution of a wide set of policy instruments varied to owner types.
- Further research is needed to analyze the attitude and behavior of forest owners that are alienated from their forests due to distance (urban owners). It is worthwhile to assess through research and analysis how modern day technologies or digital platforms like social media and mobile applications can be utilized as an efficient tool of communication to inform and motivate these owners towards sustainable management of forests, even from a distance.
- It is worthwhile to introduce the concepts, consequences and possibilities of future climate change to the forest owners through surveys and discussions. The consequences of climate change challenges such as of forest fires, and insect damage can also be part of survey and discussions. Furthermore, changes in attitudes and behavior towards management of their forests should be further studied and analyzed.

- The relationship between forest owners, forest conditions and FES needs further research and understanding due to availability of limited data. Factors such as species mixing, productivity and mortality are important in influencing the condition of the forests and crucial in facilitating the type and magnitude of FES from the forests, especially under changing climate. Therefore, the forest owner's level of understanding of these factors is important for proper management of their forests, hence, there is a scope of research and analysis in this area.
- The traditional survey questionnaire has been an important tool to understand the attitude and behavior of forest owners towards managing their forestland. It provides significant information or inputs to policy makers for drafting relevant policies. However, longitudinal studies about forest owners are very important to receive more crucial insights into forest owners dynamics.
- We observed that more information is required to better understand the cohort of inactive NIPF owners. The usual survey questionnaire could be supplemented by focus group discussions and workshop together with researchers and policy makers to gather more insights about this group for developing efficient policies to engage their active involvement in forestry. Group interaction enhances the expression of a wider range of views and feelings.

Acknowledgement

I would like to express my gratitude to my patient and supportive supervisor, Hanne Sjølie. I am extremely grateful for your friendly nature, and off course your personal support and guidance was immensely beneficial. You always had time for me and seem to have an endless patience tested by my repeated mistakes. “Thank you Hanne”. Furthermore, I would like to thank my co supervisor Birger Solberg for valuable feedback to my work (articles). I would also like to thank Dennis Becker for being co-author for the second manuscript. I am also grateful to Olivier Devineau for statistical guidance in the beginning of my PhD.

I am thankful to the administration for their support throughout my stay at Evenstad. I would like to thank Kaja for help with initial paper work. Special thanks goes to Ragnhild for being very helpful during this PhD tenure and being reason for happiness to my kids on various occasions. I also would like to say a special thank you to PhD committee, especially Henriette for being there whenever problems arise, your “happy to help” nature makes you a wonderful person.

One person who deserves a special mention is “Ane Erickson”. I am very thankful to you for taking care of my travel to Evenstad, almost every day. You are truly amazing, so much I learned from you. The discussions we had during our travel to Evenstad will be always remembered. You have been a wonderful friend, colleague and a family to us (thanks to your family too). Thanks for everything Ane!

I believe fishing, hiking and ice-skating (almost) trips helped a lot to relax during these tough PhD years. Thanks a lot, Vladimir.

One person who is missed the most by my wife and kids is Annie. You have been a wonderful friend and support to me and my family during this PhD journey. I am also very grateful to Annie and Zea for their valuable feedback to my synopsis.

I are grateful to Arif Iqbal and Mona Thaulow who made our (family) stay in Norway very smooth and comfortable. We are also grateful to Vetle Wetlesen family for their support throughout our stay in Koppang.

I have enjoyed the friendship that have evolved during my PhD with staff and fellow students. I would like to thank fellow PhD students for making my stay at Evenstad exciting. Especially Marcel Schrijvers-Gonlag for being a wonderful neighbor at office and home. You have been good support for all these years. I also thank Ana Peris for all the chats during Transpeer and at Evenstad. I would also like to thank Scott and Julia for being a wonderful support to us. I would like to thank Abbas for being a nice and helpful friend

during the last stages of my PhD, (I believe discussions about forestry and programming with you will be very useful in the future). I am thankful to Alina and Boris for being nice to my family. I would like to thank Mehmood's family for their support and prayers during last few years at Koppang. Their support was helpful to my family during my long hours of work at Evenstad.

I am extremely grateful to my parents for their love, understanding, prayers, care and sacrifices for educating and preparing me for my future. My Special thanks goes to my wife (best friend; ENNA) for being on my side during all these years. Your care, prayers and continued support was invaluable to make this PhD a wonderful experience. My little angels Taroob and Muhammad were best to ease my mind with more exciting things than piles of work. Also, I express thanks to my sister (Nusrat), brother in law (Shah Mudasir), brother (Arjumand), sister in law (Mennaz) for their support and valuable prayers. I would like to thank my in-laws (Papa, Jaji, Irfan, Ridha, Sameer, Azra) for their support and prayers. Thanks to the little ones in our family Musa and Essa for refreshing online chats during our stay in Norway.

I would like to thank NIPF owners in Norway who contributed their time and effort to complete a questionnaire survey for this PhD project. I am grateful to those who contributed in developing the survey instrument, including staff at the Statistic Norway and researchers at the Norwegian University of life sciences.

The first person I met on my arrival at Evenstad was "Harry P Andreassen" (RIP). The way he welcomed and looked after us for first few days was a wonderful welcome gesture.

I am also thankful to all the people who I did not mention but contributed to my great experience of being in Norway.

میں ان تمام لوگوں کا شکر گزار ہوں جنہوں نے پی ایچ ڈی کے ان چار سالوں میں میرا ساتھ دیا۔

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Dissertation Papers (I-IV)

Paper I

forests

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Article

Determinants of Nonindustrial Private Forest Owners' Willingness to Harvest Timber in Norway

Altamash Bashir [1,*], Hanne K. Sjølie [1] and Birger Solberg [2]

[1] Faculty of Applied Ecology, Agricultural Sciences and Biotechnology, Inland Norway University of Applied Sciences, 2400 Koppang, Norway; hanne.sjolie@inn.no
[2] Faculty of Environmental Sciences and Natural Resource Management, Norwegian University of Life Sciences, 1433 Ås, Norway; birger.solberg@nmbu.no
* Correspondence: altamash.bashir@inn.no

Received: 2 December 2019; Accepted: 2 January 2020; Published: 4 January 2020

Abstract: In Norway, 84% of the productive forest is privately owned, and these forests dominate the supply of timber to industries. However, during last 80 years, annual forest growth has seen a substantial upsurge while annual timber harvest has been rather stable, generating an increasing potential for timber supply. In this study, we provide new insights to better understand Norwegian non-industrial private forest owners' timber harvesting decisions. This was achieved by comparing the outcomes of two different statistical approaches (i.e., a combination of probit-linear models with a tobit model). These approaches are commonly applied in timber supply studies, but to the best of our knowledge have never been compared on the same dataset. The survey utilized for this study constitutes a population of Active and Inactive forest owners, based on whether the owner had harvested timber for sale during the last fifteen years. Two gross samples of 1500 and 1650 were drawn, with response rates of 56% and 49% for the Active and Inactive owner samples, respectively. The study results reveal that the average holding size varied from 25.2 ha for Inactive to 49.5 ha for both samples and 73.8 ha for Active owners. The probit model analysis indicated that knowledge of forest fund and financial objectives had the most significant impact on the willingness to harvest, with marginal effects of 11% and 12%, respectively. In the linear regression, being a male owner increased the historical timber supply by 1.48 m^3 ha^{-1} $year^{-1}$ compared to female ownership. In the second regression pathway (tobit model), the two variables male forest owner and owning forests for financial objectives triggered the supply of timber by 1.85 m^3 ha^{-1} $year^{-1}$ and 1.25 m^3 ha^{-1} $year^{-1}$, respectively. Timber prices were significant in the linear model (elasticity 1.18) and tobit model (elasticity 0.66), whereas they were non-significant in the probit model. Our study concludes that Active owners had a better understanding of acknowledging forests for economic security. Policy-makers and extension services should recognize that the Inactive forest owner group may require different actions than Active owners.

Keywords: NIPF; timber supply; questionnaire; active; inactive; regression; tobit; two-step model

1. Introduction

Globally, forest ownership structure varies significantly between countries, with about 14% of the global forest controlled by individuals or communities referred to as non-industrial private forest (NIPF) owners [1,2]. These owners account for 40% of the total forests available for wood supply in the area covered by an assessment of temperate and boreal forest resources in 55 countries [3]. In many countries like Portugal (79%), Norway (79%), Finland (62%), and the US (62%), a significant share of total forest is managed by NIPF owners, mainly for wood supply [4–7].

In Norway, about 26% of the land area is covered by productive forest, of which 84% of is privately owned and divided on about 127,000 properties [8,9]. Privately owned forest dominates the supply of timber to industries, with 89% of harvest volumes [8,9]. The forest and the related sector has historically been an important employer in many rural areas of Norway; its contribution to GDP declined from 2.5% in 1950 to 0.2% in 2017 [10,11]. The significant decline in share of GDP is due to a strong reduction in timber prices over the last 70 years. Over the same time period, the forest growing stock has accumulated substantially and increment more than doubled [9,11]. Harvest levels have increased over the last few years, while the share of owners refraining from harvest is increasing, with about half of owners not harvesting timber for sale over the last 20 years [9,12]. Many of these properties are small, but together they constitute more than 20% of the productive forest area [9]. On average, small properties have higher productivity and larger growing stock and thus possess higher possibilities for increased harvest than larger properties [9,12,13].

The management strategies adopted by owners are based on their values and reasons for owning forest. These strategies ultimately determine the forest sustainability and functionality in catering to society's demands of goods and services [14]. To achieve the objectives of reduced greenhouse gas emissions, economic activity, and employment, the EU and Norway have asserted on policies of increased wood supply [12,15,16]. Better knowledge of factors influencing NIPF owners' forest management decisions (including harvest) and reasons for owning forest is important for designing policies [14,17–19]. Studies of timber supply have been carried out in Norway [12,20–23], but in contrast to other countries with sizeable private ownership base, a lack of knowledge of the attitudes and objectives of ownership among Norwegian forest owners restricts effective policy-making. In particular, more insight on owners that do not harvest is warranted because relatively little attention has been paid to this growing owner group. We will fill parts of both these voids by combining national-level harvest, income, and tax panel data with survey data of attitudes and objectives of ownership sampled on owners who harvest and those who do not. Several of the revealed-preferences studies use the tobit modelling approach [20,21,24,25], while others use a two-step logit/probit and linear modeling approach [23,26]. The stated-preferences framework constitutes another branch of timber supply studies that we are not incorporating in this study [12,27,28].

In the two-step procedure, forest owners are first assumed to decide to harvest or not modelled by the probit model. If a positive decision is made, then the harvest volume is decided (linear model). In tobit modelling, both the decision to harvest and the volume are assumed to be determined together. Both modelling approaches can reflect reality well. It may be realistic that owners may first take the decision to harvest given prices and other factors and thereafter decide how much to harvest. For instance, total volume may be determined only when the harvest is complete, as more information about available timber volumes and forest conditions may be unveiled during the harvest operations. However, if they are using a management plan with periodic harvest volumes, forest owners may decide the timing of the prescribed harvest volumes; in this way, the decision to harvest and harvest volumes are taken together.

Although both the tobit and two-step approaches are well documented in the literature, we have not come across studies that compare the two. As the outcomes of modelling approaches cannot be directly compared between studies using different datasets, it is not clear how the choice between these two main econometric pathways steer the results. We fill part of that void by constructing models using the same dataset to compare the outcomes of the approaches directly. Another contribution of our study is the enhanced modelling used in conjunction with an extensive panel data set [29].

With this study, we provide key insights to help better understand Norwegian NIPF owner characteristics and timber harvesting decisions. Our specific objectives were to (1) evaluate the differences in the socio-economic profiles, objectives, and attitudes between owners who do and do not harvest timber for sale in Norway; (2) analyze and compare the impact of different factors on timber harvesting behavior (decision-making modes) of NIPF owners using tobit and two-step probit and linear modelling.

The rest of this paper proceeds as follows. In Section 2, we draw the hypotheses based on the literature review. Section 3 provides an overview of the theoretical background and econometric modelling techniques used to analyze the timber harvest behavior of NIPF owners. The results are presented in Section 4, while the implications of the results are discussed in Section 5 and conclusions are drawn in Section 6.

2. Literature Review and Hypotheses

The decision of forest owners to harvest/not harvest timber is guided by many factors [12,30–32]. Among many variables, timber price, forest size, distance to property, ownership objectives, policy awareness, membership in a forest organization, and socio-economic factors such as age, gender, education, income, and net wealth have been emphasized in the following studies [22,31,33–35]. However, their reported magnitude and statistical significance on timber harvesting intentions and intensities are not consistent across studies [30,36]. For instance, timber price was found to affect NIPF owners' harvesting behavior significantly in several studies [18,19,21,22], while other studies found no or ambiguous response of NIPF owners to timber prices [27,37].

Forest property size has been stressed as an essential factor influencing NIPF owners' harvesting choices in many studies, although the direction and impact may vary based on the forest conditions [12,17,33]. A positive association between the size of the forest land and NIPF owners' intention to harvest timber was reported by [34] and [21] in the USA and Norway, respectively.

Increasing age restricts the interest of forest owners in timber harvesting because of their reduced requirement for income and the intention to sell or transfer the forest property in the near future [17,23,30,38–40]. Conversely, a study conducted in Mississippi, USA found that older NIPF owners were more likely to supply woody biomass compared to younger landowners [41]. Concerning gender, [42] in Finland observed that female owners harvested 30% less timber than male owners, but harvested larger quantities when they did. The distance to forest property from the owner's residence is inversely related to timber harvest due to weaker motivations for ownership [39,43].

The higher level of income provides an opportunity for acquiring more forests and advanced equipment to improve harvesting efficiency, resulting in higher financial gains, and income may be positively related to intentions to make income from the forest. Therefore, a higher income may increase the probabilities of engaging in timber harvesting [17,37,44]. On the other hand, other sources of income reduce the importance of timber. Hence, owners tend to prioritize conservation or recreation values in comparison to harvest [20,42,45]. The above statements signify an ambiguous income–harvest relationship for forest owners [12].

In a study conducted by [17], education level had a significant impact on the willingness to harvest, with a marginal effect of 28%. This signifies that education enhances knowledge and understanding of forests as resources among forest owners. Studies by [23] and [46] in Norway and Sweden, respectively, found that owners with higher education harvested more. Conversely, [47] in Canada and [48] in Finland observed that forest owners with higher education attached greater importance to aesthetic and conservation values than to harvesting.

Public policies like forestry assistance and incentive programs are often designed to motivate owners to actively manage forest land [49,50]. The main policy instrument in Norway is the "Forest Fund". Forest owners have to set to aside a self-selected share between 4% and 40% of the forestry gross income for this fund. No tax is levied on the amount deposited in the fund, but if the forest owner decides to invest this amount in forestry activity, only 15% will be taxed [51]. The tax waiver assistance results in higher after-tax income and incentivizes maintaining or establishing new stands [12]. Therefore, we hypothesized that NIPF owners with greater knowledge of the Forest Fund would be more positive towards timber harvesting.

The reasons and objectives for owning forest property contribute significantly to the decision making of forest owners towards managing forests [52]. Forest owners' higher preference for non-timber benefits compared to timber harvesting is highlighted in many studies [17,26,53]. Similarly, authors

in [54] also reported that owners' forest management objective was to prioritize conservation or environment protection over the production of wood.

Based on the literature, we hypothesized that the factors specified in Table 1 impact timber supply.

Table 1. Description of variables (dependent and independent; type of variable) and expected relationship used in the empirical models examining non-industrial private forest owners' decision to harvest timber in Norway.

Variable (Type)	Description	Type of Variable	Expected Relationship (Y_{it})/(Y'_{it})/(T_{it})
	Dependent variables		
Harvest (Y_{it}) *	Dependent variable (binary) for probit model indicate that if timber harvested for sale = 1; Not harvested = 0	Dichotomous	
Harvest_m^3 ha^{-1} year^{-1} (Y'_{it})	Dependent variable (continuous) for linear model. Linear model includes only the forest owners' harvested timber for sale (natural logarithm (LN) transformed).	Rational number	
Harvest_ m^3 ha^{-1} year^{-1} (T_{it})	Dependent variable (censored) for tobit model, includes all forest owners, where 0 values imply forest owners did not harvest any timber in a given year (LN transformed).	Rational number	
	Independent variables		
Age	Age of forest owner (years) (2003–2012)	Natural number	-/-/-
Gender	male = 1, female = 2	Dichotomous	+/+/+
General education	Primary and secondary = 0, higher (bachelor, master, doctorate) 1	Dichotomous	+/+/+
Size of forest property	Size of property in decares (1 ha = 10 dec) (LN transformed)	Rational number	+/-/+
Distance from the property	Distance between forest land and the residence (km) (LN transformed)	Rational number	-/-/-
Gross income$_{it}$	Annual gross income before tax (sum of salaries, pensions, income from self-employment and capital) from 2003–2012 (from Statistics Norway) in millions (Norwegian krone) NOK (adjusted for inflation)	Rational number	?/?/?
Taxable net wealth$_{it}$	Taxable net wealth 2003–2012 (from Statistics Norway) in millions NOK (adjusted for inflation)	Rational number	?/?/?
Real timber prices$_{it}$	NOK per m^3 from year 2003–2012 (adjusted for inflation)	Rational number	+/+/+
Knowledge of the forest fund	1 if answered "Yes some or very much knowledge of "forest fund", 0 if answered "No knowledge"	Dichotomous	+/+/+
Visits to forest land for activity	1 if owner visited land "more than once over the last 12 months", 0 for "No visits"	Dichotomous	+/+/+
Interest in buying more forests	1 if answered "Very or slightly interested to the question about buying more forests, otherwise 0 for "Not interested"	Dichotomous	+/+/+
Plan to sell/transfer	1 if answered "Yes" on the question on planning to transfer to family/sell the property within ten years and 0 for "No specific plans"	Dichotomous	+/+/+
Nature	How important reason for owning forest is "The forest provides me the opportunity of nature experiences"	** Ordinal 4-point: Not important at all (1); slightly important (2); of relatively great importance (3); of decisive importance (4)	
Protection	How important reason for owning forest is "The forest provides me the opportunity to protect and preserve nature's diversity"?		
Conservation	How important reason for owning forest is "The forest is first and foremost a nature conservation object for me"		
Income	How important reason for owning forest is "My forest provides me income"?		
Economic security	How important reason for owning forest is "My forest provides me economic security"		
Investment	How important reason for owning forest is "My forest is an investment object for me"?		
Environmental	How important reason for owning forest is "The forest is part of the environment where I live or spend my leisure time"?		
Hunting	How important reason for owning forest is "The forest provides me the opportunity to hunt"?		
Intrinsic	How important reason for owning forest is "My forest has an intrinsic value for me (e.g., as part of a family farm or that I am a forest owner)"?		
Inheritance	How important reason for owning forest is "My forest will be inherited by close family"?		
Relax	How important reason for owning forest is "In my forest I can relax, find silence and contemplate"?		
Native	How important reason for owning forest is "I keep contact with my native area through my forest"?		
Social objectives	Intrinsic + Inheritance	Ordinal (2 to 8)	???
Financial objectives	Income + Economic security + Investment	Ordinal (3 to 12)	+/+/+
Conservation objectives	Protection + Conservation	Ordinal (2 to 8)	-/-/-
Recreation objectives	Environment + Hunting + Nature + Relax	Ordinal (4 to 16)	-/-/-

* *i* and *t* represent individual (forest owner) and time period (year), respectively. ** The broader categories—i.e., Social, Financial, Conservation, and Recreation variables—were constructed by grouping ordinal 4-point variables, due to the high correlation between the original variables. The groupings led to the change of scale represented in the table. In the analyses, the new variables were treated as continuous, as is commonly done in this kind of survey analysis [12].

3. Methods

3.1. Survey Database

In this survey, we created two populations of private individual forest owners: *Active owners* and *Inactive owners*. Private forest owners having more than 2.49 hectares of forest property were included in this study [12]. This is because Statistics Norway categorizes only private forest owners with more than 2.49 hectares of forest property into different size classes. Active owners were defined as those having harvested more than 5 m^3 of timber for sale, whereas Inactive owners were those that harvested less than 5 m^3 timber in total from 1998 to 2012 (technical assumption for timber harvest set by Statistics Norway). Three strata dimensions were used to create the samples—activity (Active/Inactive), county (18), and size class (8). The county Finnmark was not included in the study because most of forest land is publicly owned.

