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Knowledge use in the management of privately owned forests: a focus on decision support services for multi-objective forest use

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Academic Dissertation

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ABSTRACT

This dissertation examines forest owners' views of forest-related decision support services and knowledge use in them in private forests in Finland. Decision support services provide information through forest management planning and advice. The decision-making about and implementation of forest management take place in a multi-actor network that produces, distributes, and utilises knowledge in technical and social knowledge systems. The thesis is based on two surveys, extensive focus group data and field notes from workshops. It adopts a mixed methods approach.

The results show that forest owners with timber production objectives considered the current decision support services most useful. Those who emphasised nature values or had multiple objectives were less satisfied. Forest management preferences are more versatile than what they appear based on overall ownership objectives. The majority of owners are interested in diversifying their forest management to increase other forest functions alongside timber production. Two knowledge systems, technical and social, influence knowledge use in forest management. Several points of discontinuity were identified in knowledge flows within and between forest-related actors and organisations. The codified, technical knowledge system dominates knowledge production and use. The importance of the social knowledge system has not been fully recognised. Independence from time and place, gratuitousness and ease-of-use make forest-related e-service more inviting. Lack of forest inventory data or its perceived low quality and discordance with forest owner objectives deter owners from using e-service.

Forest owners expect decision support services to acknowledge their diverse and multiple forest use objectives. Information services on the management of nature values and integration of various objectives are needed. Knowledge flows are weakened by the domination of codified, forest resource-related knowledge, social structures and practices that inhibit the diffusion of knowledge within an organisation, and emphasis on the economic targets. Organisations on the forest sector are in key positions for changing the prevailing decision support practices, but so far the development of new practices has been slow.

Keywords: private forest owners, decision support service, knowledge systems, multi-actor network, mixed methods approach

TIIVISTELMÄ

Tiedon käyttö yksityismetsien hoidossa: tutkimus päätöstukipalveluista monitavoitteiseen metsänkäyttöön.

Väitöskirja tutkii metsänomistajien näkemyksiä metsiin liittyvistä päätöksenteon tukipalveluista ja tiedon käyttöä niissä. Päätöstukipalveluita ovat esimerkiksi metsäsuunnittelu ja metsänomistajien neuvonta metsien käytöstä. Metsien käyttöön liittyvät päätökset tehdään ja toimeenpannaan monitoimijaisessa verkostossa, joka tuottaa, jakaa ja hyödyntää tietoa teknisissä ja sosiaalisissa tietämysjärjestelmissä. Tutkimus käsittelee yksityisomistuksessa olevia metsiä Suomessa. Ilmiötä tarkastellaan sekä metsänomistajien että metsäpalvelujen tarjoajien näkökulmasta. Monimenetelmäinen väitöskirja koostuu kolmesta tutkimusartikkelista ja yhteenvedosta. Tutkimuksessa käytetään kahta kyselyaineistoa metsänomistajille, toimijaverkoston ryhmäkeskusteluja sekä muistiinpanoja metsäammattilaisten koulutuspäivistä.

Tulokset osoittavat, että puuntuotantoa painottavat metsänomistajat pitivät nykyisiä päätöksenteon tukipalveluja hyödyllisimpinä, kun taas luontotavoitteiset tai monitavoitteiset metsänomistajat olivat tyytymättömämpiä saamiensa tietopalveluiden ja neuvojen monipuolisuuteen. Metsänomistajien metsänhoitomieltymykset ovat monipuolisempia kuin pelkkien yleisten metsänomistamisen tavoitteiden perusteella vaikuttaa. Suurin osa metsänomistajista on kiinnostunut puuntuotannon ohella monipuolistamaan metsiensä hoitoa muiden metsänkäyttötapojen edistämiseksi. Kaksi tietämysjärjestelmää, tekninen ja sosiaalinen, vaikuttavat tiedon käyttöön metsien käyttöön liittyvässä päätöksenteossa ja päätösten toimeenpanossa. Metsiin liittyvien toimijoiden ja organisaatioiden sisällä ja niiden välillä on useita tiedonkulun epäjatkuvuuskohtia. Tekninen tietämysjärjestelmä ja siten koodattu tieto hallitsevat tiedon tuottamista ja käyttöä. Metsätalouden organisaatiot eivät ole täysin tunnistaneet sosiaalisen tietojärjestelmän roolia ja sen toiminnan merkitystä. Riippumattomuus ajasta ja paikasta, palvelun ilmaisuus ja helppokäyttöisyys tekevät sähköisestä Metsään.fi - päätöstukipalvelusta houkuttelevamman metsänomistajille. Metsävaratiedon puute tai sen heikoksi koettu laatu ja yhteensopimattomuus metsänomistajien arvojen tai tavoitteiden kanssa vähentävät metsänomistajien kiinnostusta käyttää verkkopalvelua.