Out of the populations of 55,965 Active and 72,147 Inactive owners, two gross samples of 1500 and 1650, respectively, were collected by Statistics Norway, the national body for surveys and statistics [12]. All records of forest owners in Norway are maintained by this agency. The questionnaire for Active forest owners was first developed and thereafter altered to accommodate Inactive forest owners in collaboration with Statistics Norway [12]. The Total Design Method [55] framework was employed in the administration of the survey. The respondents were also asked questions about ownership objectives and attitudes alongside demographic information. A panel data set for the years 2003–2012 of forest area, harvest, and income figures from the nationwide property and tax registers was appended with data from the questionnaires. For more details on the sampling, see [12].

3.2. Theoretical and Statistical Modelling Framework

NIPF landowners are described as maximizing utility rather than profit [17,36]. This study modelled NIPF owners' decisions as utility-maximizing choices explained by a set of observable owner-specific factors [17,33,56]. The set of observable factors determining timber harvesting were assumed to be a set of four vectors: forest owner characteristics, ownership characteristics, management characteristics, and timber prices. Hence, in our study the forest owner utility model for timber harvesting possesses a deterministic component and a random error term and can be expressed as [18,57]:

$$U_{it} = f(O, P, M, T) + e_{it}, \quad (1)$$

where U_i is owner i's utility in period t of harvesting or not and O, P, M, and T are vectors of factors influencing the decision to harvest or not: of forest owner characteristics (O), property characteristics (P), management characteristics (M), and timber price (T), and e is a random error term.

Two statistical pathways were carried out: first, a two-stage regression analysis with a binary probit and linear regression, and then a tobit (censored) regression analysis, where the dependent variable is censored (with zero values) and continuous. Tobit models predict the simultaneous decision of whether to harvest and how much to harvest [40,58,59]. The tobit model has more information associated with it compared to the probit model [22,25,60].

Binary probit regression examines the relationships between categorical data versus a binary response. The variable Y, a binary choice denoting differences in utility between being willing to harvest timber (U_{1i}) and not (U_{0i}), is unobserved but related to the observed dependent variables. In our binary probit regression model the dependent variable takes the value of "1" if the respondent harvested timber in a given year and "0" if the respondent did not. The probit model can be stated as

$$P(Y_{it} = 1) = \Phi(X_{it}\beta + \varepsilon_{it}), \quad (2)$$

where X_{it} and β represent vectors of independent variables and coefficients, respectively, Φ denotes the cumulative normal distribution, and ε_{it} is the error term [12].

Thereafter, we developed a linear regression model for the part of the panel where $Y_{it} = 1$ in the probit model to estimate the impact of variables on timber harvest volume.

$$Y'_{it} = X_{it}\gamma + \varepsilon_{it}, \quad (3)$$

where Y'_{it} is the dependent variable harvest (m^3 ha^{-1} $year^{-1}$) supplied by owner i in period t, X_{it} is a vector of explanatory variables, and ε_{it} is the error varying over i and t.

In our sample, nearly 85% of the observations on harvest were zero. Hence, the dependent variable was regarded as censored, and the limited dependent variables tobit model was applied [61]. The tobit model is defined as follows [62]:

$$T_{it} = T^*_{it} = \beta' x_{it} + \varepsilon_{it} \quad if\ the\ right-hand\ side\ is\ positive, T_{it} = 0\ otherwise, \quad (4)$$

where T_{it}* is the latent potential timber supply, T_{it} is the observed timber supply (non-negative) of owner i in year t. x_{it} and β are corresponding vectors of independent variables and coefficients, respectively. The error term ε_{it} is normally and independently distributed with a mean zero and a common variance [22,25].

3.3. Data Check

The independent variables were checked for correlation and collinearity. Some variables were excluded or grouped from the analysis at the preliminary stage due to a high correlation coefficient (>0.4) (i.e., out of the three variables information on tax deductions, member of forest organization, and knowledge of forest fund, only the latter was included in the models). Later, the variance inflation factor (VIF) was calculated for the independent variables to test for possible multicollinearity [63], but none of the independent variables (after elimination or grouping) had VIF values >2, suggesting low multicollinearity.

Data variability was reduced to achieve symmetry in the central distribution, employing logarithmic transformation [64,65]. Therefore, dependent variables Y'_{it} and T_{it} (m^3 ha^{-1} $year^{-1}$) and the independent variables (size of forest property, distance from the property, and real timber prices) were log transformed and included in all regression models (Table 1). The distribution was assessed by histograms and scatter plots in R. The assumption of homoscedasticity of errors in the linear and tobit model was rejected, implying the presence of heteroscedasticity (the condition when error term varies across the values of an independent variable). A possible consequence of heteroscedasticity is biased standard errors [66]. Therefore, we employed the heteroscedasticity covariance matrix procedure [66] using the R function vcovHC() to obtain robust standard errors to correct this bias.

In this study, many of the respondents in our sample of Active and Inactive owners did not answer all questions. The issue of receiving incomplete surveys leads to a database with missing information. The missing values in our survey database varied from 5% to 10% across all the variables. The two usual procedures to deal with missing information in datasets are list-wise deletion and multiple imputations. In list-wise deletion the entire respondent with incomplete information is removed from the dataset. The elimination of data will lead to loss of information and may cause biased results [67].

Therefore, we employed a multiple imputation procedure to fill the missing values in our dataset [68,69]. In the imputation method, the value for missing observation is calculated based on the estimates of observed values [67,69]. We created multiple datasets using the R package *mice* and combined the results of imputed datasets [70]. Furthermore, imputed datasets were used to perform regression analysis in probit, linear, and tobit models. In the following, all results refer to the imputed datasets. All statistical analyses were performed using R software [71].

4. Results

4.1. Descriptive and Survey Statistics

Out of the 1500 and 1650 questionnaires sent to Active and Inactive forest owners, 842 and 795 questionnaires were returned, respectively. The adjusted response rates after accounting for non-deliverables and non-responses were 56% and 49% for the Active and Inactive owner samples, respectively. Mean values and standard deviations were calculated for all variables (Table 2). The mean age was 53 years for all NIPF owners, compared to 51.7 years for Active and 55.7 years for Inactive owners. The majority of questionnaires came from male owners (75–77%) for all three classes of Inactive owners, Active owners, and all owners combined. In terms of general education level, no significant difference were observed across activity classes of NIPF owners. Almost 60% of respondents had primary education and 40% of respondents had a bachelor degree or higher. The average holding size varied between 25.2 ha for Inactive to 49.5 ha for both samples and 73.8 ha for Active owners. On average, Inactive NIPF owners had more than twice (78.9 km) the distance between residence and forest property in comparison to Active forest owners (34.4 km). Income and net wealth varied between the owner groups, with means of the individual annual gross income and net wealth averaged over the years 2003–2012 being slightly higher for Active owners (0.48 and 1.08 M (Norwegian krone(NOK); 1 NOK ≈ 0.10 euro) than Inactive owners (0.44 M NOK and 0.82 M NOK). Furthermore, according to the data, 74% of the Active respondents reported knowledge of the Forest Fund, in contrast to 30% of Inactive owners. Overall, the share of owners who had visited the forest property at least once over the last 12 months ranged from 45% in the Inactive group to 59% among all owners and 73% of the Active group. Among Active owners, 42% planned to sell or transfer the property within the next ten years, compared to 28% of Inactive owners. Additionally, 37% of the Active forest owners reported interest in buying more forests, in contrast to 23% of the Inactive owners.

Table 2. Descriptive statistics (mean values and standard deviations) of the independent variables tested to affect NIPF owners' decision to harvest timber (owners grouped as Active and Inactive based on harvesting activity from the last 15 years). Weighted numbers. SD = standard deviation. See Table 1 for variable definition.

Variable	Inactive Owners		Active Owners		All Owners	
	Mean	SD	Mean	SD	Mean	SD
Age	55.74	14.07	51.72	13.71	53.73	13.89
Gender	1.26	0.43	1.24	0.43	1.25	0.43
General education	0.38	0.48	0.42	0.50	0.40	0.49
Size of forest property ha, (LN_ha)	25.26 (2.48)	61.69 (1.05)	73.88 (3.46)	244.45 (1.38)	49.57 (2.97)	153.07 (1.22)
Distance from the property, km (LN_KM)	78.97 (1.73)	370.12 (2.06)	34.47 (1.25)	235.25 (1.76)	56.72 (1.49)	302.74 (1.91)
Gross Income (M NOK)	0.44	0.70	0.48	0.62	0.46	0.66
Taxable net wealth (M NOK)	0.82	3.46	1.08	6.07	0.95	4.77
Real timber prices NOK per m^3 (LN_NOK per m^3)	285.18 (5.62)	66.59 (0.24)	294.00 (5.66)	65.53 (0.24)	289.64 (5.64)	66.06 (0.24)
Knowledge of the forest fund	0.30	0.45	0.74	0.53	0.52	0.49
Visits to forest land for activity	0.45	0.49	0.73	0.49	0.59	0.49
Interest in buying more forests	0.23	0.42	0.37	0.48	0.30	0.45
Plan to sell/transfer	0.28	0.45	0.42	0.49	0.35	0.47
Social values	3.75	1.39	3.85	1.45	3.80	1.42
Financial values	5.44	2.01	6.88	2.47	6.16	2.24
Conservation values	4.39	1.67	4.33	1.53	4.36	1.60
Recreation values	10.55	3.47	11.30	3.34	10.93	3.41

The objectives of owning forests varied between the owner groups (Figure 1). The largest differences were found in financial objectives. Overall, 60% of Inactive owners did not see their forest property as an important entity for financial gains, compared to 33% of Active owners. More Inactive than Active owners (15% compared to 6%) categorized intrinsic and heritage (social) objectives as a factor of no importance for owning forest. However, for all owners, recreational and social objectives were the most important of all objectives.

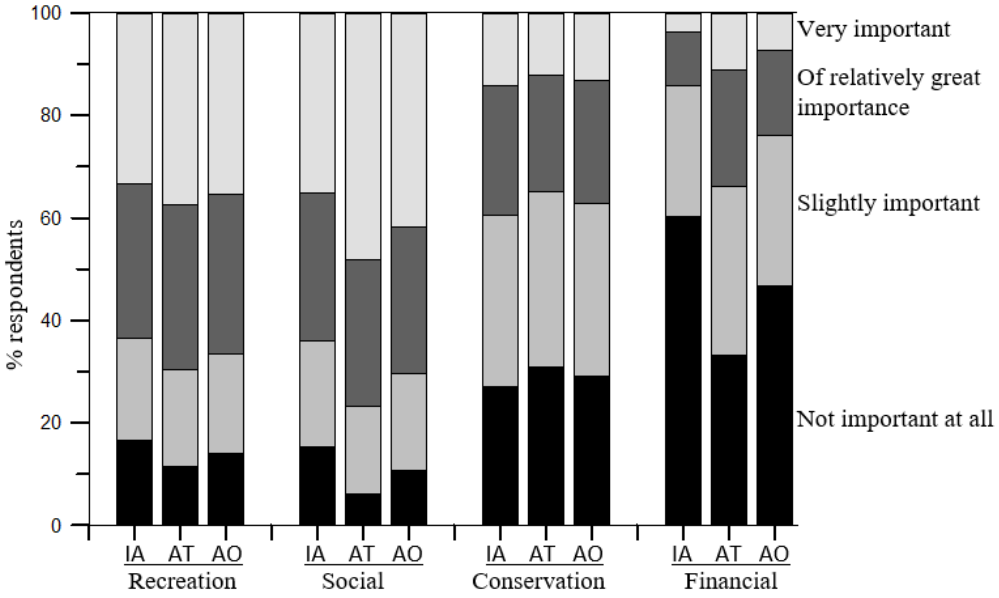

Figure 1. Objectives for owning non-industrial private forest (NIPF) among Active (AT), Inactive (IA), and All owners (AO).

4.2. Willingness to Harvest Timber: Regression Analyses

First the two-step probit and linear regression approach was carried out, followed by tobit modeling. Out of the included variables in the probit model, age, income, wealth, and timber price were non-significant (p-value > 0.05) (Table 3). Forest owners with higher education and with interest in buying more forest property were more responsive to harvesting. In addition, the forest owners possessing thorough knowledge of Forest Fund were more willing to harvest timber compared to others with no knowledge. Forest owners owning forests for financial gains/economic security and social consideration (inheritance) were statistically significant factors leading forest owners to harvest. Whereas, owners that designated forests for conservation and recreation objectives were restrictive to timber harvest. Distance to travel from home to forest had a significant negative impact on the observed willingness to harvest.

Table 3. Parameter estimates and marginal effects of the probit model in the period 2003–2012 (N = 16,370 over 10 years).

Factor	Estimate	Std. Error	p-Value	Marginal Effects
Age	−0.002	0.001	0.074	−0.0002
Gender	0.108 **	0.034	0.001	0.0136
General education	0.071 *	0.028	0.011	0.0091
Size of forest property	0.266 ***	0.010	$<2 \times 10^{-16}$	0.0343
Distance from the property	−0.040 ***	0.008	4.43×10^{-14}	−0.0052
Gross income	0.017	0.015	0.238	−0.0024
Taxable net wealth	−0.001	0.001	0.373	−0.0100
Real timber prices	0.024	0.060	0.687	0.0035
Knowledge of the forest fund	0.830 ***	0.042	$<2 \times 10^{-16}$	0.1149
Visits to forest land for activity	0.341 ***	0.038	$<2 \times 10^{-16}$	0.0455
Interest in buying more forests	0.100 **	0.030	0.040	0.0127
Plan to sell/transfer	0.143 ***	0.028	4.13×10^{-7}	0.0187
Social objectives	0.040 ***	0.011	0.0004	0.0050
Financial objectives	0.099 ***	0.007	$<2 \times 10^{-16}$	0.1243
Conservation objectives	−0.062 ***	0.011	3.40×10^{-8}	−0.0076
Recreation objectives	−0.020 ***	0.005	4.09×10^{-10}	−0.0023
Constant	−3.539 ***	0.352	$<2 \times 10^{-16}$	
Pseudo R^2	0.45			

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

We calculated the marginal effects to show the change in the probability of harvest given a 1% change in the explanatory variable, with all other variables held constant [37,72]. The variables with the largest impacts on the willingness to harvest were knowledge of Forest Fund and financial objectives, with marginal effects of 11% and 12%, respectively. In addition, an increase of 2.718 times the size of productive forest area increased the probability to harvest by 3%.

The second-stage linear model assessed how much timber forest owners harvested, given that they decided to harvest in the first-stage probit model. The model accounted for all forest owners who harvested timber at a given year within the time period 2003–2012, hence excluding owners who did not harvest that year. Contrary to the first part of the analyses, after owners decided to harvest, age and timber price seemed to have an impact on the harvest levels (Table 4). Age inversely influenced the timber harvest, whereas higher timber prices elevated the quantity of harvest. Results from the coefficient size in the linear model imply that the gender factor tended to remain significant in determining harvest volumes even after the owner had decided to harvest according to the probit model. Being a male owner increased the timber supply by 1.48 m^3 ha^{-1} compared to female ownership. Higher education and objective of owning forest for financial gains significantly inclined NIPF owners to harvest. Owners with financial objectives harvested 1.1 m^3 ha^{-1} $year^{-1}$ more timber than others. Interest in buying more forest as well as social and conservation objectives were statistically insignificant variables. However, recreation objectives and forest property area significantly influenced the harvest volumes, in the inverse direction. Timber harvest was reduced by 7% with a 10% increase in productive forest area. The variables taxable net wealth and income significantly and positively influenced timber supply. Timber harvest rose in the range of 1.02 to 1.25 m^3 ha^{-1} with an increase of 1% in net wealth and income. The elasticities for wealth and income were observed as 0.02 and 0.10, respectively. Finally, timber price was significant with an elasticity of 1.18, indicating that 1% increase in timber price elevated timber harvest by 1.18%.

Table 4. Parameter estimates of the linear model in the period 2003–2012 (N = 2682) (Dependent variable: m^3 ha^{-1}).

Factor	Estimate	Std. Error	*p*-Value
Age	−0.007 **	0.002	0.001
Gender	0.392 ***	0.064	1.110×10^{-9}
General education	0.255 ***	0.566	7.009×10^{-6}
Size of forest property	−0.739 ***	0.022	$<2 \times 10^{-16}$
Distance from the property	0.062 ***	0.017	0.0003
Gross income	0.224 ***	0.065	0.0006
Taxable net wealth	0.020 ***	0.003	1.622×10^{-10}
Real timber prices	1.176 ***	0.128	$<2 \times 10^{-16}$
Knowledge of the forest fund	0.133	0.130	0.305
Visits to forest land for activity	0.065	0.099	0.507
Interest in buying more forests	−0.079	0.067	0.240
Plan to sell/transfer	0.151 **	0.054	0.006
Social objectives	−0.029	0.019	0.132
Financial objectives	0.104 ***	0.015	1.972×10^{-11}
Conservation objectives	−0.023	0.022	0.306
Recreation objectives	0.016	0.011	0.152
R^2	0.38		

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

In the tobit model, 7 out of the 16 explanatory variables significantly influenced the timber harvesting behavior of NIPF owners (Table 5). Similar to the probit but contrary to the linear model, knowledge of the Forest Fund and frequent visits to forest inclined forest owners more towards timber harvest. Gender and owning forest for financial gains significantly influenced harvesting behavior across all three statistical models. In the tobit model being a male forest owner and owning forests

for financial objectives elevated the supply of timber by 1.85 m^3 ha^{-1} and 1.25 m^3 ha^{-1}, respectively. Whereas owners valuing the forests for conservation objectives restricted timber harvesting to 1.23 m^3 ha^{-1} less than other owners. Additionally, NIPF owners visiting more than once over the last 12 months harvested more timber (2.23 m^3 ha^{-1}) compared to owners with no visits. Higher timber prices and income attributes inclined owners to harvest, like in the linear model. With a 1% increase in forest owner income, the supply of timber could be raised by 1.35 m^3 ha^{-1}. A timber price increase of 1% resulted in an increase in the harvest level of 0.66%. Lastly, in the tobit model, contrary to the probit and linear model, forest area, distance to forest property, and education were not significant in determining harvesting behavior of forest owners.

Table 5. Parameter estimates of the tobit model in the period 2003–2012 (N = 16,370 over 10 years).

Variable	Estimate	Std. Error	*p*-Value
Age	−0.009	0.005	0.060
Gender	0.618 **	0.196	0.001
General education	0.153	0.147	0.299
Size of forest property	0.106	0.089	0.238
Distance from the property	−0.071	0.043	0.098
Gross income	0.288 ***	0.069	3.209×10^{-5}
Taxable net wealth	−0.197	0.709	0.781
Real timber prices	0.658 ***	0.199	0.0009
Knowledge of the forest fund	2.512 ***	0.258	$<2 \times 10^{-16}$
Visits to forest land for activity	0.804 ***	0.222	0.0003
Interest in buying more forests	0.192	0.198	0.331
Plan to sell/transfer	0.212	0.139	0.1291
Social objectives	0.110	0.062	0.077
Financial objectives	0.229 ***	0.042	4.822×10^{-8}
Conservation objectives	−0.179 ***	0.046	0.0001
Recreation objectives	−0.040	0.031	0.163
Constant	−12.098 ***	2.986	5.134×10^{-5}
Pseudo R^2	0.09		
Log-likelihood	−6999.85		

** Significant at 5% level, *** Significant at 1% level.

5. Discussion

NIPF owners possess a vast proportion of productive forest and play a paramount role in the sustainability of forests and the forest sector in Norway [73]. However, a total of about 22% of the productive forest area had no timber harvest for sale during the last twenty years [8,9]. In-depth analyses of factors influencing NIPF owners' forest management decisions are warranted to formulate efficient policies that encourage sustainable supply of timber and non-timber services [17]. Our study used a statistical approach to encompass the observed behavior of forest owners at different stages in the timber harvesting decision-making in Norway.

Forest area was significant in the probit and linear models, but with different sign and inversely related to timber harvest intensity in the linear model. The forest area was inversely related to timber supply because of the higher productivity and larger growing stock recorded on the smaller properties [9,12,13]. The finding that forest property size affects harvesting decisions is consistent with earlier findings [21,27,74]. We found that gender was a significant factor influencing timber harvesting across all models. In European and many other countries, significant gender differences are observed among private forest owners [73,75,76]. Female forest owners place more emphasis on conservation values than their male counterparts, and hence are less inclined towards harvesting [45]. Compared to male owners, female forest owners have been found to be older across Europe with less competence in forestry [76] and low engagement in practical forestry [75].

The results support our hypothesis that information on the Forest Fund has a strong significance in motivating NIPF owners towards timber harvesting in Norway. These type of forestry incentives

are positively influencing timber harvesting activities [77,78]. Hence, it should be noted that 40% of the forest owners possess a low level of awareness about and participation in these programmes. Sjølie et al. [12] found that forest owner organizations were the main source of information for Active owners. Only a small share of Inactive forest owners (17%) were members of the forest organizations in comparison to Active owners (72%). The direction of effects remains to be elucidated, but higher participation in forest organization might raise awareness and encourage activity on forestland. Forest owners with a previous record of harvesting possess a sense of familiarity with forest policies, and hence have fewer reservations about starting a new activity [79–81]. In contrast, forest owners with limited knowledge about the Forest Fund erroneously estimate taxes after timber harvest and the cost of stand establishment after harvesting [12,41,82].

The statements that determined ownership objectives in our study are financial security from the timber harvesting. The financial attribute was the strongest separating factor between Active and Inactive NIPF owners. The results support our hypothesis that Active forest owners with economic objectives for managing their forests were positively inclined towards timber harvesting. Our study results are consistent with [18,32,52,83], indicating that forest property is considered as an asset by forest owners to attain a sense of financial security and well-being. On the contrary, a number of studies recorded that NIPF owners do not recognize forests for financial security but more for recreation or other non-timber amenities [47,84]. A total of 50% of Inactive forest owners did not visit their forest property during the last 12 months. The reason could be that a significant number of Inactive owners (21%) in the study were above 70 years of age and many lived far away from their property, which is consistent with findings from other countries [26,40,85,86].

The European Union adopted an updated version of its renewable energy directive in 2018 [87], committing to cover at least 32% of its energy from renewable sources by 2030. Norway is also covered by this directive, as it is part of the European Economic Area. Forest biomass is expected to contribute significantly to Europe's renewable energy mix towards 2030. Currently, 8% of the total energy and about two-thirds of the bioenergy supplied in the EU stems from biomass; the total bioenergy supply from forests is projected to grow by 2030 [88,89]. In this regard, the present study contributes to our understanding of the driving forces of timber supply, which may aid authorities in formulating policies that encourage more forest owners towards timber harvesting.

A larger harvest will also contribute to higher economic activities in rural areas and promote viable and sustainable rural communities. This will help to fulfil a core objective of Norway's political agenda—to develop rural areas with proper population settlement patterns distributed over the country [82]. The same concept is also adopted by the EU through the rural development policy of diversification of economic activity in rural areas [90].

In this study, we followed a statistical modelling approach of probit-linear and tobit regression to determine the significance of various variables in different settings of forest owner timber harvesting decision-making. Comparing the modelling approaches, we believe that both the one-step and two-step approaches could realistically reflect forest owner decision-making. These two statistical pathways give two sets of results that vary in their assumptions. The probit/linear model result outcomes are more useful to be employed when harvesting timber is decided as two separate decisions—firstly harvest or not harvest, and secondly the quantity of timber to harvest. Whereas, when both decisions come at once, then results from the tobit model will have more relevance. Therefore, both models have significant contributions based on the situation of the forest owner. Furthermore, it needs to be validated which approach may reflect forest owners' actual decision-making in different settings. This may vary according to the specific situation or forest owner and property characteristics. Better understanding of forest owner decision-making processes is a topic for future studies.

However, the given elasticity of supply with regard to price was very high in the linear model and insignificant in the probit model. In the tobit model, this elasticity was 0.66, about at the expected value consistent with the elasticities reported by previous studies [22,26]. The higher elasticity in the

linear model may be due to the fact that only positive harvest volumes were included in the model; and thus this elasticity applies to owners who had already made the decision to harvest.

6. Conclusions

Our study found that forest owners with economic objectives were more inclined to harvest, and that male owners harvested more than female owners. Across all three statistical models applied for the analysis, the two variables gender and economic objectives were observed to be significant in influencing timber harvest, whereas other variables like age, distance to property, timber price, knowledge of the forest fund, and property size also had an impact on harvesting in some models. Both modelling approaches (i.e., probit/linear and tobit) reflect forest owner decision-making. The suitability of the approaches in specific contexts could be further explored, as this study only compared and presented the outcomes of both statistical pathways.

Our study provides detailed insights about the factors influencing the timber harvesting behavior of NIPF owners in Norway. This study also identified the owner groups that may require special attention from forest policymakers and extension services, such as female owners and owners with limited knowledge on forest policy instruments. Policies and information campaigns may be more effective when directed to particular groups of forest owners. Policy-makers should consider these factors for designing effective and efficient forest policy instruments.

Author Contributions: Conceptualization: H.K.S. and A.B.; data availability: H.K.S. and B.S.; methodology: A.B. and H.K.S.; data analysis: A.B.; project administration: H.K.S. and B.S.; supervision: H.K.S.; validation: A.B., H.K.S. and B.S.; writing—original draft: A.B.; writing—review and editing: A.B., H.K.S., and B.S. All authors have read and agreed to the published version of the manuscript.

Funding: Funding was granted from the Norwegian Ministry of Agriculture and Food, the Faculty of Environmental Sciences and Natural Resource Management, Norwegian University of Life Sciences, and the Faculty of Applied Ecology, Agricultural Sciences and Biotechnology, Inland Norway University of Applied Sciences, and is greatly appreciated.

Acknowledgments: Authors are also grateful to Olivier Devineau at the Inland Norway University of Applied Sciences for statistical guidance.

Conflicts of Interest: The authors declare no conflicts of interest.

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forests

MDPI

Correction

Correction: Bashir et al. Determinants of Nonindustrial Private Forest Owners' Willingness to Harvest Timber in Norway. *Forests* 2020, *11*, 60

Altamash Bashir [1,*], Hanne K. Sjølie [1] and Birger Solberg [2]

[1] Faculty of Applied Ecology, Agricultural Sciences and Biotechnology, Inland Norway University of Applied Sciences, 2400 Koppang, Norway; hanne.sjolie@inn.no
[2] Faculty of Environmental Sciences and Natural Resource Management, Norwegian University of Life Sciences, 1433 Ås, Norway; birger.solberg@nmbu.no
* Correspondence: altamash.bashir@inn.no

We have found some errors in our recently published article [1]. Consequently, the authors wish to make the following corrections to the paper. The errors resulted due to an incorrect interpretation of the direction of significance of the gender variable in the regression models.

Abstract: The two sentences of the Abstract section should now read: "In the linear regression, being a female owner increased the historical timber supply by 1.48 m^3 ha^{-1} $year^{-1}$ compared to male ownership. In the second regression pathway (tobit model), the two variables female forest owner and owning forests for financial objectives triggered the supply of timber by 1.85 m^3 ha^{-1} $year^{-1}$ and 1.25 m^3 ha^{-1} $year^{-1}$, respectively".

1. Results

Willingness to Harvest Timber: Regression Analyses.

On page 9 of the original paper, the sentence: "being a **male** owner increased the timber supply by 1.48 m^3 ha^{-1} compared to **female** ownership", should state: "being a **female** owner increased the timber supply by 1.48 m^3 ha^{-1} compared to **male** ownership".

In the original paper on page 9–10, the sentence: "In the tobit model being a **male** forest owner and owning forests for financial objectives elevated the supply of timber by 1.85 m^3 ha^{-1} and 1.25 m^3 ha^{-1}, respectively" should state: "In the tobit model being a **female** forest owner and owning forests for financial objectives elevated the supply of timber by 1.85 m^3 ha^{-1} and 1.25 m^3 ha^{-1}, respectively".

In Table 5 of the original paper, the revised values for taxable net wealth should read as 0.197 instead of −0.197. Revisions did not bring any changes in the text, as the value was non-significant in the model.

2. Discussion

In the second paragraph, the Discussion should read as follows: "**In general**, female forest owners place more emphasis on conservation values than their male counterparts, and hence are less inclined towards harvesting [45]. **However, our study observed that for the period of 2003–2012, female forest owners harvested more timber in comparison to male owners**". However, compared to male owners, female forest owners have been found to be older across Europe with less competence in forestry [76] and low engagement in practical forestry [75]".

3. Conclusions

The two sentences in the Conclusion paragraph should now read: "Our study found that forest owners with economic objectives were more inclined to harvest, and that **female** owners harvested more than **male** owners". "This study also identified the owner groups

Citation: Bashir, A.; Sjølie, H.K.; Solberg, B. Correction: Bashir et al. Determinants of Nonindustrial Private Forest Owners' Willingness to Harvest Timber in Norway. *Forests* 2020, *11*, 60. *Forests* **2021**, *12*, 1368. https://doi.org/10.3390/f12101368

Received: 16 September 2021
Accepted: 29 September 2021
Published: 9 October 2021

that may require special attention from forest policymakers and extension services, such as owners with limited knowledge of forest policy instruments".

Reference

1. Bashir, A.; Sjølie, H.K.; Solberg, B. Determinants of Nonindustrial Private Forest Owners' Willingness to Harvest Timber in Norway. *Forests* **2020**, *11*, 60. [CrossRef]

Paper II

Non-industrial private forest owners' knowledge of environmental values in their forest and their attitudes towards environmental conservation

Altamash Bashir[1], Hanne K. Sjølie[1], Dennis Becker[2], Birger Solberg[3]

[1]Inland Norway University of Applied Sciences, Faculty of Applied Ecology, Agricultural Sciences and Biotechnology, P.O. Box, 2400, Koppang, Norway

[2]College of Natural Resources, University of Idaho, Moscow, USA

[3]Norwegian University of Life Sciences, Faculty of Environmental Sciences and Natural Resource Management, Ås, Norway

Corresponding author E-mail: altamash.bashir@inn.no

Abstract: Non-industrial private forest (NIPF) owners manage substantial parts of the forest in many countries, and their knowledge and attitudes are thus important for the supply of ecosystem services. In Norway, NIPF owners possess 84% of the productive forestland. We utilized questionnaire-based survey to develop a model of the environmental knowledge and two models of conservation attitudes. More than half of the respondents (53%) state that "Protect and conserve nature's diversity" is as an important reason for owning forest, while the corresponding number for the objective "The forest being first and foremost a nature preservation object" is 19%. Forest owners who have harvested, have forestry education, who visit forest frequently and have had direct contact with the municipality about forestry and have registered environmental values in their forest, stated more environmental knowledge. Owning forest for nature diversity and preservation objectives were positively associated with environmental knowledge. The owners seeking forests/forest property related information possess higher environmental knowledge in turn influence positively on the environmental conservation attitudes. However, the two analyzed conservation attitudes are received very differently among forest owners. We argue that the high support for protecting and conserving nature's diversity suggest that the multifunctional forestry concept has proved successful in Norwegian forestry.

Key words: Non-industrial forest owner objectives; Environmental conservation; Forest preservation; Survey; Probit model; Socio-demographic factors

1. Introduction

The loss of biodiversity and its impact on environmental sustainability is a global concern to humankind (CBD, 2000; Glowka et al., 1994; Selvik, 2004). In recent times, strategies for protecting, conserving and preserving nature diversity have attracted substantial public support and prioritization in government policies at both national and international platforms (Angelstam et al., 2004; Bakaki and Bernauer, 2016; Eriksson and Klapwijk, 2019; Hooper et al., 2005; Paloniemi and Tikka, 2008). To this end, the Convention on Biological Diversity (2010) recommends countries to achieve the Aichi biodiversity targets by 2020, that include conserving 17% of terrestrial land and major targets for reducing the loss of natural habitats, including forests (CBD, 2000; Mitani and Lindhjem, 2015; NMCE, 2014).

Forests are storehouses of a significant proportion of global biodiversity, teeming with about 90 percent of the terrestrial biodiversity. However, the gradual reduction of biodiversity had profound effect on the way forests evolved as resource to meet the demands of timber and non-timber benefits of the society (Benz et al., 2020; EEA, 2006; Kurttila, 2001). About 38 % of mainland Norway is forest, home to approximately 60% of the domestic plant and animal species (about 24 000 species) (Kim-Anh and Nina, 2016; NMCE, 2014). Therefore, it has been recommended to expand protected areas to increase the representation of forest ecological systems in Norway (Framstad and Blindheim, 2010; Lindhjem and Mitani, 2012; Selvik, 2004). In 2016, the Norwegian parliament voted the objective to protect 10% of the forest area (NMCE, 2019; Stortinget, 2015). Areas under protection is growing steadily, and as of 2020, about 5% of all forest area and 3.8% of the productive forest area is strictly preserved with forestry prohibited by law (Frivillig Vern, 2020). During the last fifteen years, forest preservation on private land has been voluntary with the selected areas typically being defined as nature reserves and the set-aside areas being economically compensated (Frivillig Vern, 2020). Outside the areas of strict preservation, biodiversity measures are taken across the forest landscapes through

various programmes. Practically all forestland in Norway where timber is harvested is certified, mainly according to the Program for the Endorsement of Forest Certification (PEFC) standard, but also some land according to the Forest Stewardship Council (FSC) standard. As part of the certification, a set of measures are taken, including officially registering and setting aside biological hot-spots, and maintaining buffer zones around lakes and rivers and ensuring retention trees during forestry operations (PEFC, 2015).

As non-industrial private forest (NIPF) owners control the majority of the forest in Norway, they play important roles to improve biodiversity by measures in production areas and through supply of areas for conservation (Barton et al., 2013; Bashir et al., 2020; Lindhjem and Mitani, 2012; Mitani and Lindhjem, 2015). Therefore, understanding forest owners' attitudes towards environmental conservation is indispensable to achieve biodiversity policy goals. Although, Lindhjem and Mitani, 2012 and Mitani and Lindhjem, 2015 have investigated attitudes of NIPF owners towards participation in voluntary forest conservation programs in South-Eastern Norway, very little research is available on the national scale regarding attitudes to protect and conserve nature outside conservation programmes. As knowledge is pivotal for decisions, understanding forest owners' knowledge of environmental values alongside attitudes towards conservation is crucial in establishing well designed polices and extension programmes.

Thus, this study has as goals to examine NIPF owners' stated knowledge of environmental values in their forests and their attitudes towards nature protection and conservation. In addition, we give an overview of previous studies related to this goal, focusing on studies from Scandinavia and North America.

2. Literature review

Attitude, motivation and behaviour of forest owners towards managing their forests shape the supply of timber and non-timber products and services to society (Feliciano et al., 2017). These attitudes and behaviours are found to be highly influenced by property and personal characteristics, management strategies, socio-demographic factors, conservation ethics, and financial status of the forest owner (Amigues et al., 2002; Bashir et al., 2020; Boon et al., 2004; Tian et al., 2015; Vedel et al., 2015; Mitani and Lindhjem, 2015). Several studies indicate that possessing higher knowledge of environmental values of forests incline forest owners towards biodiversity conservation (Eriksson et al., 2013; Langpap and Wu, 2004; Mäntymaa et al., 2009; Nordlund and Westin, 2011).

A number of studies (Bjärstig and Kvastegård, 2016; Gatto et al., 2019; Uliczka et al., 2004) indicate that less access to knowledge and information about forest ecosystem services hinders forest owners from positive attitude towards nature diversity and conservation. Forest owners with membership in environmental organizations are generally in favour of preservation and conservation of forests (Eriksson and Klapwijk, 2019; Urquhart et al., 2017). Mitani and Lindhjem (2015) found that the owner's membership in an environmental organization is positively correlated with an expectation to follow forest biodiversity and conservation programs. A good number of forest owners value amenity objectives and nature preservation as motivation for property ownership in comparison to economic goals (Eriksson and Klapwijk, 2019; Kendra and Hull, 2005).

Some studies observed that participation in conservation and biodiversity programmes is negatively correlated with forest size (Langpap and Wu, 2004; Mitani and Lindhjem, 2015). However, a study of 393 NIPF owners in south-central Sweden observed that size of the forest property is insignificant to forest owner's attitude towards conservation (Uliczka et al., 2004).

Uliczka et al (2004) also found that owner age is negatively affecting decisions for conservation of biodiversity, and young owners are more biocentric and more willing to set aside forestland for conservation in return for financial compensation. Langpap and Wu (2004) and Mitani and Lindhjem (2015) stated that with one year of age increase, the probability to be involved in biodiversity and conservation programs decreases by 0.43% and 0.71%, respectively.

Several studies show that highly educated owners have pro-conservation values and assign greater importance to aesthetic and forest conservation values than to timber production (Beach et al., 2005; Farmar-Bowers and Lane, 2009; Hallikainen et al., 2010; Hayrinen et al., 2015). In Finland, Koskela and Karppinen (2021) identified that more educated forest owners are interested in biodiversity projects. Drescher et al (2017) and Uliczka et al (2004) found that forestry education is an important factor in influencing forest owners' attitudes towards biodiversity conservation in Canada and Sweden, respectively.

Forest owners living far from their forest properties emphasize conservation of biodiversity more than timber production (Hayrinen et al., 2015; Nordlund and Westin, 2011). Similarly, Mitani and Lindhjem (2015) observed that the probability to participate in biodiversity and conservation activities decreased by 16.8% for owners living in the same municipality compared to living far from the forest property.

Gender differences were observed in the evaluation of forests for aesthetic and landscape objectives in many Nordic studies (Lidestav and Ekström, 2000; Nordlund and Westin, 2011; Palander et al., 2009; Umaerus et al., 2013). Female owners tend to possess more biocentric values and pro-environmental attitudes than their counterparts (Hayrinen et al., 2015; Vaske et al., 2001), whereas male forest owners are more inclined towards traditional forest activities (Umaerus et al., 2013). In the US, Amacher et al (2004) and Kline et al (2000) found that wealthier forest owners put higher value on non-timber services from their forest. In

contrast Joshi and Arano (2009) stated that NIPF owners in West Virginia with higher income did not prioritize non-timber services from their forestland.

Lindhjem and Mitani (2012) reports that forest owners who harvest timber are less inclined towards conservation programs than owners who do not harvest. Forest owners' visiting frequency to their forests has been found to positively impact the knowledge of and protective attitude towards nature diversity and conservation (Uliczka et al., 2004).

Our literature review highlights several factors that influence the environmental conservation attitude of NIPF owners, like forest owner and property characteristics, objectives of owning forests, economic situation, information, knowledge and level of education. As established by many studies, knowledge is an important factor for attitudes. However, we have not come across any studies that explain the level of environmental knowledge and information among NIPF owners. Better understanding this driving factor is important for policy-makers and extension services. Further, conservation is traditionally an area embedded in conflicts, and closely related conservation concepts may be received very differently among stakeholders. The literature of different conservation attitudes among forest owners is scant. More insight into the nuances in conservation attitudes will help policy-makers, environmental and forest owners organizations to develop conservation strategies compatible with forest owners attitudes that in turn have larger chances of success. Therefore, we will compare forest owners' responses to the two objectives. While the first objective reflects a strategy that fits into a multifunctional forestry setting, the second conservation objective puts the preservation as the primary goal of the ownership.

In addition to dissecting these two attitudes and providing new understanding of driving factors of forest owners' environmental knowledge, our study adds to the literature by its nationwide, representative survey data with self-reported activity, information sources, economic activity and demographic variables.

3. Methodology

3.1 Behaviour theory, hypotheses and statistical method

In developing the conceptual framework of the knowledge-attitudes relationships (Figure 1), we draw on the social cognitive hierarchy model (McFarlane and Boxall, 2003, 2000). The model stipulates that knowledge, information and socialization influences are important predictors for attitudes. In addition, based on previous studies mentioned in chapter 2 (e.g. Uliczka et al., 2004), we expand this model by adding economic factors as predictors. Our two main hypotheses are, first, that socialization influences (S) and information factors (I) influence the level of knowledge of environmental (KE) values among individual forest owners, and second, that the KE factors together with information, socialization influences and economic factors explain the attitudes towards environmental conservation. The two objectives, *Protecting and conserving nature's diversity* and *Nature preservation*, are abbreviated ND and NP, respectively.

Thus, we estimated statistically three models:

$$KE_i = f(S, I,) + e_i \qquad \text{Eq. 1}$$

$$ND_i = f(KE, S, I, EF) + e_i \qquad \text{Eq. 2}$$

$$NP_i = f(KE, S, I, EF) + e_i \qquad \text{Eq. 3}$$

where KE_i is the level of knowledge of the forest environmental values stated by forest owner *i*, S_i the social factors influencing forest owner *i*, I_i the information sources used by forest owner *i*, EF_i the economic factors characterizing forest owner *i*, ND_i and NP_i the attitudes of forest owner i towards nature diversity and nature preservation, respectively, and e_i is error term.