Metsänomistajat odottavat päätöksenteon tukipalveluiden tunnistavan heidän moninaiset tavoitteensa metsien omistamisessa ja hoidossa. Luontoarvojen huomiointiin ja erilaisten tavoitteiden integrointiin tarvitaan tietopalveluita. Tieto- ja neuvontapalvelujen puute liittyen muuhun kuin tasaikäisrakenteiseen puuntuotantoon havaittiin ongelmaksi kaikissa kolmessa tutkimuksessa. Koodatun, metsävaroihin liittyvän tiedon dominointi, sosiaaliset rakenteet ja käytänteet, jotka heikentävät hiljaisen tiedon liikkumista organisaatiossa ja taloudellisten tavoitteiden korostuminen heikentävät tiedonkulkua. Metsäsektorin organisaatiot ovat avainasemassa vallitsevien päätöksenteon tukikäytäntöjen muuttamisessa, mutta toistaiseksi uusien käytäntöjen kehitys on ollut hidasta.

Asiasanat: yksityismetsänomistajat; päätöstukipalvelu; tietämysjärjestelmä; monitoimijaverkosto; monimenetelmätutkimus

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Professor Jessica E. Leahy and Associate Professor Vilis Brukas provided their acquainted feedback and constructive critics as pre-examiners of this thesis. Thank you for your expertise and encouragement. Docent Heli Saarikoski kindly accepted our invitation to serve as my opponent in the defence.

Finnish Ministry for Agriculture and Forestry (grant number 311 340) has funded the research project Knowledge, communication and targeting of biodiversity conservation (Tiko) where the data for articles I and II come from. Funding from Doctoral Programme in Interdisciplinary Environmental Sciences (DENVI) in University of Helsinki; The Finnish Cultural Foundation, South Savo Regional Fund; the Niemi Foundation; Doctoral School in Environmental, Food and Biological Sciences in UH and the Foundation of South-West Finland's Forest Management Associations has made it possible for me to concentrate on research work. Finnish Forest Centre allowed me to use their data for the third article, and provided the register data. Thank you Kirsi Greis, Veikko Iittainen, Anssi Niskanen and Juha Väisänen for your help with that study.

My superiors in various organisations have given me freedom to pursue doctoral studies and research work alongside and within the projects I have worked with. Thank you Marko Mäki-Hakola (former Forest Owners' Union Western Finland), Juha Hakkarainen (Central Union of Agricultural Producers and Forest Owners) and Matleena Kniivilä (Pellervo Economic Research PTT) for your support. Special thanks to Matleena as my former mentor for your encouragement and sharing your views.

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I want to acknowledge also those forest owners who have answered the surveys and forest and environmental professionals and other stakeholders who have contributed in focus groups, workshops and otherwise during the work, given their time and shared their views. Your contribution has been essential in finding the right questions to ask as well as finding possible answers.

Research that produces nothing but books will not suffice (K. Lewis 1946). This thesis was initiated with the thought to find better ways to act on everyday decision making situations in Finnish forestry. I hope it makes the reader to think and ponder their views and assumptions about current forestry practices and invites us to seek for more sustainable solutions with its practice-oriented approach.

My late grandfather Arvo Pynnönen had no chance to go to school much – he went to help his father with forest work as a young boy. With very little formal education he was one of the most civilised person I have known. What did I learn from him? To stay curious and stay humane.

Helsinki, February 2020

Sari Pynnönen

LIST OF ORIGINAL ARTICLES

The thesis consists of a summary and the following three research papers reprinted with the permission of the publishers. In the text the papers are referred to by their Roman numerals.

I Pynnönen S., Paloniemi R., Hujala T. (2018). Recognizing the Interest of Forest Owners to Combine Nature Oriented and Economic Uses of Forests. Small-scale Forestry 17:443–470. https://doi.org/10.1007/s11842-018-9397-2

II Pynnönen S., Salomaa A., Rantala S., Hujala T. (2019). Technical and Social Knowledge Discontinuities in the Multi-Objective Management of Private Forests in Finland. Land Use Policy, Volume 88, November 2019, 104156. https://doi.org/10.1016/j.landusepol.2019.104156

III Pynnönen S., Haltia E., Hujala T. Digital forest information platform as service innovation: Finnish Metsaan.fi service use, users and utilisation. Manuscript.