In Table 1 the dependent and independent variables used in the statistical analyses are defined and our hypotheses about their influence directions specified. For the statistical estimation, we used probit regression models due to the binary nature of the three dependent variables. The equation for the probit model can be expressed as;

$$P(Y_i = 1) = \Phi(\beta_0 + \beta_1 X) + \epsilon_i \qquad \text{Eq. 4}$$

where Φ denote the cumulative normal distribution, β_0 and β1 are coefficients of the probit regression models and ε_i is the error term.

For the model KE_i, $Y_i = 1$ when the respondent states "rather well" or "very well" to the survey question about level of knowledge of environmental values in their forest and 0 otherwise. Similarly, for the model ND_i, the probability takes the value of 1 if the forest owner reports "relatively great importance" or "very important" to the survey question about owning forest for nature diversity and conservation, and a value of zero if the owner has answered "no" or "slight importance" to this question. The same classification is followed for NP_i, but here the question is about forest preservation. When presenting ownership objectives to the forest owners in the survey, we did not provide more details with the implications of different objectives on forest management and harvest. However, the first objectives, *My forest provides me the opportunity to protect and preserve nature's diversity*, is a strategy compatible with other ownership objectives. The second objective, *The forest is first and foremost a nature preservation object*, puts nature preservation as a primary objective.

In this article we use "forest diversity" to mean the "nature diversity and conservation" objective, "nature preservation" when we refer to the second objective, and combined impact of nature diversity and nature preservation as "environmental conservation" in order to make the presentation and discussion of results easier to follow.

We evaluated all pairwise correlations in order to exclude or group highly correlated variables. Variables with correlation coefficient value > 0.4 were either grouped or dropped from further analysis. To maintain normal distribution, the variables Distance and Productive area were log-transformed. The regression models were tested for multicollinearity using variance inflation factor, which remained below 1.5 for all variables, indicating low multicollinearity (Allison, 1999).

The survey dataset for the analysis contained missing values, as several of the forest owners' responses were incomplete. The values for missing observation were estimated from observed values using multiple imputations (Schafer and Graham, 2002). The mice package in R was used to perform these imputations in the dataset (Buuren and Groothuis-Oudshoorn, 2011).

3.2. NIPF dataset

The main data used in the analysis originates from a national survey of NIPF owners developed and distributed across Norway by Statistic Norway in close collaboration with the Norwegian University of Life Sciences. The population constituted all private forest owners with property equal or above 2.5 hectares. Owners were divided into two groups based on quantity of timber harvested during the period 1998-2012. The group named as Active had harvested $5m^3$ or more of timber for sale during this period whereas the group classified as Inactive had harvested less than that over these fifteen years. The gross sample consisted of 1500 active owners and 1650 inactive owners drawn out of the two populations of 56 965 active owners and 72 147 inactive owners. A pre-testing was done to improve the setup of the survey and the questions were altered based on the feedback. The questions covered a large area of interest like socioeconomic, personal and property characteristics, alongside questions related

to attitudes, reasons for owning forests and the owner's stated level of knowledge of environmental values in their forests.

In addition, the survey data were for each forest owner supplemented by annual data on taxable income, taxable wealth and timber harvest volume, as provided by the Norwegian Statistical Bureau. The Total Design Method developed by Dillman, (1978) was applied to implement the survey effectively. The survey questionnaire was distributed in February 2014 to the randomly selected sample of forest owners, and data collection ended in June 2014. More details on the survey and dataset are found in Sjølie et al (2019) and Bashir et al (2020). Before statistical analyses were carried out, all observations were weighted according to county and property sizes.

4. Results

Table 2 gives a descriptive overview of the data used in the analysis. The response rate was 52%, based on the return of 1637 questionnaires, after exclusion of non-deliverables and non-responses. 25% of the respondents were female and 75% male. The mean forest holding size was 49.57 ha, with average distance of 56.72 km from the property to the residence. 44% of the respondents had harvested more than $5m^3$ of timber for sale at least once during the years 1998-2012, and 59% of the respondents visited the forest more than once per year. Approximately half of the owners had direct contact with the forestry section in their municipality for advices and suggestions related to forestry issues on their property. Mean age of the respondents was 58 years and 40% of them possessed higher education. A small number of owners (23%) had forestry or agricultural-related education while 22% had registered environmental values on their forest property. 14 % of the respondents agreed that media and professional journals are important sources of information for the management of their forests.

Out of total, 35% of the respondents replied "rather well" to "very well" to the statement "I know the environmental values of my forest" and 53% associated conservation of nature's

diversity of great importance or very important reason for owning forests. This was almost three times as many as the share of owners (19%) stating that nature preservation is a primary objective for owning forests.

The results of the probit model for environmental knowledge are presented in Table 3, which shows that the following independent variables were not statistically significant: Age, Education, Media and professional journals and Farming. The variable Registered environment values has the marginal effect of 0.276, meaning that the probability that an owner possess knowledge of environmental values in their forest increases by 27.6 % if the owner has registered the environmental values in their forests, all other factors being equal.

We also carried out separate analysis for active and inactive sample of forest owners. The results were rather similar to the outcome from the whole sample of respondents, with the exception that the inactive female forest owners expressed even less knowledge of environmental values in their forest than the group of active female owners.

The probit model results explaining the magnitude and direction of factors determining the attitude of private forest owners towards nature diversity and towards nature preservation are presented in Table 4. The second column shows that the following variables were significantly affecting the attitude of nature diversity: Forest harvest activity, Size of forest property, Visits to forest, Environmental knowledge, Media and professional journals, Centrality and Direct contact with municipality. The marginal effects column displays that owners who have visited the forest property during the last year have a 5.5% higher probability to own forest for conserving nature diversity than the other forest owners. The factors standing out as affecting the most are Environmental knowledge and Media and professional journals, each having marginal effects of 11% and 13.5%, respectively. In contrast, we see that being an active forest owner (i.e. having harvested timber) is negatively correlated with the nature

diversity objective, in the meaning that such owners have a 9.1 % lower probability of owning forest for diversity purpose than inactive owners.

The nature preservation probit model results (column 4 and 5 in Table 4) show that only three variables (Age, Forest harvest activity, and Environmental knowledge) are significant. Age is positively related to forest owner's decision to own forest for nature preservation, in the meaning that if the age increases by 1 year, the probability of having nature preservation as main objective increases by 0.36%. Being active forest owner reduced this probability by 6.8%, whereas it increased by 6.1% for the group of forest owners who possess knowledge of environmental values in their forest.

5. Discussion

Private forestlands are highly recognized as a key resource for successfully implementing environmental conservation policies and strategies (Drescher et al., 2017; Kamal et al., 2015; Norton, 2000). However, promoting environmental conservation or preservation on private forestland is still a challenge as conflicts may easily occur when attempting to accommodate both timber harvest and environmental services, not at least biodiversity (Drescher et al., 2017; Koskela and Karppinen, 2021). Continuous efforts are done to reconcile forest ecosystem services on such land (Primmer and Karppinen, 2010). To this backdrop, we have concentrated on obtaining better understanding of NIPF owners' knowledge of environmental values and their attitudes towards environmental conservation.

Our extensive, national-wide survey based on stratified, random sampling combined with tax record data ensures the national representativeness and rendered inclusion of important driving variables related to attitudes, demography, forest, income and wealth.

The response rate in our survey was 52 %, which is on the same level or higher than comparable studies like Amigues et al (2002) with response rate 30% and 400 respondents in

Sweden; Lindhjem and Mitani, (2012) with 39% response rate and 2007 respondents from Norway, Drescher et al (2017) with response rate 55% and 800 respondents from Ontario, and Uliczka et al (2004) with response rate 58% and 393 respondents from Sweden.

Not unexpectedly, the knowledge results reported in Table 3 clearly shows that owners who actually have registered environmental values on their property, also have highest knowledge about environmental values on their land. It is also interesting to note that general education has no statistical significance on this knowledge, whereas education in agriculture and forestry has. It seems also logic that harvest activity, visits to forestland, and direct contact with municipality have significant positive influence on this knowledge. The lack of significance of the variable Media and professional journals indicates that instead of such magazines, owners have obtained knowledge of environmental values in forestry education, through planning and undertaking of operational forestry and from the municipality.

Table 3 also demonstrates that female forest owners have less knowledge about the environmental values of their forest than male owners. More information on environmental issues could preferably be combined with other information programmes directed towards female owners, also because they are reported to be less informed about forest management than male owners (Follo, 2008). Studies based on cognitive hierarchy models show similar results regarding managing various environmental problems (Eriksson et al., 2013; Eriksson and Klapwijk, 2019; Nordlund and Westin, 2011).

Several of the results shown in Table 4 need to be discussed. None of the 6 variables Gender, Gross income, Taxable net wealth, Distance from the property, Forestry or agriculture education, and Farming are statistically significant – neither in the nature diversity group nor the preservation group of owners.

While 53% of the respondents emphasize the objective of conserving nature's diversity, only 19% of the owners consider their forest as first and foremost a nature preservation object

(Table 2). The latter group accounts for about 16% of total forest land of NIPF owners covered by our survey. This indicates that the multifunctional forestry concept has a strong position among the NIPF owners in Norway and much stronger than owning the forest only for nature preservation. In the conservation alternative, the owner's consideration of protecting nature's diversity can be combined with their other ownership objectives. This diverges strongly from nature preservation which may not be compatible with other objectives. The argument that our findings suggest that the multifunctional forest management strategy is successful.

In Nordic forestry, nearly all of the productive forestland is certified and range of measures are taken across the landscape upon forestry planning and operations to conserve biodiversity and other ecosystem services. Thus, a large part of the respondents (47%) who do not have nature diversity attitudes know about these regulations and may therefore conclude that the environment are sufficiently well taken care of by following them. Forest owners who do not harvest may not be aware of these regulations, which may explain why the variable Forest harvest activity is significantly negative in both measured attitudes

Since the first certification in Norway was implemented in 1998 ("Living Forest"), the standard has been developed and forest management adapted (Sverdrup-Thygeson et al., 2008). The environmental awareness of forest owners has most likely increased considerably as part of this process and may explain why a significant number of forest owners are positive to nature diversity and conservation; they may see this as an intrinsic part of forest management. In addition, forest owner associations have a central role in the voluntary forest protection processes (Frivillig Vern, 2020), which may explain why owners are positive towards nature diversity and conservation. In most of these voluntary cases, just a smaller part of the property is preserved in these processes, and owners may thus perceive that as an acceptable strategy for the property.

The small share of answers in favor of nature preservation (see Table 2) might be a reason for the few significant variables in Table 4. We also observed smaller Psuedo R^2 (0.04) value for both diversity and preservation models, however many similar survey based studies have stated similar values for R^2 (Kuuluvainen et al., 1996; Hallikainen et al., 2010; Mitani and Lindhjem, 2015). Both diversity and preservation encompass attitudes towards environmental conservation; however, as seen in Table 4, owners perceive the two management options very differently. This shows that owners are sensitive to the different environmental conservation strategies. We interpret this as forest owners perceive nature preservation as a policy that limits their property rights, in line with the findings in Kamal et al., (2015). In contrast, conserving nature may be interpreted as a measure intervening less with the property rights and the owner's control over the forest, and an objective that can be combined with other objectives of their ownership, as reported by (e.g. Koskela and Karppinen, 2021). After all, most forest owners are multi-objective oriented (Favada et al., 2009).

Out study but confirms that forest owners who have environmental knowledge and are informed about forestry (by receiving management inputs from media and professional journals, visiting their forest, having knowledge about the environmental values in their forests, and following media and reading professional journals) are more interested than other owners to use nature conservation as objective in their forest management. This is in line with results reported by (Frondel et al., 2012; McFarlane and Boxall, 2003; Urquhart et al., 2017). Similarly, Uliczka et al (2004) observed that forest owners with high level of education in forestry or conservation implemented more biodiversity measures, such as setting aside areas during harvesting, in their management plans. Educational programmes of how to combine timber production with biodiversity measures may lead to even more interest among owners to carry out management that supports multifunctionality.

Our results show that forestry education and information are effective instruments for implementation of forest environmental policies, in line with results reported by (Doremus, 2003; Langpap, 2006; Uliczka et al., 2004). We correctly hypothesized that owners visiting their forest property possess higher level of awareness of their forest's significance for environmental conservation. Frequent forest visits may indicate that forest owners have detailed knowledge about the forest and are capable to plan suitable management. Uliczka et al (2004) also observed that frequent visiting forest owners possessed high level of general knowledge about biodiversity conservation.

6. Conclusions

This study provides better understanding of environmental knowledge and attitudes among NIPF owners in Norway. Future research may look deeper into the knowledge and interest of specific activities among forest owners and their attitudes towards trading off different products and services across stands or the landscape. Our survey-based study concluded being female forest owners reduces the level of knowledge on environmental value of forests. The gender gap in forestry knowledge has substantial documentation (Follo, 2011), and is an important area for forestry extension services and support. Forest owners who visit the forest and are well connected with the municipality possess higher level of knowledge about the environmental values and have forest diversity as an ownership objective.

The environmental conservation policies directed to forest owners should include educational and awareness programmes to as only one third of the owners have knowledge of the environmental values and more knowledge will aid owners to take better decisions.

While 53% of the respondents adhere to the objective of protecting and conserving nature's diversity, less than a fifth of the owners, owning together 16% of the productive forest, consider their forest as first and foremost a nature preservation object. This suggests that the

multifunctional forestry strategy in Norway is successful, as most owners support well or very well to the objective of conserving nature's diversity.

Acknowledgements

The authors highly appreciate funding granted by Norwegian Ministry of Agriculture and Food, the Faculty of Environmental Sciences and Natural Resource Management, Norwegian University of Life Sciences and the Faculty of Applied Ecology, Agricultural Sciences and Biotechnology, Inland Norway University of Applied Sciences.

Author statement

Altamash Bashir: Conceptualization, Methodology, Formal analysis, Writing - Original Draft, Writing - Review & Editing, Validation, Visualization. **Hanne Sjølie:** Conceptualization, Writing - Review & Editing, Validation, Resources, Supervision, Project administration. **Birger Solberg:** Validation, Writing - Review & Editing, Validation, Resources, Project administration. **Dennis Becker:** Writing - Review & Editing

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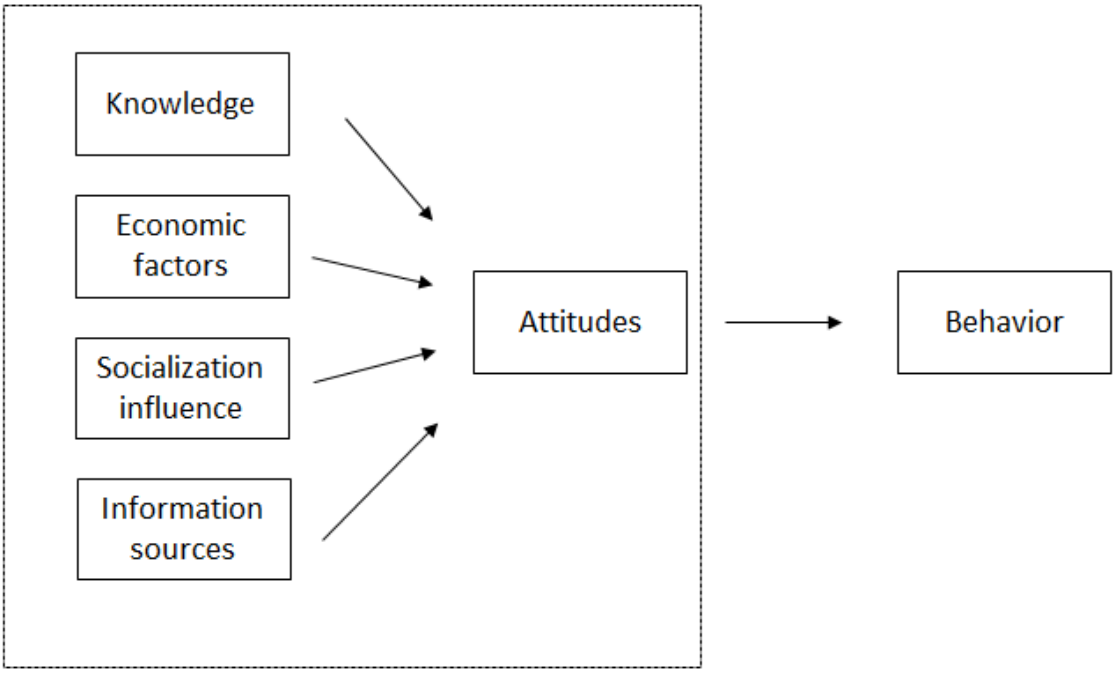

Figure 1. Conceptual framework of the knowledge-attitude modelled relationship. Dotted line presents the analysed part the framework in this work.

Table 1. Definitions of dependent and independent variables used in the three models: knowledge of environmental values (KE), attitude towards conservation of nature diversity (ND) and nature preservation (NP) "x" in the column to the right means that the variable is not included in the respective model.

Group of variables	Variables	Description of the variables	Type of variable	Hypothesized relationship KE/ND/NP
	Environmental knowledge (KE_i)	1 if the respondent answer "correspond rather well" or "correspond very well" to the statement: "I know the environmental values of my forest"; 0 if the respondent answer "doesn't correspond at all" or "correspond slightly"	Dichotomous	indepedent/+/+
	Nature diversity (ND_i)	1 if the respondent answer "of relatively great importance" to "very important" to the statement "My forest provides me the opportunity to protect and preserve nature's diversity" ; 0 if the respondent answer "not important at all" or "slightly important"	Dichotomous	x/independent/x
	Nature preservation (NP_i)	1 if the respondent answer "of relatively great importance" to "very important" to the statement "My forest is first and foremost a nature preservation object for me" ; 0 if the respondent answer "not important at all" or "slightly important"	Dichotomous	x/x/indepedent
Socialization influence	Age	Age of forest owner in 2012 (yrs)	Natural number	-/-/-
	Gender	male = 1, female = 2	Dichotomous	-/+/+
	Education	Primary and secondary = 0; higher education (Bachelor, master, doctorate) = 1	Dichotomous	+/+/+
	Distance from the property, Km, (LN_km)	Distance between forest land and the residence (km) (LN transformed)	Rational number	x/+/+

	Farming	1 if agriculture farming on the property, 0 = not agriculture farming on the property	Dichotomous	+/-/-
	Centrality	According to the municipality of residence of the forest owner. 0 = At least central municipalities, 1 = Smaller central municipalities, 2 = Some central municipalities, 3 = Central municipalities	Ordinal	+/+/+
Economic factors	Gross Income (M NOK)	Average annual gross income before tax (sum of salaries, pensions, income from self-employment and capital) from 2008-2012 (from Statistics Norway) in millions NOK(2017 prices adjusted for inflation)	Rational number	x/?/?
	Taxable net wealth (M NOK)	Average taxable net wealth 2008-2012 (from Statistics Norway) in millions NOK(2017 prices adjusted for inflation)	Rational number	x/?/?
	Size of forest property ha, (LN_ha)	Size of property in decares (1 ha = 10 dec) (LN transformed)	Rational number	x/-/-
Information sources	Visits to forest land for activity	1 if owner "visits land" more than once over the last 12 months , 0 for No visits	Dichotomous	+/+/+
	Registered environment values	1 if environmental values have been registered on forest property; 0 of not registered or does not know (Registration of environmental values mean mapping of important biological areas and areas with special environmental qualities).	Dichotomous	+/+/+
	Media and professional journals	1=if media and professional journals is rather or very important source of information for management of	Dichotomous	+/+/+

	the forest; 0 if slightly important or not important at all.		
Direct contact with municipality	1 if answered Yes to question that are you in direct contact with the forest section of your municipality regarding forestry issues, otherwise 0 = No	Dichotomous	+/+/+
Forestry or agricultural education	1=Yes, if have forest or agricultural education, otherwise 0	Dichotomous	+/+/+
Forest harvest activity	1=Active, if harvested timber for sale at least once during the 15 years 1998-2003; 0=Inactive, i.e. not active	Dichotomous	+/-/-

Table 2. Descriptive statistics of dependent and independent variables.

Variables	NIPF owners	
	Mean	SD
Environmental knowledge	0.35	0.47
Nature diversity	0.53	0.49
Nature preservation	0.19	0.39
Age (Years)	58.26	13.59
Gender	1.25	0.43
Education	0.40	0.49
Forest harvest activity	0.44	0.49
Gross income (M NOK)*	0.48	0.33
Taxable net wealth (M NOK)*	1.18	5.73
Size of forest property (ha)	49.57	153.07
Size of forest property (ln(ha))	2.97	1.22
Distance from the property to residence (km)	56.72	302.74
Distance from the property to residence (ln(km))	1.49	1.91
Visits to forest land for activity	0.59	0.49
Registered environment values	0.22	0.41
Media and professional journals	0.14	0.35
Direct contact with municipality	0.50	0.49
Forestry or agricultural education	0.23	0.42
Farming	0.29	0.45
Centrality	1.79	1.23

* In 2017 the exchange rate were 9.33 NOK per euro, and 8.26 NOK per USD

Table 3. Estimated coefficients and marginal effects of variables used in the probit models that analyse variables influencing private forest owner's stated level of knowledge of environmental values in their forest.