Article I was planned by Pynnönen, in discussions with Paloniemi and Hujala. Data was collected together by the others and other TIKO project members. Pynnönen was responsible for analysing the data. Interpretation of results was discussed togehter by all authors. Pynnönen had a leading role in manuscript preparation, Hujala and Paloniemi contributed to it.

Article II was planned by Pynnönen in discussions with Hujala. Salomaa had the main responsibility in designing the data collection for the focus groups, other authors participated in planning and collection of the data. Pynnönen had the main responsibility for the training days and data collection carried out there. Pynnönen was responsible for analysing the data. Analyses were discussed with Hujala. Pynnönen had the leading role in manuscript preparation, other authors commented on the manuscript at different phases.

Article III was planned together by all authors, the original idea originated from Pynnönen. Pynnönen had the leading role in formulating the questionnaire for data collection, Haltia and the team from Pellervo Economic Research participated. Pynnönen was responsible for qualitative analysis and Haltia for quantitative analysis and model development. Pynnönen had a leading role in manuscript preparation, Haltia wrote parts regarding the model. Hujala commented on the manuscript.

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1. INTRODUCTION

Human societies are dependent on various ecosystems and their functioning, along with the natural resources they provide and regulate (MEA 2005). Forests play many roles in transitioning to climate- and resource-wise sustainable societies and lifestyles. Standing forests can sequester carbon into trees and forest soils and thus help mitigate and adapt to climate change. Timber products substitute fossil-based materials and hence offer more sustainable solutions for example through construction. Forests can also mitigate the effects of climate change e.g. by regulating waterflows and cooling down local climates. The functioning of many ecosystems and therefore the provision of ecosystem services, for example food production, depends on forests. Utilising forests in Finland and globally must be balanced to both secure climate change mitigation and biodiversity protection, and to fulfil the fundamental food, fibre and energy needs of humankind.

Biodiversity loss is a global, threatening trend that has accelerated due to human influence on natural ecosystems, and which will negatively impact ecosystem functioning and service provisioning (Ceballos et al. 2017). Protecting biodiversity within separate set-aside conservation areas (Margules and Pressey 2000) has not been effective enough to halt its loss (Jenkins and Joppa 2009; Tittensor et al. 2014). Thus new, more cost-effective, socially more agreeable and large-scale approaches are needed for conserving forest biodiversity alongside timber production. Combining production and protection in the same areas advances the ecological sustainability of forestry (Graham and Jain 1998; Hartley 2002). Such integrated forest management approaches, which combine the production of several goods and services simultaneously in the same forest area (Sabogal et al. 2013), are of increasing interest for forest policy (Schulz et al. 2014).

Societal demands on forests, including privately owned forests, have been increasing both for mobilisation of forest resources and for other forest functions such as recreation and carbon sequestration, and hence the use of private forests has been raised to the policy agenda in Europe (Schmithüsen and Hirsch 2010; Ficko et al. 2019). In the same time changes in the body of forest owners, such as urbanisation, have diversified the ways in which forest owners manage their forests Europe-wide (Weiss et al. 2019). Management decisions of many private forest owners together dictate the provision of ecosystem services on landscape level, and hence the goals set for forests by the society cannot be achieved without involving private forest owners (Mayer 2019).

Due to magnitude of extractive forest use in boreal countries the conservation of these forest ecosystem services is dependent on production forests, and the ability to combine provision of multiple goods and services within forest management (Kuuluvainen 2009; Mönkkönen et al. 2011). 86% of Finland's forests (26 million hectares) are classified as productive forestland (Natural Resources Institute Finland 2018), with 60% owned by private, often small-scale forest owners (Natural Resources Institute Finland 2019). Forest industry annually buys 80% of their roundwood from these forests (Natural Resources Institute Finland 2018). The planning and advisory practices offered for private forest owners and implementation of forest management by service providers in these forests determine to a great extent the conservation of forest biodiversity in forest landscape where private, small-scale forest ownership prevails. The 1996 Forest Act (1093/1996; amendments 1085/2013) mandated upholding biodiversity as one of the main objectives of forest management; nevertheless, certain forest habitats, such as herb-rich forest patches, have become too scarce to

maintain their biodiversity (Auvinen et al. 2007); over one-third of Finland's endangered species inhabit forests (Rassi et al. 2010).

Knowledge on ecosystem services and their values can inform and improve decision-making about environment and use of natural resources. However, conventional knowledge production system (scientific and expert led production of knowledge) has been criticised for its inability to address complex questions related to the use of natural resources (Lyons et al. 2014). Sustainable management and governance of ecosystems depends on our ability to gain insights and information from multiple knowledge systems (Tengö et al. 2014), including for example local and practical knowledge in addition to scientific or professional knowledge. Achieving sustainability requires not only production of more diverse knowledge, but also paying attention to processes in which the knowledge is generated and validated (Cornell et al. 2013), as simply providing more knowledge does not automatically result in better and more informed decisions (Saarikoski et al. 2018).

Management of natural resources is inevitably based on and shaped by social and institutional norms and practices, and bears the history of earlier decisions within it (Wilshusen et al. 2002). Political priorities, economic interests and established power structures play a role in decision making too (Saarikoski et al. 2018), possibly undermining the influence of environmental knowledge (Cowell and Lennon 2014). Wide understanding about the complex interactions of people and nature and about the drivers affecting these interactions is needed for transition towards sustainable governance of ecosystems and their use (Tengö et al. 2014). These interactions may include for example compromising and coordinating conflicting goals such as job-growth and protection of pristine forests.

Knowledge affects the ways people and organisations think and act (Peltola 2013), and hence it is important to analyse not only the modes and impacts of knowledge but also the reasons why certain knowledge is used or not used in decision-making (Saarikoski et al. 2018). More effective production and distribution of knowledge with new, flexible Information and Communication Technology (ICT) tools has enabled new people and organisations to participate in decision making, which has changed the roles of the state and experts that previously led environmental action and produced centralised expert knowledge (Mol 2006; Soma et al. 2016). These new tools have caused a fundamental change in access to information, enabling spreading of knowledge rapidly to a broader public (Cornell et al. 2013). As a consequence, traditional knowledge holders and vested interests are challenged by new voices and interests, creating new sources of expertise and authority (Cornell et al. 2013).

Several concepts have been used in the literature to describe Finnish forest owners. Distinctive characteristics are the high share of private ownership, the high number of individual owners and the habit of several generations within a family concurrently managing forest holdings and also of transferring forest ownership to the next generation within the family. The terms "non-industrial private forestry" (NIPF) and non-industrial private forest owners have been used particularly in the USA, and refer to 'forestland that is privately owned by individuals or corporations other than forest industry and where management may include objectives other than timber production' (Helms 1998, p. 124). The use of the term has decreased (Harrison et al. 2002). The term "family forest owner" has been used to describe the conventionality of forest ownership in a situation where someone in almost every family owns forestland and decision-making takes into account the continuity of the ownership over generations. In Nordic countries, family forestry has a long tradition of families managing the forests alongside their other economic activities such as agriculture (Harrison et al. 2002).

However, with changes in the body of forest owners, this term has also lost some of its descriptive power in Finland. The term "small-scale forest owner" is suitable with the forest ownership structure in most European countries, including Finland, whereas it does not correctly describe the size of forest holdings in the USA or Japan (Harrison et al. 2002). However, the forest estates in Finland are generally larger compared with many other European countries, though approximately one-fifth of forest estates are less than 10 hectares also in Finland. In this thesis, in the context of Finland, the term "forest owner" (FO for short) refers to private, non-industrial, in most cases rather small-scale forest owners, who in many cases have inherited their forests and will pass them down to their children. They may have several objectives for their forests, and have different resources and various intentions for managing or using their forests.

Concepts of sustainable forest management and multiple-use forestry have been gaining space during last decades, replacing the long-standing idea of sustained (timber) yield forestry (Hoogstra-Klein et al. 2017). However, the concept of multiple-use forestry is abstract and vague, and its content varies internationally (Hoogstra-Klein et al. 2017). Other concepts used for the approach are inter alia multifunctional forestry and ecosystem services oriented forestry (Maier and Winkel 2017). Forest management comprises economic, ecological and social practices of constructing, reproducing and reorganising information that are intertwined with each other and take place both in human and natural systems (Hokajärvi et al. 2011)**.** Forest management is a human-centric concept: it includes different kinds of human activities that affect forest ecosystems, in order to achieve set goals that may be related to timber extraction or forest conservation (Grossberg 2009). In this thesis the term "forest management" is used to describe the above defined human-nature system, and the term "forest management activities" deals with concrete management operations conducted in a forest, such as tending of seedling stand.