Factor	Knowledge of environmental value of forests	
	Estimates	Marg. eff
Age	-0.0003	-0.0001
Gender	-0.2160*	-0.0654
Education	0.0397	0.0131
Forest harvest activity	0.2646***	0.0798
Visits to forest land for activity	0.3981***	0.1199
Registered environment values	0.9194***	0.2762
Media and professional journals	0.1860	0.0553
Direct contact with municipality	0.2338**	0.0699
Forestry or agricultural education	0.3392***	0.1018
Farming	0.0509	0.0156
Intercept	-0. 9979 ***	
Pseudo R^2	0.19	

*Significant at 10% level, **Significant at 5% level, ***Significant at 1% level

Table 4. Estimated coefficients and marginal effects of variables used in the probit model for analysing main variables influencing private forest owner's attitude towards owning forests for nature diversity and nature preservation.

Variables	Nature diversity		Nature preservation	
	Estimates	Marg. eff	Estimates	Marf. Eff
Age	0.0012	0.0004	0.0140***	0.0036
Gender	0.0959	0.0359	-0.1241	-0.0032
Forest harvest activity	-0.2437***	-0.0912	-0.2641**	-0.0685
Gross Income	-0.1871	-0.0700	-0.1203	-0.0312
Taxable net wealth	-0.0099	-0.0036	-0.0013	-0.0003
Size of forest property(LN_ha)	0.1070***	0.0400	0.0357	0.0009
Distance from the property, Km, (LN_KM)	-0.0266	-0.0099	-0.0237	-0.0061
Visits to forest land for activity	0.1471*	0.0550	0.0050	0.0013
Environmental knowledge	0.2945***	0.1102	0.2351**	0.0610
Media and professional journals	0.3608***	0.1350	0.1668	0.0433
Direct contact with municipality	0.1011*	0.0378	-0.0305	-0.0079
Forestry or agricultural education	0.0043	0.0016	-0.1501	-0.0389
Centrality	0.0583*	0.0218	0.0430	0.0111
Farming	-0.0913	-0.0341	-0.1735	-0.0450
Intercept	-0.5289*		-1.6057***	
Pseudo R^2	0.04		0.04	

*Significant at 10% level, **Significant at 5% level, ***Significant at 1% level

Paper III

Forest plan pathways among non-industrial private forest owners in Norway: from acquisition to implementation of forest plans

Altamash Bashir[1], Hanne K. Sjølie[1], and Birger Solberg[2]

[1]Inland Norway University of Applied Sciences, Faculty of Applied Ecology, Agricultural Sciences and Biotechnology, P.O. Box, 2400, Koppang, Norway

[2]Norwegian University of Life Sciences, Faculty of Environmental Sciences and Natural Resource Management, Ås, Norway

Corresponding author E-mail: altamash.bashir@inn.no

Abstract: Forest plan (FP) is a key decision-support tool for forest managers and a central policy instrument in many countries. Despite its pivotal importance in forest management, there is a lack of studies that analyze the acquisition, familiarity and implementation of the FP which all have to be in place for the FP to be a successful decision-support tool and forest policy instrument. We surveyed a sample representative of the population of Norwegian non-industrial private forest (NIPF) owners to quantify the importance of a broad set of factors, including ownership objectives, socio-demographic, property and information sources variables on the FP pathway, i.e. acquisition of FP, awareness of its content and implementation of the plans' proposals. Applying PCA on twelve ownership objectives, we found that most forest owners are multi-objective. Our combined approach of conditional classification trees and logistic regression analyses on the FP pathway provides insight into the familiarity and use of FP in forest owner subgroups as well as individual drivers. The results indicate that 37% of Norwegian NIPF owners have a FP. Among the owners having FP, 66% have good knowledge of its content and 40% implement its proposals. The strongest variables to predict FP familiarity and use were previous harvests, productive area, advice about forestry from the public management, knowledge of public support schemes for forestry and perceived relevance of the FP. We conclude that suppliers, consultants, forestry bureaucracy and policy-makers should emphasize information dissemination and relevance of the FP to increase its success as a decision-support tool and forest policy instrument.

Keywords: Forest owner behavior, PCA, Decision trees, Probit models, Multi-functionality, Decision-support tool, forest policy instrument

1. Introduction

Sustainability and multi-functionality principles have become increasingly emphasized in forest management and forest policies around the globe (Hujala et al., 2009; McDonald and Lane, 2004; Nichiforel, 2010; Nichiforel et al., 2018). The implementation of these principles results in more complex management with higher requirements of precision, knowledge and documentation of the forest system for the manager as well as the policy-makers (Segura et al., 2014). Forest plan (FP) is a pivot in the knowledge and information system that provides the managers with the data to support strategic, tactical and/or operational forest management planning. Due to its perceived importance for forest management, FP is a key forest policy instrument[1] towards small-scale private forestry in several countries (Brukas and Sallnäs, 2012; Hokajärvi et al., 2009; Serbruyns and Luyssaert, 2006). In addition, FP is also a certification criterion in many countries (PEFC, 2015). However, FP differ greatly in purpose, scope and level of details (Bettinger et al., 2017; Solli 2013). In this paper, we focus on the FP as decision-support tools for non-industrial private forest owners (NIPF) typically consisting of inventory results, maps and management proposals (Eid, 2006; Nuutinen, 2006; Størdal et al. 2006).

As FP is closely linked to forest policy and national certification requirements, the development, users and content of FP are country-specific (Ficko and Boncina, 2015). For instance, Nuutinen (2006) and Brukas and Sallnäs (2012) considered FP mainly as a policy instrument for proper forest management among Finnish and Swedish private forest owners, respectively. Hujala et al (2009) in Finland regarded FP as an important instrument for implementing forest policies; however, Eyvindson et al (2010) stated that FP compiled in Finland by professional planners are without proper consultation with forest owners. Bouriaud et al (2013) stated that FP is a compulsory forest planning tool in Eastern and Central European countries.

[1] We use the definition of policy instrument from (Brukas and Sallnäs, 2012): 606): "A policy instrument is a deliberate structured effort by governors to solve a policy problem by modifying actions of the governed"

In many European countries, enhancing forest management activity among NIPF owners is a policy goal (Forest Europe, 2015). This policy is further emphasized to achieve objectives of climate change mitigation, rapid urbanization and need for rural development (Weiss et al 2019; UNECE/FAO 2020). In the US, Joshi and Arano (2009) observed that forest owners are more likely to engage in forest management if they have FP. Findings from Slovenia and Spain suggest that forest owners consider FP as important decision-aid tools (Bruña-García and Marey-Pérez, 2017; Ficko and Boncina, 2015). However, studies from France and the US show that only 3-6% of forest owners have FP (Agreste, 2013; Butler and Leatherberry, 2004).

The success of FP as a policy instrument depends not only on the forest owners acquiring the plan, but also that they know its content and are implementing its proposals (Ficko and Boncina, 2015). However, to the best of our knowledge, there is a lack of empirical studies addressing the influence of owner characteristics, objectives and motivations of managing forests, socio-economic situation and property characteristics on the acquisition of the FP, awareness of its content and finally its implementation. A better understanding of these relationships ought to be of interest for improved policy design and better tailoring of FP and extension services. A better understanding of the success of the current FP among forest owner subgroups can be useful for developing FP products and services that can reach larger audiences and aid mitigating the longstanding problem of low participation of NIPF owners in forest management and planning. We fill part of this void by carrying out quantitative analyses to answer three research questions that together form the FP pathway:

1) What characterize forest owners who do have FP?
2) What characterize forest owners who know the content of their FP?
3) What characterize forest owners who implement the proposals of their FP?

We base our analyses on a large survey dataset representing the population of Norwegian NIPF owners. Even if we are undertaking the study in Norway where about 80% of

the productive forestland is owned by NIPF owners, its relevance extends to other countries with NIPF owners.

Due to the lack of literature of forest owners' knowledge and implementation of FP, we chose an open, explorative approach to find subgroups using decision-tree (DT) analyses. Based on the DT outcomes, we built regression models to compare the DT outcomes and obtain the importance of individual predictors for gaining more insight into the role of FP in NIPF owners' decision-making.

We continue by presenting the study area, the organization of FP projects in Norway and methods.

2. Methodology

2.1 Study area and survey design

Norway has approximately 8.6 million hectares of productive forest land, representing 26% of the total land area (Fig. 1). The predominant and most economically important tree species are Norway Spruce (*Picea abies*) and Scots Pine (*Pinus sylvestris*) which comprise about 75% of the total forest area (Statistics Norway, 2021a). NIPF ownerships extend to approximately 80% of the productive forestland, divided into more than 125 000 properties (Rognstad et al., 2016; Statistics Norway, 2021b). The total net annual growth is about 24 million cubic meters (2015-2019) while removals averaged 11.1 million cubic meters in the years 1996-2019, and NIPF lands constitute approximately 70% of the net annual growth and 74% of the removals (Statistics Norway, 2021a).

This study analyzed data collected in 2014, by a nationwide mail survey sent to 3150 randomly selected Norwegian NIPF owners having more than 2.49 hectares of productive forest land. The survey was developed and administered collaboratively by Statistic Norway and the Norwegian University of Life Sciences. To increase the survey efficiency the methodology followed the Tailored Design Method (Dillman, 1978). The questionnaire survey included three

mailings: first the questionnaire was sent to all respondents. In the second and third mailing, a reminder card enclosed with the questionnaire was sent to respondents one and two months after the first mailing. A total of 1637 respondents returned the survey, giving a response rate of 52 percent. We gathered information from forest landowners across all counties in Norway, excluding Finnmark, due to its insignificant private ownership. The survey included questions of the use and management of forest, attitudes, reasons for owning forest and FP. Tax record information about forest owner's taxable income and wealth as well as productive forest area was appended to the survey data by Statistics Norway.

2.2 Forest management plans in Norway

In Norway, FP are not mandatory by law, but it is an important forest policy instrument regulated by law (Norwegian Ministry of Agriculture and Food, 2004). The main objectives aimed at by the FP policy are increased harvest, improved silviculture, better control of the management and documentation of key habitats for ensuring sustainable forestry (Norwegian Agricultural Authority, 2013). FP is typically renewed every 15-20 years, and due to the property structure with many small forest ownerships, the vast majority of new FP are organized as projects for larger areas, i.e. one or more municipalities. The initiative to make new FP is taken by the county-level public management in collaboration with local public management and forest owner organizations (Norwegian Agricultural Authority, 2010; 2020). Once it is decided that an area will have new FP, a steering board for the process consisting of representatives from public management, forest owners and timber buyers is appointed by the local public management. While the authorities set regulations about the basic prerequisites of the content of the plan, the parties may choose the inventory method (Norwegian Ministry of Agriculture and Food, 2004). The authorities provide direct subsidies and tax deductions to owners who buy the plans given that the technical requirements are met and that owners provide the authorities with the plan. Environmental mapping as demanded by the Program for the

Endorsement of Forest Certification (PEFC) certification is carried out as an integrated part of the FP inventory. Through the group PEFC certification, timber buyers as the certificate holders ensure that the mapping of the environmental values is carried out in accordance with the certification requirements (PEFC, 2015).

Participation in these FP projects is voluntary, but subsidies are used to enhance participation. Also, for supplying timber, the current certification requires that if necessary, remapping of key habitats should be undertaken at a maximum of fifteen years (PEFC, 2018). This remapping will often coincide with the cycles of the local FP projects and acts as an incentive for forest owners to participate. Depending on the design of the local FP projects, owners may buy only environmental mapping with no FP. Still, the FP participation rates vary from about half of the area in the coastal region with limited commercial forestry traditions to more than 90% of the productive forest area in the traditional forestry areas in the Eastern part of Norway (Korsvold, 2020).

The final FP products to the owners typically consist of a forest map with delineated stands, timber inventories of the stands and a description of treatments (Eid, 2006). The description of treatments is usually a standardized projection of harvest and silviculture investments, based on an underlying growth and yield simulator that provide harvest prognoses. The environmental mapping part consists of a map with set-aside hotspot (key habitat) areas and a description of the required treatment for maintaining their biological values.

2.3 Quantitative modelling framework

To answer the three research questions, we followed a two-stage procedure: In the first step, the respondents' answers on the question of having a FP were analyzed (AcquireFP). In the second stage, where the sample consisted of only forest owners indicated having FP in the first stage, two outcome components were analyzed: the forest owners' self-reported knowledge of the content of their FP (ContentFP) and the owners' self-reported

implementation of the FP's proposals (ImplementFP). Thus, the two stages provide increasingly more details into the actual success of FP as the forest owners' decision-support tool. As behavior theory, we assumed rational utility-maximizing forest owners – i.e. that each forest owner chooses the alternative which (s)he thinks brings the highest utility. We assumed the role of FP for the individual owner to be steered by owner and property characteristics as well as the access to information and social context. For the DT, we assessed a broad set of variables related to the property, attitudes, sources of information, future plans for the property, demographic and socio-economic factors to understand which groups of owners acquire FP, know the content and implement the proposals. The significant variables from DT were brought forward to build the regression models.

The response variable in the first stage is discrete; a value of 1 was assigned if the respondent possessed a FP and 0 otherwise. The two dependent binary variables for the second stage, the awareness of the content of FP and its implementation, were both responded on a four-point Likert scale turned into dichotomous variables (Table 1).

2.4 Principal component analysis (PCA)

Several of the twelve reasons for owning forests were highly correlated. We therefore employed PCA dimensionality reduction procedure to merge them into a set of principal components that consist of interpretable and uncorrelated combined variables to avoid multicollinearity in further analyses (Kuuluvainen et al., 1996). The three components with eigenvalues greater than one were selected (the so-called Kaiser's rule) with a lower cut-off of PC loadings of 0.30 (Favada et al., 2009; Kuuluvainen et al., 1996). The new, composed ownership objective variables were included in the DT and regression analyses.

2.5 DT and regression analysis

DT analysis is a well-established non-parametric supervised learning and data mining technique used for classification in complex and big datasets (Durán-Román et al., 2021; Han et al., 2012). DT's appeal in comparison to general regression analysis lies in its straightforward interpretation of associations between the response and a set of predictive variables and between predictive variables (Durán-Román et al., 2021; Hothorn et al., 2006; Loh, 2014).

In this study, we utilized conditional inference classification DTs to explore multivariate relationships between the outcome variables and a set of candidate predictor variables, using the ctree function of the "party" package in R (Hothorn et al., 2006). The conditional inference DTs build models using algorithms that recursively partition the data into a number of binary splits called nodes (Loh, 2014). The algorithm determines the variables to be split at each node and the nodes are connected to each other by branches. The null hypothesis that there is no relationship between the predictor and response variables is tested. The partitioning maximizes the homogeneity within the branches and the process will come to an end when the null hypothesis cannot be rejected (Hothorn et al., 2006). The stop criteria are based on adjusted p-values following the Bonferroni test type (Bland and Altman, 1995). We chose 0.1 as the maximum p-value. This procedure made certain that the appropriate-sized tree is grown. This also implies that pruning or cross-validation to avoid overfitting is not required (Pinet et al., 2015; Hothorn et al., 2006).

We thereafter built logistic regression models with variables that were significant in the respective classification DTs. The two variables Distance and Productive area were log-transformed in the regressions to satisfy the normal distribution assumption, and each Probit model was tested for multicollinearity using the Variance Inflation Factor (vif) test in R. Sample

weights were added to the observations for the statistical analyses, but not for the DT that do not provide population estimates, but merely classify the respondents.

3. Results

3.1 PCA dimensional reduction

For this study, PCA was conducted on 1637 complete records of the 12 ownership objective statements described in Table 2, where respondents rated statements of owning forest land on a four-point scale from “not at all important” to “extremely important”. The highest means were observed in the nature, leisure and intrinsic value statements while the lowest means were seen in the financial objectives.

The Principle Component (PC) loadings for the first three PCs with eigenvalues > 1 are displayed in Table 3. The three PC accounted for 65% of the variance. In PC1, the loadings of all twelve statements were in the range of 0.4 to 0.8, suggesting a strong multi-functionality as the primary objective of the NIPF owners. Component 1 was thus labeled multiobjective (MO). Component 2 consisted of the three statements describing economic reasons (Economic security, Income, and Investment) with loadings of 0.6-0.7, named ECON. The two nature diversity and preservation statements in component 3 were recorded with loadings of 0.3-0.4 and labelled Environmentalist (ENV).

3.2 Descriptive statistics

Table 4 presents summary statistics for the full sample of forest owners and the two subsamples of owners having and not having FP, and significance levels of t-tests of differences between owners with and without FP. Out of the total sample of 1637 respondents, 37% responded having a FP. Among the owners with FP, 66% stated having knowledge about the content in the FP and 40% that they implement the proposals of the FP.

Comparing the subsample of owners with a FP with those without a FP, we find that all variables except for taxable net wealth are significantly different. Owners with FP are on average younger, have more education, live closer to the property, are more urban, have higher income, larger properties, more future plans for the property and acquire considerably more information from a set of sources. In addition, more of them are male and do farming and they have more pronounced ownership objectives.

The mean age was 58.3 years for all forest owners, and owners with FP were on average three years younger than others. The average property size was for all owners of 49.6 hectares, varying from a mean of 25 hectares for owners without FP to 223.5 hectares among owners with FP. On average, owners lived 56.6 km from the property with owners having FP living on average 28.2 km away and owners not having FP living on average 73.1 km from the property. 44% of the forest owners had harvested timber over the fifteen years, varying from 27% of owners without FP to 75% of owners with FP. Owners with FP used various information sources considerably more than owners without FP.

3.3 Classification DT and regression analysis

The AcquireFP conditioned classification tree produced a total of 15 terminal nodes in the final model (Fig. 2) classifying owners with and without FP. The barplots at the terminal nodes represent the proportion of respondents having FP in the subsample. The root node, hence the single most important predictor and given on the top of the tree, in AcquireFP tree is harvest activity, which presents the maximum significant difference between NIPF owners with or without FP. Other important variables in the model were contact with the municipality for advice on forestry, knowledge about public support schemes, property size, county of forest holding, forestry or agricultural education, economic reasons for owning forests, distance to property from residence and plans of transferring the land.

In the AcquireFP tree the number of owners with FP decreases when moving from the right to the left. In the seven nodes (18, 22, 25-29) on the right side of the tree, 50 to 100% of owners have FP. The owners with FP in these nodes harvest timber and do either receive advice from the municipality or have larger properties. More than 80% of the owners who harvest timber, receive advice on forestry from the municipality and have forest in a traditional forestry region, have FP. Out of those, among economically oriented owners who have plans of transferring the property and live close to the forest, 99% have FP. In addition to previous harvests and advice from the municipality, the size of the holding is a decisive factor for having FP. Out of the owners with property exceeding 26.14 hectares, 67% of owners have FP (node 18), compared to 23% of the owners with smaller properties (node 17).

On the left side of the tree, low shares of forest owners have FP. These are inactive owners without knowledge of public schemes. Among owners who do not harvest and do not have knowledge of the public support schemes, the effect of forestry municipality advice is conditional upon the forest area as among the owners with properties smaller than 122 hectares who receive advice, the share having FP is as low as among owners who do not receive advice from the municipality (nodes 4, 6, 7).

In the ContentFP classification tree (Fig 3), the right side of the tree includes the largest share (65 to 100%) of NIPF owners that know the content of plan well. These owners think that the FP is well adapted to their objectives, and either do not want to outsource the management (nodes 15-19) or are willing to outsource the management but receive advice from the municipality. Among owners who consider the plan as relevant, do not want to outsource the management and use media and journals as information sources, the geographical factor plays only a minor role. The subgroup on the left side of the tree (node 3, 6, 8) have lower shares of owners that know the content of the plan well. A part of these owners do not think that the FP is well adapted to their objectives and do not have knowledge

about public support schemes. Among the owners who do not think the plan is well adapted to their objectives, but do have information about public support schemes, owner age and county steer the extent to which forest owners know the content of the FP, with older owners having less knowledge about the FP.

The ImplementFP tree used fewer variables than the other two trees (Fig 4). The variable stating that FP is well adapted to the owner objectives takes the root node position in this tree similar to the ContentFP tree, explaining the most of the difference between owners who implement the plan and not. On the right side of the tree, forest area steers decisively the extent to which owners that do not think the plan is well adapted to their objectives, implement the proposals. 94% of economically oriented owners with higher education and who think the FP is well adapted to their objectives and with property in counties other than Agder or Vestland implement the FP. On the left side of the tree, the subgroup of owners who think the FP is well adapted to their objectives and have less of economic objectives, contact with the municipality makes a difference. Out of the owners who are not in contact with the municipality, 37% implement the FP, but this number grows to 62% among the owners who are in contact with the municipality.

The estimates and marginal effects for each of the three Probit models are provided in Table 6 using the significant variables from each DT. Knowledge of public support schemes, contact with the municipality and harvest activity increased the probability of having a FP by 13%, 15%, and 18% respectively. This means that owners that have harvested at least once during the 15-year period with knowledge of public support schemes who receive advice from the municipality have about 46% higher probability of having a FP compared to other forest owners. However, forest owners possessing property in county class 1 and 2 (defined in Table 5) have greatly lower chances of having FP.

In the ContentFP probit model all included variables were significant. If the FP is adapted to the objectives of the owner, the probability of knowing the content of plan well increases by 26%. Likewise, a forest owner who has direct contact with the forestry section of the municipality and receives information about forestry from media and journals is more likely to have good knowledge about the content of the FP. Owners with the intention to outsource the management of the forest have lower probability of knowing the content of plan. County is also an important predictor.

Finally, in the ImplementFP model, owners with a positive value of the most influent variable FPadaptedforobjectives have 39% higher probability to implement the proposals of the FP than others. In addition, owners who receive advice from the forestry section of the municipality are 15% more willing to implement the proposals of FP on their property compared to other forest owners. County also makes a significant probability impact.

4. Discussion

We have found that 37% of the Norwegian NIPF owners possess FP. Out of the owners who have FP, 66% know the content of plan well and 40% implement the FP proposals on their property. Our study sheds new light on the complexity of FP. High acquisition rates is no assurance of the success of the FP as a policy instrument or management decision-aid tool, as less than half of the forest owners who buy the plan do actually implement its proposals.

The two variables that were significant across all trees and all regression models were direct contact with the municipality for advice on forestry and county group while the perceived relevance of the FP (FP adapted to owner objectives) was significant in the two trees and models it was included. In addition, knowledge of public support schemes was important for the acquisition and knowledge of the FP content, but not its implementation. While general and forestry/agricultural education, plans to sell/transfer, ownership objectives

and distance between property and residency aided in the classification of the FP acquisition and implementation, they were not significant in the regression models.

We found that previous harvests is a strong predictor and classifier for having FP, but not for knowing the content of or implementing the FP. Joshi and Arano (2009) suggest that owners with a FP are more likely to harvest timber using self-reported activities. There are arguments that the causal effects go in both directions. Information about the timber resources may be a trigger for harvest, but owners may be informed about the resources and make management plans in other ways than by written FP (Kittredge, 2004; Kittredge et al., 2008). In analyzing our data including a panel of harvested timber over a 15-year period (Bashir et al., 2020), we found no effect of the acquisition of FP on subsequent harvest (data not shown). Purchasing FP in Norway is a large investment for the forest owner that typically is covered by the owner's forestry investment fund (Skogfond). The fund is credited with timber incomes and previous harvests provide the necessary means for buying the plan. Even if timber is cut and sold without a written FP, owners may experience that having a FP eases the operational planning considerably and may thus be motivated to acquire a FP. Previous harvests was in our DT not a classifier for the ContentFP and ImplementFP. Thus, despite the association between previous harvests and having a FP, owners who harvest may as well base the decisions on other information sources, suggesting the broader cognitive basis for management (Davis and Fly, 2010). To summarize, more time-series research is warranted about the causal relationships between FP and harvest, whose effects may be country-specific due to variations in law and certification requirements.

In line with several previous studies like Butler et al (2007), Ficko (2019) and Majumdar et al (2008) our findings suggest that forest area is a significant predictor for forest management planning. The lower FP enrollment rate on smaller properties can be due to a complexity of reasons connected to forest types and area (Bruña-García and Marey-Pérez,

2017; Hirschnitz-Garbers and Stoll-Kleemann, 2010). Smaller properties may face more practical management constraints (Best, 2004; Best and Wayburn, 2001). Pan et al (2007) found that forest owners with larger properties put more time and effort into management and with the higher potential incomes from it, are more willing to acquire plans.

Our study results show that a forest owner's perceived relevance of the FP is an important predictor for the familiarity and use of the FP, as 80% of owners who consider the FP being relevant, know the content of the plan well and 61% implement the proposals of the plan. Earlier studies (Davis and Fly, 2010; Ficko and Boncina, 2015) suggest that forest owners' participation is lower at the implementation stage of forest planning because the FP are not adapted to their objectives and understanding of forest management which can result in forest owners staying away from outreach and extension programs (Davis and Fly, 2010). Hujala et al (2007) found that the perceived FP meaningfulness is higher if the plan is adapted to the forest owner's objectives. In Norway, most FP are based on standardized "best practice" timber-production forest management even if non-timber objectives are important among owners (Sjølie et al., 2019) which possibly creates a discrepancy between forest owners' objectives and the FP content and proposals, reducing its considered relevance and acting as a barrier for enhanced use of the FP.

In addition to the plan adaptation variable that only was part of the second stage, counties and contact with the municipality forestry section for advice were significant across all trees and regressions. The marginal effect of the latter variable in the ImplementFP model is as high as 38%, indicating that improving outreach through the public management may contribute to realizing not only the extensiveness of the FP, but also considerably its potentials as a decision-aid tool for forest management planning. Most FP in Norway suggest silviculture actions, and as the municipality typically provides information about direct subsidies and tax deduction to silviculture, which may help in explaining that owners who

receive information from this side actually implement the plans' proposals. County effects are strong, and even if they vary between the models, the general picture is that forest owners in the traditional forest regions in Eastern Norway have 10-20% higher likelihood to acquire, knowing the content and implement proposals of FP (Tables 5-6, Fig. 4). As demonstrated by Figures 2-4, the county effects appear in combination with a set of other variables, suggesting its prevalent effect. Large regional variation in NIPF owners' possessions of forest management plans was likewise reported by studies in the US (Butler and Leatherberry, 2004; Measells et al., 2005; Rasamoelina et al., 2016).

Looking forward, some studies suggest that in the near future due to economic constraints, the alternatives for FP such as online programs or courses can contribute to increasing activity on NIPF owners land (Butler et al., 2014; Kueper et al., 2014; Sagor et al., 2014). However, these kinds of initiatives possesses certain challenges like reaching out to owners with lower digital skills (VanBrakle, 2015).

Our study used a combined approach of conditional classification tree and logistic regression analysis to visualize and estimate factors explaining forest owners' FP behavior. We believe that the combined results provide in total more information as these two techniques complement each other. While the DT point to the forest owner subgroups and thresholds for a positive response, the probit regressions provide the estimated impact of each independent variable and sort all variables according to their importance.

5. Conclusions

The main factors explaining the forest plan pathway among Norwegian NIPF owners are direct contact with municipality for advice on forestry, county of the property, knowledge of public support schemes, reasons for owning forests and perceived relevance of the FP. 37% of the owners in our survey do have FP and of those who have FP, 40% implement its proposals. FP have a paramount role to play in the sustainable management of forests. The

results indicate that the forestry sections in the municipalities can play an important role by reaching out and aiding more forest owners to use the FP as a decision-support tool. Furthermore, for the FP to be actually used, it has to be deemed relevant by the forest owners, thus adapted to the forest owner's objectives. We show that owners with and without plan differ across a broad set of variables, indicating that actions to stimulating the interest of owners who do not acquire FP could be targeted towards specific owner groups

Our study can be utilized by FP suppliers for adapting products and services, forestry consultants, bureaucracy and policy-makers to better reach out to various forest owner groups to increase the success of the FP as a decision-aid tool and forest policy instrument. FP in Norway are highly subsidized; improving its use will increase the cost-effectiveness and efficiency of this policy instrument.

Acknowledgements

The authors are thankful for financial support from the Norwegian Ministry of Agriculture and Food, the Faculty of Environmental Sciences and Natural Resource Management at the Norwegian University of Life Sciences and the Faculty of Applied Ecology, Agricultural Sciences and Biotechnology at the Inland Norway University of Applied Sciences.

Author statement

Altamash Bashir: Conceptualization, Methodology, Formal analysis, Writing - Original Draft, Writing - Review & Editing, Validation, Visualization. **Hanne Sjølie:** Conceptualization, Writing - Review & Editing, Validation, Resources, Supervision, Project administration. **Birger Solberg:** Validation, Writing - Review & Editing, Validation, Resources, Project administration

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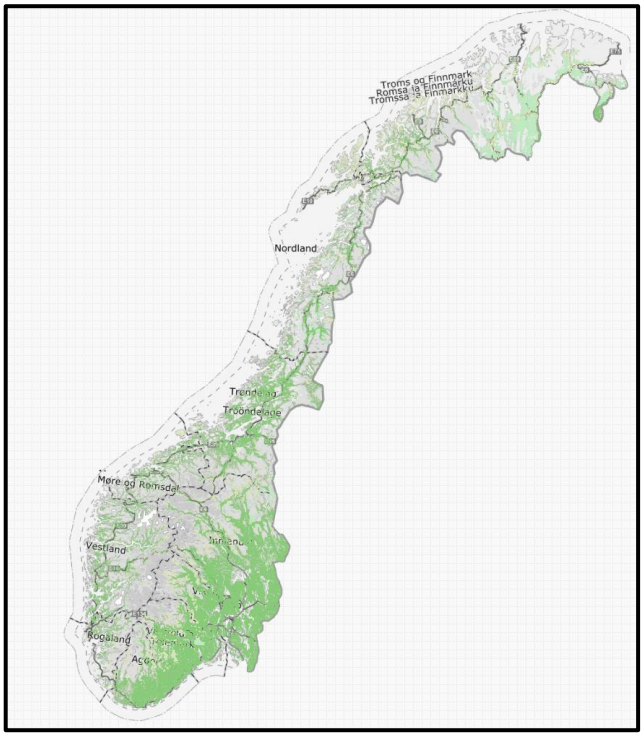

Fig. 1. Map of counties with forest resources in Norway (kilden.nibio.no).

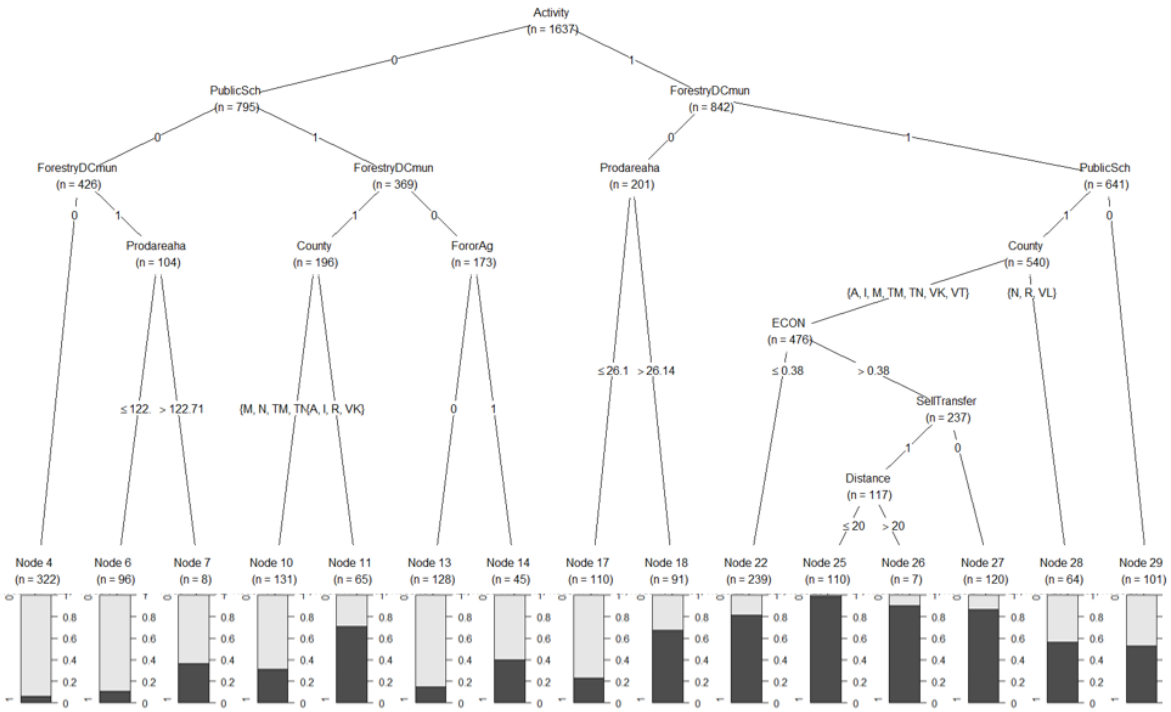

Fig 2. Conditional classification tree showing the variables' influence on NIPF owners' acquisition of Forest plan (AcquireFP). Each oval in the tree contains a particular variable. Each oval in the tree contains a particular variable. The *n* values at the leaves display the total number of observations that fall in the terminal nodes. For visibility, the counties were denoted with codes in the tree: Agder (A), Innlandet (I), Møre og Romsdal (M), Rogaland (R), Troms (TM), Trøndelag (TN), Vestfold og Telemark (VT)

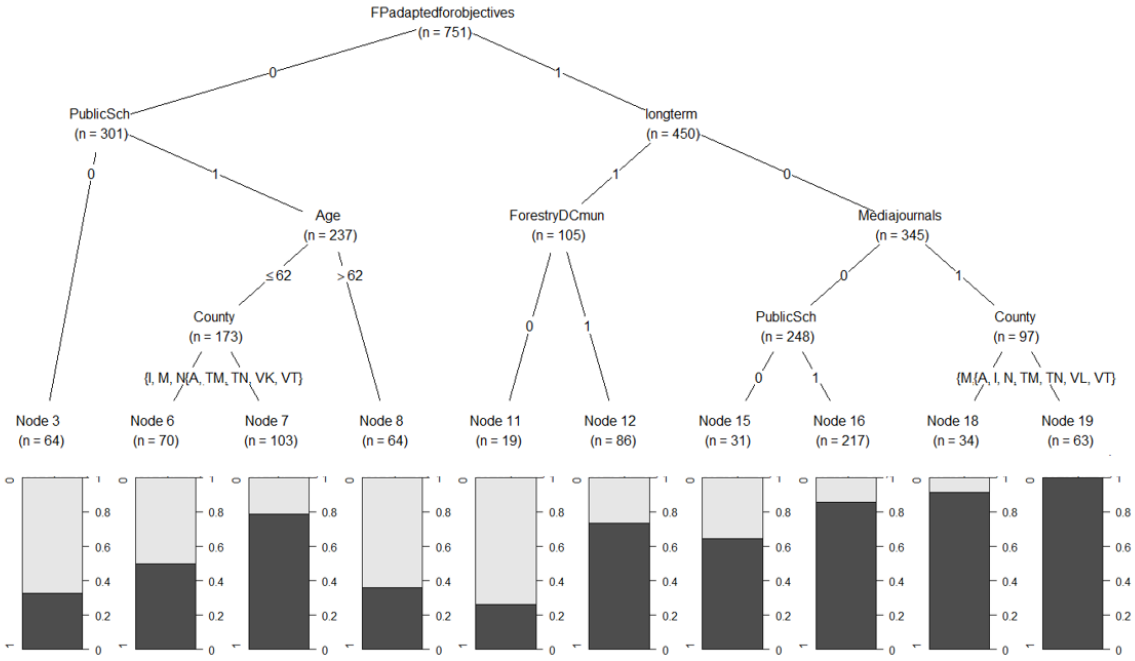

Fig 3. Conditional classification tree showing the variables' influence on NIPF owners having good knowledge of the content of the FP (ContentFP). Each oval in the tree contains a particular variable. The *n* values at the leaves display the total number of observations that fall in the terminal nodes. For visibility, the counties were denoted with codes in the tree: Agder (A), Innlandet (I), Møre og Romsdal (M), Rogaland (R), Troms (TM), Trøndelag (TN), Vestfold og Telemark (VT)

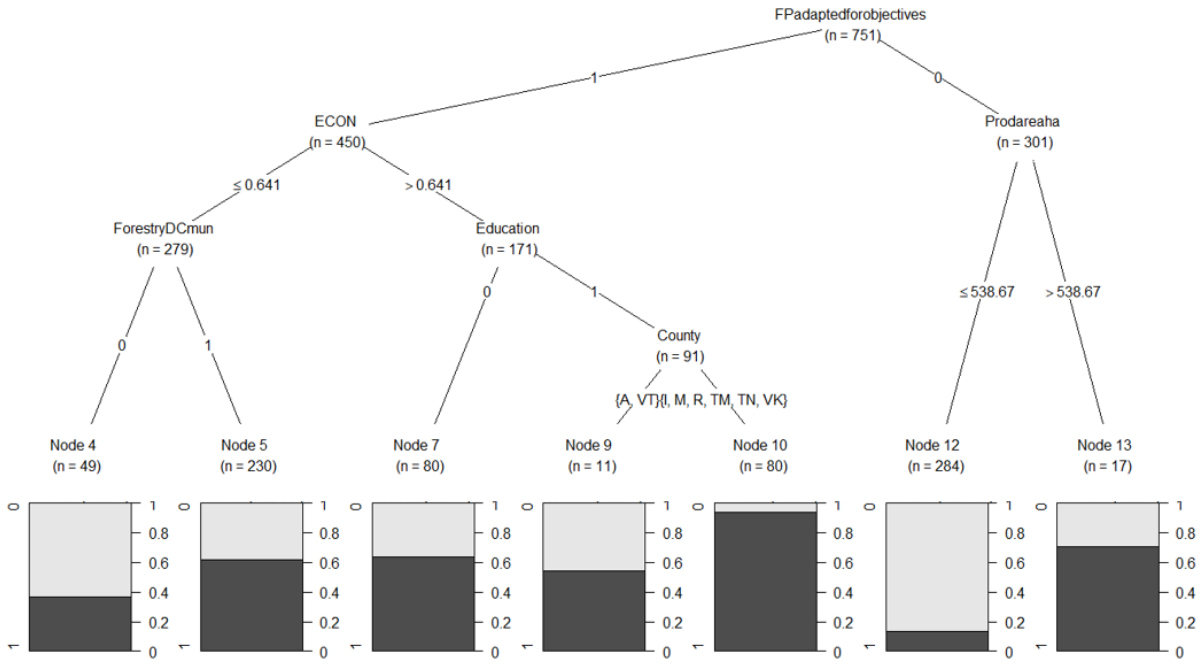

Fig 4. Conditional classification tree showing the variables' influence on NIPF owners implementing the proposals in the FP (ImplementFP). Each oval in the tree contains a particular variable. The *n* values at the leaves display the total number of observations that fall in the terminal nodes. For visibility, the counties were denoted with codes in the tree: Agder (A), Innlandet (I), Møre og Romsdal (M), Rogaland (R), Troms (TM), Trøndelag (TN), Vestfold og Telemark (VT).

Table 1. Definitions of dependent and independent variables used in the decision and regression models: Forest Plan (FP), knowing the content of the forest plan well (ContentFP) and implement the proposals from the forest plan (ImplementFP).

	Variables	Description of the variables	Type of variable
Dependent variables	Forest plan (FP)	1 if the respondent answer "Yes" to the statement: "Do you have a forest plan for your property"; 0 if the respondent answer "No" or "Don't know"	Dichotomous
	Content of forest plan (ContentFP)	1 if the respondent answer "correspond rather well" or "correspond very well" to the statement: "I know the content of the forest plan well"; 0 if the respondent answer "doesn't correspond at all" or "correspond slightly"	Dichotomous
	Implementation of Forest plan (ImplementFP)	1 if the respondent answer "correspond rather well" or "correspond very well" to the statement: "I implement the proposals from the forest plan"; 0 if the respondent answer "doesn't correspond at all" or "correspond slightly"	Dichotomous
Independent variables	Age	Age of forest owner in 2012 (yrs)	Natural number
	Gender	male = 1, female = 2	Dichotomous
	Education	Primary and secondary = 0; higher education (bachelor, master, doctorate) = 1	Dichotomous
	Distance from the property, Km, (LN_km) (Distance)	Distance between forest land and the residence (km) (LN transformed)	Rational number
	Farming	1 if agriculture farming on the property, 0 if not agriculture farming on the property	Dichotomous
	Centrality	Statistics Norway's definition of centrality (scale 0-3, where 0 = Least central municipalities and 3 = Central municipalities). According to the	Ordinal

	municipality of residence of the forest owner.	
Gross Income (M NOK) (GRIncM)	Average annual gross income before tax (sum of salaries, pensions, income from self-employment and capital) from 2008-2012 (from Statistics Norway) in millions NOK(2017 prices adjusted for inflation)	Rational number
Taxable net wealth (M NOK) (NettaxM)	Average taxable net wealth 2008-2012 (from Statistics Norway) in millions NOK(2017 prices adjusted for inflation)	Rational number
Size of forest property ha, (LN_ha) (Prodareaha)	Size of property in decares (1 ha = 10 dec) (LN transformed)	Rational number
Plan to sell/transfer (SellTransfer)	1 if answered Yes for question on "having plan for transfer to family or sell it", and 0 for "no specific plans"	Dichotomous
Media and professional journals (Mediajournals)	1 if media and professional journals is rather or very important source of information for management of the forest; 0 if slightly important or not important at all.	Dichotomous
Direct contact with municipality (ForestryDCmun)	1 if answered "Yes I am in direct contact with the forest section of your municipality regarding forestry issues", otherwise 0.	Dichotomous
Public support schemes for forestry (PublicSch)	1 if the respondent answer "Yes, I have some or good knowledge" to the question "Do you know that there exist public support schemes for forestry"; 0 if the respondent answer "No"	Dichotomous
Forestry or agricultural education (FororAg)	1 if the respondent has forest or agricultural education, otherwise 0	Dichotomous
Other forest owners /family/ neighbours/ friends	1 if the respondent answer "Rather important" to "very important" to the statement "My forest provides me the opportunity to protect and preserve nature's diversity"; 0 if the respondent	Dichotomous

	answer “not important at all” or “slightly important”	
Forest harvest activity (Activity)	1 means Active – i.e. have harvested timber for sale at least once during the 15 years 1998-2003; 0 means Inactive, i.e. has not harvested for sale during this period.	Dichotomous
Forest plan adapted to my objectives (FPadatedforobjectives)	1 if the respondent answer “correspond rather well” or “correspond very well” to the statement: “The forest plan is adapted to my objectives of the forest”; 0 if the respondent answer “doesn’t correspond at all” or “correspond slightly”	Dichotomous
Delegate longterm management (Longterm)	1 if the respondent answer “Rather-very interested” or “already used this option” to the statement: “delegate administration and implementation of harvesting and management, making decisions on the longterm activity level, for example for a ten year period”; 0 if the respondent answer “Not interested at all” or “A little interested”	Dichotomous
County of property	A total of 10 counties covering the whole of Norway except Finmark: Agder (A), Innlandet(I), Møre og Romsdal(M), Nordland(N), Rogaland(R), Troms(TM), Trondelag (TN), Vestfold og Telemark(VT), Vestland (VL)	

Table 2. Definition and descriptive statistics of 12 questions on the reasons for owning forest: The results are used in the principal component analysis. The quantification was done using ordinal 4-point scale: Not important at all (1); slightly important (2); of relatively great importance (3); of decisive importance (4).

Variable	Description	Mean	SD
LEISURE	Answer on the question "My forest is part of the environment where I live or spend my leisure time"	2.96	0.96
HUNT	Answer on the question "The forest provides me the opportunity to hunt"?	2.30	1.16
NATURE	Answer on the question "The forest provides me the opportunity of nature experiences"	3.04	0.93
DIVERSITY	Answer on the question "The forest provides me the opportunity to protect and preserve nature's diversity"	2.62	0.92
PRESERVE	Answer on the question "The forest is first and foremost a nature preservation object for me"	1.82	0.90
INCOME	Answer on the question "My forest provides me income"	1.78	0.91
ECON_SEC	Answer on the question "My forest provides me economic security"	1.60	0.85
INVEST	Answer on the question "My forest is an investment object for me"	1.60	0.84
INTRINSIC	Answer on the question "My forest has an intrinsic value for me (e.g. as part of a family farm or that I am a forest owner)"	2.91	1.02
INHERITANCE	Answer on the question "My forest will be inherited by close family"	2.88	1.06
RELAX	Answer on the question "In my forest I can relax, find silence and contemplate"	2.92	1.01
NATIVE	Answer on the question "I keep contact with my native area through my forest"	2.06	1.12

Table 3. PCA summary statistics for 12 statements of reasons for owning forests

Variable	Rotated principal component loading		
	PC1 (Multiobjective) (MO)	PC2 (Economic) ECON)	PC3 (Environmentalist) (ENV)
LEISURE	**0.757**	-0.207	-0.025
HUNT	**0.590**	-0.018	0.119
NATURE	**0.806**	-0.267	0.117
DIVERSITY	**0.722**	-0.294	**0.306**
PRESERVE	**0.441**	-0.411	**0.433**
INCOME	**0.463**	**0.768**	0.092
ECON_SEC	**0.493**	**0.747**	0.169
INVEST	**0.488**	**0.622**	0.206
INTRINSIC	**0.670**	0.086	-0.567
INHERITANCE	**0.627**	-0.016	-0.562
RELAX	**0.785**	-0.275	0.012
NATIVE	**0.604**	-0.136	-0.102
Variance	4.827	2.009	1.020
% of Variance	40.223	16.738	8.500
Cumulative % of variance	40.223	56.962	65.461

Table 4. Descriptive statistics (mean and standard deviation) of the variables (see Table 1 for definitions). Significance levels (10% = *; 5% = **; 1% = ***) refer to t-tests of differences between forest owners with FP and forest owners without FP. Weighted observations

Variables	All owners (n=1637)		Owners with FP (n=751)		Owners without FP (n=886)	
	Mean	SD	Mean	SD	Mean	SD
Response variables						
Forest plan (FP)	0.37	0.48	-	-	-	-
Content of forest plan (ContentFP)	-	-	0.66	0.47	-	-
Implementation of Forest plan (ImplementFP)	-	-	0.40	0.49	-	-
Independent variables						
Age	58.3	13.57	56.3	12.76	59.4***	13.9
Gender	1.25	0.43	1.22	0.41	1.27**	0.44
Education	0.40	0.49	0.42	0.49	0.39***	0.49
Distance from the property, Km (ln_km)(LN_km)	56.6 (1.49)	302.7 (1.91)	28.2 (1.23)	102.0 (1.68)	73.1***	371.71
Farming	0.30	0.46	0.41	0.49	0.23***	0.42
Centrality	1.8	1.23	1.86	1.24	1.75*	1.24
Gross Income (M NOK)	0.48	0.33	0.54	0.40	0.45***	0.29
Taxable net wealth (M NOK)	1.19	5.73	1.28	6.37	1.13	5.32
Size of forest property ha, (ln_ha)	49.6 (2.97)	153.07 (1.22)	91.7 (3.73)	223.5 (1.18)	25.0***	79.70
Plan to sell/transfer	0.36	0.48	0.45	0.50	0.30***	0.46
Media and professional journals	0.14	0.35	0.23	0.42	0.1***	0.29
Direct contact with municipality	0.50	0.50	0.77	0.41	0.34***	0.47

Public support schemes for forestry	0.56	0.50	0.81	0.39	0.41***	0.49
Forestry or agricultural education	0.23	0.42	0.35	0.48	0.16***	0.36
Other forest owners/family/neighbours/ friends	0.23	0.42	0.28	0.45	0.21***	0.40
Harvest activity	0.45	0.50	0.75	0.43	0.27***	0.45
Forest plan adapted to my objectives	-	-	0.57	0.49	0.15***	0.36
Delegate long term activity level	0.18	0.38	0.21	0.40	0.16**	0.36
Multiobjective	-0.13	0.99	0.20	0.92	-0.33***	0.98
Economic	-0.10	0.89	0.12	0.92	-0.24***	0.84
Environmentalist	0.002	1.04	0.11	0.95	-0.06***	1.08

Table 5. The grouping of counties into three classes based on classification tree outcome, and represented with dummy variables for further analysis in the Probit analysis.

Dummy variables	AcquireFP	ContentFP	ImplementFP
0	A,I,VK	M,R	N,VL
1	VL,R,N	I,VL,VK,N	A,VT
2	TM,TN,M,VT	A,TM,TN,VT	I,M,R,TM,TN,VK

Table 6. Probit model estimates of the empirical models for estimating NIPF owner's inclination towards having forest plan, its awareness and implementation. Only significant variables from each decision tree were brought into the regression models. "n/a": variable not included in decision tree. Significance levels (10% = *; 5% = **; 1% = ***).

	AcquireFP (n=1637)		ContentFP (n=751)		ImplementFP (n=751)	
Variables	Estimates	Marg. eff	Estimates	Marg. eff	Estimates	Marg. Eff
Age	-	-	-0.009*	-0.003	-	-
Education	-	-	-	-	0.15	0.047
Distance from the property, Km, (LN_km)	-0.01	-0.003	-	-	-	-
Size of forest property ha, (LN_ha)	0.37***	0.092	-	-	0.07	0.023
Plan to sell/transfer	0.10	0.023	-	-	-	-
Media and professional journals	-	-	0.39**	0.113	-	-
Direct contact with the municipality	0.54***	0.146	0.45***	0.142	0.50***	0.153
Public support schemes for forestry	0.52***	0.128	0.30*	0.088	-	-
Forestry or agricultural education	0.18	0.044	-	-	-	-
Harvest activity	0.65***	0.179	-	-	-	-
Forest plan adapted to the objectives	n/a	n/a	0.87***	0.258	1.28***	0.386
Delegate longterm activity	-	-	-0.50***	-0.149	-	-
Economist	0.09	0.021	-	-	0.08	0.025
Countyclass1	-0.62***	-0.158	0.57**	0.183	0.58*	0.169
Countyclass2	-0.37***	-0.096	0.61**	0.196	0.71***	0.209
Constant	-2.21***		-0.63*		-2.42***	
Pseudo R^2	0.36		0.16		0.23	

Paper IV

Information needs of Norwegian non-industrial private forest owners for improved forest management and environmental considerations

Altamash Bashir[1], Hanne K. Sjølie[1], and Birger Solberg[2]

[1]Inland Norway University of Applied Sciences, Faculty of Applied Ecology, Agricultural Sciences and Biotechnology, P.O. Box, 2400, Koppang, Norway

[2]Norwegian University of Life Sciences, Faculty of Environmental Sciences and Natural Resource Management, Ås, Norway

Corresponding author E-mail: altamash.bashir@inn.no

Abstract: Information is essential for carrying out the best forest management practices. In this study, we attempted to examine the information needs among non-industrial private forest (NIPF) owners in Norway. The study was based on a postal questionnaire sent to a gross sample of 3150 individuals with a response rate of 52%. Logistic regression models were developed to examine willingness of NIPF owners to receive more information for improved forest management: information about environmental values in the forest and information to increase forestry activities. About 31% of forest owners stated a need for more information about environmental values of their forest. Similarly, 45% of forest owners state that with more information, they could increase forestry activities on their forest property. The results of the probit regression models suggest that while female owners and owners with higher education are more open to information about environmental values, younger owners state that information could make a difference for forestry activities. Current information sources had large effects, with respondents who used public authority as a source of information for managing forests were 14% more likely to be interested in environmental information and 13% more likely to be open to information about forestry. The results also indicated that economically oriented respondents and those who seek information from peers and public authority were, with more information, more likely to increase forestry activities in the forest. On the contrary, older respondents, owners involved in farming activities or possess forestry or agricultural education were less likely to increase forestry activities with more information. As in particular public authority stands out as an important information source for those who are interested in more knowledge, this platform can be further explored to reach even more owners better. More information disseminated tailored to NIPF owner groups could enhance

the efficiency of the forest management decision-making and contribute towards achieving policy goals for sustainable forestry.

Key words: Survey; respondents; public authority; peers; probit model

1. Introduction

In many countries across the globe large share of forests are controlled by private owners (FAO, 2020). According to one assessment of forest cover in 234 countries, 22% of the forest is owned by privates (FAO, 2020). About half of the forest in Europe (Russia excluded) is privately owned with large country-specific variations (UNECE and FAO, 2020). Specifically, the forests owned by private owners in countries (Sweden, Finland, Norway) account for more than 50% of the total forest area. More than three quarters of the European private forestland is owned by individuals (UNECE and FAO, 2020). Thus, the management decisions by these individuals have significant implications on the flow of ecosystem services to the society from forest (Gatto et al., 2019; Vokoun et al., 2006). Many efforts are taken on the national and international levels to influence the behavior and attitude of these forest owners towards maximizing the supply of these forests ecosystem services (Kilgore et al., 2007; Serbruyns and Luyssaert, 2006). However, good management practices is conditional on information; access to information varies widely between groups of non-industrial private forest (NIPF) owners. Information as a forest policy tool is widely used in many countries (Baumgartner et al., 2003; Serbruyns and Luyssaert, 2006).

There are studies of the extensiveness and the impacts of lack of information among NIPF owners, concluding that a lack of information can result in reduced motivation for forest management and finally inactiveness (Huff et al., 2017; Matilainen and Lähdesmäki, 2014; Upton et al., 2019). In Europe, 30% of European NIPF owners showed little motivation towards managing forests resulting in little active management (Wiersum et al., 2005). Similarly, Gan and Kolison (1999) in southeastern Alabama, USA, observed that due to lack of knowledge, 38% of NIPF owners were not able to manage their forests properly. In addition, (Kelly et al., 2015; Kilgore et al., 2007; Rouleau et al., 2016) also reported that lack

or limited information result in lower level of enrollment of forest owners in conservation activities and forestry programmes.

However, since the NIPF owner population is so heterogeneous, information campaigns could benefit from being tailored to subgroups of forest owners. The information needs vary across types of NIPF owners (Schubert and Mayer, 2012). However, designing and providing more target-oriented services to forest owners requires that the subgroups of forest owners that are positive to receive information should be recognized and categorized (Hayrinen et al., 2015). A set of studies have found that certain groups of forest owner are keen to receive more information and services for performing better forest management (Côté et al., 2017; Kendra and Hull, 2005; Nordlund and Westin, 2011). Rouleau et al (2016) stated that characteristics such as gender, age, education, residence, property size and objectives for owning forest influence the decision to seek more or better information for managing forests. Female, urban and highly educated NIPF owners are more open to receive more information for their decision-making towards forest management (Côté et al., 2017; Nordlund and Westin, 2011; Rouleau et al., 2016).

However, the diversity among forest owners is increasing due to economic and social changes (Ficko et al., 2019; Haugen et al., 2016; Hogl et al., 2005; Weiss et al., 2019) with growing urbanization rates and decreasing rates of farmers, which have implications for the efficiency of different information channels. Furthermore, forest owner populations become also increasingly heterogeneous regarding appraisal of forest values, reasons for owning forests and pathways of forest management (Blanco et al., 2015; Eriksson, 2012; Eriksson and Fries, 2020; Ficko et al., 2019). Therefore, there arises a need to update studies of the information needs of forest owners and to analyze them in different geographical areas and group owners based on the information needs. With its vast NIPF land base and average forest holding on the NIFP land being 46 ha (Statistics Norway, 2021) and fewer owners harvest

timber for sale today than in the past (Statistic Norway, 2020), we use Norway as a case study.

Many studies were carried out with focus on understanding the factors influencing the timber supply (Bashir et al., 2020; Favada et al., 2009; Sjølie et al., 2019) and behaviors and attitudes towards environmental conservation among forest owners (Kelly et al., 2015; Lindhjem and Mitani, 2012; Mitani and Lindhjem, 2015). Furthermore, many other studies have been undertaken to observe the impact of various information programmes in North America and Europe for maximize the involvement of forest owners in active forest management (Kilgore et al., 2007; McGrath et al., 2020; Rouleau et al., 2016).

However, our approach is different, in the sense that we attempt to look into future prospects and determine about what type of forest owners are in need of more and/or better information for contributing to increased forest activities and environmental conservation. The recognition of the interested cohorts of forest owners will act as effective resource database to draft policies that are specific and target oriented. This will help to disseminate outreach activities and policy strategies smoothly and efficiently at lower costs with better value. The dissemination of better information may increase confidence and satisfaction and engage more forest owners towards forest activities and environmental conservation (Kärhä et al., 2020). In addition, a thorough understanding about the information needs among forest owners can help to revise and improve and, then smoothly disseminate target oriented forest policies that encompass relevant extension programmes and outreach activities to the forest owners (Eriksson and Fries, 2020). Besides the international relevance of our study, such analyses from Norway is lacking. We are thus filling parts of several voids by shedding light on how information on two aspects of forestland management, environmental values and forestry activities, could be tailored to different groups of owners in general and by increasing the understanding of information needs among Norwegian NIPF in particular.

The overall goal of this research is to examine the information needs among NIPF owners in Norway and to consider how forest owner, property characteristics and objectives of forest and access to information are related to the desire to achieve more or better information with intention to improve the management of the forestland. Specifically the objectives of the study are to categorize subgroups of NIPF owners that are interested to have 1) more information about the environmental values of their forest 2) more information to increase forestry activities in their forest.

2. Methods

2.1 Study area

The Norwegian forestland is divided into about 126 000 properties, of which 94% are owned by private individuals. Together, these properties cover 78% of the 7.0 million hectares productive forestland (Statistics Norway, 2021a). 60% of the properties have less than 50 hectares productive forest and most of the small properties harvest seldom or not at all; over the last twenty years there has been no harvest on more than half of the NIPF properties (Statistic Norway, 2020). About 15% of the NIPF owners have positive incomes from forestry in a given year; however even for those owners, forestry's share of total incomes was about 7% but with large variations within the population (Statistic Norway, 2021b). Due to the large population base of owners that do not have forestry as main occupation or income, there exist several approaches to reach out, inform and engage forest owners of both public and private initiatives. About 35 000 forest owners are enrolled in forest owner member organizations (Norwegian Forest Owners' Federation, s.a) which supply their members with forestry-related information and practical advices for forest planning and operations. The Forestry Extension Institute offers courses of practical forestry as well as forestry planning and operations; while

the majority of forestry-related organizations in Norway are members, the government provides a substantial part of the finances (Norwegian Forestry Extension Institute, 2020).

The Ministry of Agriculture and Food is responsible for the Forestry Act and the forest policy (Ministry of Agriculture and Food, 2005), while the county governor oversees the regional implementation of the schemes. As the municipalities are responsible for compliance of much of the forestry-related regulations and subsidies, most municipalities have bureaucrats with forestry background. Even if a part of their role is to provide information to forest owners about regulations and options for receiving subsidies, their capacities and resources may vary widely but there is limited public information about the success of the public management in reaching out to forest owners. Forest owners may also use media and professional journals as information sources for forest planning. As the forest owner population is changing into more urban, fewer full-time foresters, less trained in forestry, more female and more digital, the forest owner associations try new ways to reach forest owners (Olsvik, 2011); additional efforts may help to activate female forest owners (KUN, 2018).

2.2 Survey database

This study is based on the data from a national survey of NIPF owners across Norway. First two populations were created based on previous harvest: *Active owners* are those who have harvested 5 m^3 or more of timber for sale during the period 1998-2012 whereas *Inactive owners* had not harvested this quantity over the given period. All properties should be owned by private individuals and being larger than 2.49 ha of productive forestland. Owners were stratified using county and size class and the two populations counted 56 965 active and 72 147 inactive owners. Two gross samples, of 1500 active and 1650 inactive owners, were randomly selected from the populations. The survey was developed as collaboration between the Norwegian University of Life Sciences and the Statistics Norway. The questionnaire

included general information about the property and the owner, attitudes to the forest and motives for the ownership, sources of information on forestry issues. Annual data on taxable income, taxable wealth and timber harvest volumes and incomes provided by the Statistics Norway were appended to the responses. The questionnaire was sent by mail in February 2014. The data collection ended in June 2014 after one reminder sent two weeks after the first dispatch. To implement the survey effectively the Total Design Method developed by (Dillman, 1978) was employed. For more information about survey and dataset refer to Sjølie et al (2019) and Bashir et al (2020). All observations were weighted according to county and property sizes before initiating statistical analyses.

2.3 Statistical analyses

The statistical analyses are based on binary probit regression. Two separate empirical probit models were developed to examine the openness of NIPF owners to receive more information for improved forest management: more information about the environmental values of their forest and more information for increased forest activities. The two dependent binary variables were both responded on a four-point Likert scale turned into dichotomous variables for better-fit models. The first dependent variable represents NIPF owners' stated needs to receive more information on environmental value of their forests. The variable is assigned the value 1 for the owners who respond "corresponds rather well" to corresponds very well" to the statement "I need more information about the environmental values of my forests". If an owner responds "doesn't correspond at all" or "correspond slightly" the variable's value equals 0 otherwise. Similarly, the second probit model of NIPF owners' stated interest to receive more information for increased forest activities on their forestland. The dependent variable in this model also possess two values (1 and 0) in terms of NIPF landowners' interests to receive information to increase forest activities on their forest land.

The variable was assigned the value 1 if a landowner "agree a little" or "agree completely" to the statement "With more/better information, I could have increased the activity level in my forest". If an owners ticked "disagree completely" or "disagree a little", a value of 0 was assigned. Probit regressions were used to examine the relationship between the dependent variable and a set of independent variables in the two models. Table 1 provides detailed description of all variables included in the models. These explanatory variables represent forest owner and property characteristics, forest management decisions and information sources. To estimate the empirical model, we employed binary logistic regression procedure because of the binary scale of the dependent variables (Allison, 2016).

$$P(Y_i = 1) = \Phi(\beta_0 + \beta_1 X) + \epsilon_i$$

Where: *P* is the probability that a NIPF owner is willing to receive more information for improving knowledge of environmental values of their forests or increase the forest activities on their land base, β is the vector of regression coefficients. The primary goal of this study is to explore the significant factors that influence NIPF landowners' willing to receive more or better information for increased forest management activities. Therefore, the focus will laid on the identification of significant independent variables and their associated signs. In addition, marginal effects were computed to have a valid explanation and implications of each explanatory variables using Eq 2

$$\frac{\Delta P_i}{\Delta X_i} = P_i(1 - P_i)$$

$\frac{\Delta P_i}{\Delta X_i}$ equals to change in Pi with unit change in X.

Correlations were calculated between each pair of explanatory variables and the independent variables in each model were tested for multicollinearity using the Variance Inflation Factor (VIF) test. For all variables, the VIF values in the models were less than 2 indicating multicollinearity would not affect the regression results adversely (Freund and Wilson, 1998). The samples of the two populations of Active and Inactive owners were merged into one sample for the analyses, with sample weights added to ensure that the observations represent the population of NIPF in Norway.

3. Results

3.1 Descriptive statistics

About 31% of the forest owners stated a need to for more information about environmental value of their forest. Similarly, 45% of forest owners agree that more or better information could help them to increase harvest activities on their forest property. Of the 3150 questionnaires mailed to randomly selected landowners, 1,637 completed questionnaires were returned. The overall response rate was 52%, after accounting for undeliverable questionnaires. About 75% of the respondents were men and 40% of the participants reported having college or university education. The average landowner had 49.7 hectares of forestland. Furthermore, 23% of the survey participants reported to have education related to forestry or agriculture and 30% of the respondents said that they do farming. The owners have a set of information sources for forest management: the public authority (38% of respondents), media (15%) and peers (23%). Overall, 35% of landowners stated to have knowledge about the environmental values of their forest. The objectives for owning forestland included having forest for nature diversity (53%) and nature preservation (20%) and economic reasons.

3.2 Modeling results

The results of the probit model regressions are reported in Table 3 and 4. For the Environmental values model, significant variables ($p < .10$) include gender, education, farming, public authority and knowledge of environmental values, forestry or agriculture education and nature diversity. All coefficients but knowledge of environmental value of forests, farming and economically objectives recorded positive coefficients. Thus, female respondents and respondents with higher education had a higher probability to state a need of more information for increasing the knowledge about environmental values of their forest. On the contrary, owners who are also farmers, owners who have forestry or agricultural education and owners who state that are knowledgeable about the environmental values of their forest state to a lesser degree need of more information. Respondents who had public authority (municipality or forest organization) as a source of information for managing forests are state higher need of information of environmental values. Marginal effects were computed to display the importance of each variable on the probably that an owner is interested in more information. Being a female or having higher education each increases the chances by 5 to 6% to express openness to more information about environmental values. The strongest impact was observed among forest owners who stated public authority as a source of information for managing forests; these are 13% more likely to express such need. On the contrary, having forestry or agricultural education, being a farmer or having knowledge of the environmental values of the forest reduced the likelihood to express need for more information of environmental values by 5%, 7% and 14%, respectively.

For the probit regression model information for increased forest activities, positive coefficients for significant variables were found for peers, public authority and economic objectives. On the contrary, age, farming, knowledge of environmental value of forest and forest or agricultural education were significant with a negative sign. This suggests that older

respondents, owners who are involved in farming activities, that possess forestry or agricultural education or who have good knowledge of the environmental values of the forest were less open to more information for increasing forestry activities. An owner in contact with public authority have 13% higher probability of being open to more information to increase forestry activities, while the number is 6% for those who use peers as a source of information. Whereas, each of the subgroups of NIPF owners who are farmers, who have forestry or agricultural education or possess knowledge of environmental values of their forests have 6-9% lower probability of being interested in more information.

4. Discussion

Information instruments are utilized in an effort to increase the awareness among forest owners for sustainable management of their forests. From previous studies, it is evident that many forest owners lack information in different aspects of the forest management, including biodiversity conservation and timber harvest (Kärhä et al., 2020; Measells et al., 2005; Toivonen et al., 2005). This study analyzed the information needs of forest owners for knowledge building towards environment consideration and increased forest activities, with respect to socio-economic, property factors and attitudes and objectives of managing forests. This study provides a contribution in recognizing forest owner subgroups based on information needs that can be utilized to provide effective targeted extension and outreach programmes to address lack of knowledge among forest owners.

Many studies have stated that forest owners are interested in receiving information about their forest (André et al., 2017; Eyvindson et al., 2019; Kärhä et al., 2020; Laamanen and Kangas, 2015; Pynnönen et al., 2021). We observed that 31% of NIPF owners are in need of more information towards improving their level of knowledge of environmental values of their forests. Gender, education, and public authority as information source had a significant and positive effect towards seeking more information about environmental knowledge of their

forests. Other studies have also observed that female owners and highly educated owners were keen to avail more learning opportunities and consequently improve knowledge relating to the forest management (Côté et al., 2017; Follo et al., 2017; Lidestav and Nordfjell, 2005; Nordlund and Westin, 2011). Similarly, 45% of the owners state that with more information, that could manage the forest more actively with younger owners, economically oriented owners and owners who use peers and public authorities as information sources, but not having technical education but not doing farming stand out as with a desire to have more information for increase forestry activities. Thus, a large part of the owners open to more information, do already receive information about forestry and it seems to that the established channels like public management and peers could be further used and explored for disseminating for information. Owners with technical education may on the other hand feel that they already are sufficiently knowledgeable. The useful information offered will bring confidence and satisfaction to the forest owners, and help them to engage more in forest management activities (Kärhä et al., 2020). It seems forest owners communicating with public authority (municipality or forest organization) are open to learning and receiving more information about both environmental value of their forest and increasing forest activities on their forest property. This is in line with other studies (André et al., 2017; Crona and Bodin, 2006; Schubert and Mayer, 2012). Learning through observing peers was important factor increasing eagerness in owners to demand more knowledge and information for increased forest activities. Other studies (Kueper et al., 2014; Lind-Riehl et al., 2015; Schubert and Mayer, 2012) also emphasized on the role of peers for the dissemination of information. The peers are considered as experienced personals in managing their property therefore trusted as sources of information for decision-making in forestry (Haythornthwaite, 1996). Overall, it is evident that forest owners' are comfortable communicating with public authority and peers,

therefore these can act as stronger and smoother channels of communication for disseminating program information, as also stated by (André et al., 2017).

In addition, our study noted that older forest owners are less willing to receive more information to increase forest activities. It could be explained by the fact that older forest owners have lesser financial requirements or limitations in comparison to younger ones (Conway et al., 2003). In addition, many of the older forest owners are thinking of selling or transferring their forest property (Markowski-Lindsay et al., 2017). Being farmer or having high level of awareness about environmental value of their forest reduces owner's interest in receiving more information on environment and activities on their forests. In addition, owners with forest-related education seemed less interested towards information on increasing forest activities. Similarly, (Toivonen et al., 2005) observed that persons less forestry education were interested in getting more information about forest management issues.

Lack of information about forestry related programs or services prevents landowners from maximizing their forestland potential (Measells et al., 2005; Wicker, 2002). In addition, the heterogeneity of private forest ownership, declining knowledge levels and low forest involvement are raising concerns about the forest management behavior of forest owners (André et al., 2017; Stoettner and Ní Dhubháin, 2019; Weichselgartner and Kasperson, 2010). Therefore, more information inputs to NIPF landowners' will help them to execute informed decisions regarding the management of their forestland. Our study results indicate that information through advising is important policy tool to direct forest owners towards improving environmental knowledge and increasing timber harvesting activities to achieve policy goals of Norway to develop rural areas (Follo, 2011) and environmental sustainability (NMCE, 2020). The information provided to forests owners can also reduce the need of stricter regulations or control mechanism and can help to reduce financial liabilities caused due to various subsidies and incentives (FAO and UNECE, 2020). Butler and Leatherberry

(2004), VanBrakle (2015), VanBrakle et al (2013) also suggested that the information as policy tool could be used as an alternative option to incline forest owners towards better forest management. These studies even suggested that information dissemination through outreach programs have same impact on forest owner's management decisions as forest management plans.

However, some studies state that the decision-making behavior of forest owners may not be hindered only due to lack of information but its use by the targeted group (Moser and Dilling, 2007). Therefore, in addition to produce more and better information for the particular class of owners, there is also a need to analyze situational framework of forests owners in which information is provided and decision are made based on that information (André et al., 2017; Moser and Dilling, 2007; Weichselgartner and Kasperson, 2010).

Our study is a first attempt in the Norwegian context of scrutinizing subgroups of owners that are open to information about the management of their forest. The findings indicate that groups that are interested in building knowledge about environmental values differ from those directed towards forestry activities. Demographically, the former groups are made up of female owners, owners with college or university education and owners who do not do farming. The latter groups on the other hand consist of younger owners and owners who are not farmers. It's worth noting that respondents with more former knowledge express less interested in requiring more, and this holds true for both possessing forestry or agricultural education and self-reported knowledge about environmental values across both models. This may suggest that these owners feel that they have the necessary knowledge for managing the forest and that outreach activities should aim at introductory levels. Farming should not be considered as merely an occupation, but more of place in the sociological landscape. The negative impact of farming in both models could be steered by several factors. Farmers may receive information about forestry through networks or family relations other

than reported (for instance if generational knowledge transfer lies back in time) and may thus feel well enough informed, they may be skeptical to information campaigns or be too occupied with farming for being interested in forest management knowledge-building. We could not scrutinize the underlying factors with our data, but believe that the lack of farmers' interest should be explored in future studies.

Our findings also suggest that the owners' objectives have consequences for their keenness to information. The fact that owners who believe in taking care of nature's diversity are more open to information about the environmental values than owners who think that their forest is first and foremost a nature preservation object, might be caused by how they see that the forest should be managed. While the former group may look for ways to manage the forest and produce timber where environmental aspects are accounted for, the latter group may disregard forestry altogether and if the forest should be left untouched, there is less need for training on how to carry this out. Economically-oriented owners express that they will increase forestry activities with more information, suggesting that some types of outreach should have an economic focus to reach the target group.

While the use of media and journal do not have an impact on the interest of acquiring new knowledge, having peers as discussion partners do have a positive impact in the forestry activities model. However, the use of public authority expels the main influence on the interest for information about both environmental values and forestry activities, which is an interesting finding as the public forestry management is occupied mainly with forestry and may indicate that forest owners value impartial information. Understanding better the success factors behind these figures would be important to continue building on the municipality bureaucrats' knowledge capacities.

Our attempt to unveil the driving factors of information needs among a representative sample of Norwegian NIPF owners is to the best of our knowledge the first study of its kinds

in Norway. We believe that the two questions forming the dependent variables have served this purpose well; however the questions could have been better framed to reveal the interest or willingness to receive more information. The question about environmental values represents a stated need for more information and even if owners acknowledge a need for more information, they would not necessary be open to receive more information due to other barriers. Similarly, the question about forestry activities could also have been more precisely formulated to reflect the stated information needs or openness to receive more information. However, we believe that as a first assessment, our study provides a valuable contribution in revealing which groups of owners that can be targeted for various types of forest-related information. Future studies could also benefit from bringing in aspects like the preferred format and volume of information dissemination, alongside more details about the content that different groups of owners wish to learn about in order to further target information dissemination.

5 Conclusion

Information as a policy instruments is becoming increasingly important to encourage forest owners to manage their forests sustainably and ensuring that the flow of the values to the society are maintained. We observed that 31% and 45% of NIPF owners possess interests to receive more information about environmental value of their forests and forestry activities, respectively. Furthermore, we found that female respondents, respondents with higher education and NIPF owners in contact with public authority for managing forests expressed a higher need for information about environmental values of their forest. With more information, economically oriented respondents and respondents influenced by peers and public authority for managing forests were likely to increase forestry activities. The lack of knowledge due to limited access to the information may result in unawareness of various

programs, schemes or incentives, and thus reflects in limited use of these resources. This eventually may be visible through less productivity and activities on their land base. We found that the keenness to receive information about forest management is steered by a set of demographic variables (gender, age, education), objectives (economic, nature diversity), existing knowledge (forestry or agricultural education, knowledge of environmental values) and current information sources (public authority, peers, farming). Thus, targeting outreach programs to subgroup of owners who express an openness to more information could improve the effectiveness of this forest policy tool.

Acknowledgements

The authors would like to thank Norwegian Ministry of Agriculture and Food, the Faculty of Environmental Sciences and Natural Resource Management at the Norwegian University of Life Sciences and the Faculty of Applied Ecology, Agricultural Sciences and Biotechnology at the Inland Norway University of Applied Sciences for the financial support.

Author statement

Altamash Bashir: Conceptualization, Methodology, Formal analysis, Writing - Original Draft, Writing - Review & Editing, Validation, Visualization. **Hanne Sjølie:** Conceptualization, Writing - Review & Editing, Validation, Resources, Supervision, Project administration. **Birger Solberg:** Validation, Writing - Review & Editing, Resources, Project administration

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Table 1. Definitions of dependent and independent variables used in the probit regression models.

Variables	Description of the variables	Type of variable
Dependent variables		
Information about environmental values of forest	1 if the respondent answer "correspond rather well" or "correspond very well" to the statement: "I need more information about the environmental values in my forest"; 0 if the respondent answer "doesn't correspond at all" or "correspond slightly"	Dichotomous
Information for increased forestry activity	1 if the respondent answer "agree a little or agree completely" to the statement: "With more/better information, I could have increased the activity level in my forest"; 0 if the respondent answer "disagree completely" or "disagree a little"	Dichotomous
Age	Age of forest owner in 2012 (years)	Natural number
Gender	male = 1, female = 2	Dichotomous
Education	Primary and secondary = 0; higher education (bachelor, master, doctorate) = 1	Dichotomous
Size of forest property	Size of property in hectares (1 ha = 10 dec) (ln transformed)	Rational number
Farming	1 if agriculture farming on the property, 0 if not agriculture farming on the property	Dichotomous
Media and professional journals	1 if media and professional journals is "Rather important" or "Very important" source of information for management of the forest; 0 if "Slightly important" or "Not important at all".	Dichotomous
Peers	1 if the Other forest owners/family/	Dichotomous

	neighbours/friendsis “Rather important” or ”Very important” source of information for management of the forest; 0 if “Slightly important” or “Not important at all”. *	
Public authority	1 if the forestry section or the responsible for forest in the municipality is “Rather important” or ”Very important” source of information for management of the forest; 0 if “Slightly important” or “Not important at all”.	
Knowledge of environmental value of forest	1 if the respondent answer “correspond rather well” or “correspond very well” to the statement: “I know the environmental values of my forest”; 0 if the respondent answer “doesn’t correspond at all” or “correspond slightly”	Dichotomous
Forestry or agricultural education	1 if having forestry or agricultural education; otherwise 0	Dichotomous
Economic	Sum of the ordinal-scale responses on the three variables: INCOME: answer on the question “My forest provides me income”, ECON_SEC: answer on the question “My forest provides me economic security”, INVEST: answer on the question “My forest is an investment object for me” (thereafter outcome from principal component analysis used in the regression models)	Natural number
Nature diversity	1 if the respondent answer “of relatively great importance” to “very important” to the statement “My forest provides me the opportunity to protect and preserve nature's diversity” ; 0 if the respondent answer “not important at all” or “slightly important”	Dichotomous

Nature preservation	1 if the respondent answer “of relatively great importance” to “very important” to the statement “My forest is first and foremost a nature preservation object for me” ; 0 if the respondent answer “not important at all” or “slightly important”	Dichotomous

Table 2. Descriptive statistics (mean and standard deviation) of the variables used in the study (see Table 1 for definitions).

Variables	All owners (n=1637)	
	Mean	**SD**
Dependent variables		
Information about environmental value of forests	0.31	0.45
Information for increased forest activities	0.45	0.50
Independent variables		
Age	58.3	13.57
Gender	1.25	0.43
Education	0.40	0.49
Size of forest property ha,	49.6	153.07
(LN_ha)	(2.97)	(1.22)
Farming	0.30	0.46
Media and professional journals	0.14	0.35
Peers	0.23	0.42
Public authority	0.38	0.48
Knowledge of environmental value of forest	0.35	0.47
Forestry or agricultural education	0.23	0.42
Economic	-1.04	0.89
Nature diversity	0.53	0.50
Nature preservation	0.20	0.40

Table 3. Estimated coefficients and marginal effects of variables used in the probit models that analyse variables influencing private forest owner's need for more information about the knowledge of environmental values in their forest. Significance levels (10% = *; 5% = **; 1% = ***).

Variables	More information about environmental value of forests	
	Estimates	Marg. Eff
Age	-0.002	-0.0007
Gender	0.171*	0.0559
Education	0.194**	0.0635
Size of forest property (LN_ha)	-0.0008	-0.0003
Farming	-0.228**	-0.0744
Media and professional journals	-0.074	-0.0241
Peers	0.035	0.0113
Public authority	0.385***	0.1257
Knowledge of environmental value of forest	-0.414***	-0.1353
Forestry or agricultural education	-0.159*	-0.0519
Economic	-0.0008	-0.0002
Nature diversity	0.133*	0.0433
Nature preservation	0.124	0.0406
Constant	-0.694**	
Pseudo R^2	0.04	

Table 4. Estimated coefficients and marginal effects of variables used in the probit models that analyse variables influencing private forest owner's need of more information about increasing forest activities in their forest. Significance levels (10% = *; 5% = **; 1% = ***).

Variables	More information to increase forest activities	
	Estimates	Marg. Eff
Age	-0.012***	-0.0047
Gender	0.027	0.0101
Education	-0.070	-0.0265
Size of forest property	0.019	0.0072
Farming	-0.156*	-0.0589
Media and professional journals	0.058	0.0218
Peers	0.154*	0.0581
Public authority	0.348***	0.1316
Knowledge of environmental value of forest	-0.231**	-0.0871
Forestry or agricultural education	-0.246**	-0.0927
Economic	0.085*	0.0322
Nature diversity	0.082	0.0311
Nature preservation	0.062	0.0238
Constant	0.496*	
Pseudo R^2	0.04	

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Forest owners' attitudes towards their forests have large impacts on the sustainability of forest management. In this context, my research strives to provide greater depth of understanding of how the diverse socio-demographic and property characteristics of forest owners, their attitudes and behavior ultimately affects their management decisions, such as timber harvesting, biodiversity conservation, possessing a forest management plan or seeking information. To achieve this research goal, I utilized a questionnaire dataset originated from a national survey of non-industrial private forest (NIPF) owners, developed and distributed across Norway by the Norwegian University of Life Sciences in close collaboration with Statistics Norway. The results signify that most owners manage their forests for multiple objectives; ranging from ensuring social values and biodiversity to timber production. A main finding in this thesis is that the multifunctional forestry as a management strategy has a strong position among the NIPF owners in Norway. Forest owners managing their property for economic objectives consider their forest property as an important asset to attain financial security and well-being. Information from public management authorities may increase knowledge about forest management like timber harvest incentives, schemes for forest activities, environmental knowledge, and use of forest plans. This research study provides important contribution by pointing to specific groups of forest owners that demand special attention from forest policymakers and extension services while drafting different policies and executing various information campaigns. This study also provides valuable insights that can guide forest policy makers to formulate and execute policies and strategies that encourage forest owners to further manage and utilize forest resources while adhering to the principles of economic, ecological and social sustainability.