This thesis is motivated by two factors evident in Finnish forestry: the need for enhanced owner-orientedness in forest-related decision support services and the decline of forest biodiversity due to intensive forest use practices. Forest related decision support services are a means of information provision through for example forest management planning and advising forest owners about their forests. Timber production has been a dominant goal of forest management services in Finland, but demand for services for other forest uses is increasing from the side of forest owners (Mattila and Roos 2014; Häyrinen et al. 2015). So far the service offerings related to non-timber products, nature- and game-oriented forest management, or landscape and recreational values of forests have been scant, superficial, or unsuccessful. As a result of decision-support service system's stiffness, the content and partly also the shape of services do not meet the diverse needs of forest owners. This decreases the effectiveness of decision support services (Hujala et al. 2007) and may cause forest owners to retreat from actively deciding about the use of their forests (Häyrinen et al. 2015). The disproportionate emphasis on timber production causes efficiency losses to society by jeopardising the provision of various ecosystem systems from forests (Pohjanmies et al. 2017). Prevailing biodiversity conservation measures used in Finnish production forests have not been sufficient at halting biodiversity loss (Hanski 2008; Mönkkönen et al. 2011). Alteration of forest landscapes and habitats, particularly the decrease in decayed wood due to intensive forestry, has been identified as a major cause for the decline of forest species (Hyvärinen et al. 2019).

Finland has committed to several international agreements that aim for nature conservation, e.g. Convention on Biological Diversity CBD (Ministry of Environment 2018). Halting

the loss of biodiversity requires action both on global and local level and Finland must respect its commitments in this regard. Moreover, I personally consider it our righteous responsibility towards the planet and humankind. To find solutions that ensure using forests in Finland is globally sustainable in ecological, social and economic sense has been an important driver behind this doctoral thesis.

2. AIM OF THE THESIS

The purpose of this thesis is to examine the services and practices of decision support in the system of private forest management, from the viewpoints of forest owners and of the network of service providers and relevant authorities. Emphasis is placed on the knowledge systems used in providing support for forest owners' decisions concerning their forests. The knowledge and understanding gained from empirical evidence in articles I, II and III is summarised, and suggestions are then given for developing the services. From the theoretical viewpoint, this interdisciplinary thesis combines the theories of knowledge management and knowledge lifecycle along with the diffusion of innovations and adoption of e-services. Forest owner research and forest management planning create the background for this thesis. The general research questions to be answered in this thesis summary are:

1. What kind of decision support services do forest owners wish for to support their (multi-objective) forest uses?
2. How is knowledge used in the management of small-scale private forests in Finland?
3. What discontinuities occur in the knowledge use of decision support services?

The research questions of individual papers and their core interest are presented in Table 1.

Table 1. Research questions and core interests of the articles

	Research questions	Core interest
Article I	How are objectives and forest management preferences of Finnish forest owners connected with each other and how do they overlap? How are the objectives and management preferences linked to current advisory services? How should forest advisory services be developed to better match forest owner needs?	Finnish forest owner needs and desires for decision-support services
Article II	What roles do different forms of knowledge (codified, encapsulated or tacit) play in the multi-objective management of privately owned forests? How do technical and social knowledge systems interlink in these (decision-making and) management processes? What are the reasons for the discontinuities in information flows within and between forest-related actors? What solutions and positive developments have organisations identified or developed to enhance information flows?	Multi-actor knowledge network in the process of tactical and operational forest management, decision-making and implementation
Article III	Which forest owner characteristics explain the probability of actively using the Metsaan.fi e-service? What attributes in the service affect whether a forest owner utilises or does not utilise the service? How might the service better support forest owners in their forest-related decision-making?	Web-based e-service as an innovative form of a decision support service

3. THEORETICAL FRAMEWORK

3.1. Forest owner research

The need to understand forest owners' forest management behaviours has created the research area of forest owner typologies (Harrison et al. 2002). Research concerning forest owner manners and attitudes is important for effectively influencing forestry practices (Ziegenspeck et al. 2004). Typologies have mostly been used to produce better understanding about forest ownership objectives, but also for studying wood mobilisation, forest management approaches, conservation efforts and involvement in forest owner associations (Ficko et al. 2019). The early stages of forest owner research concentrated on the role forest owners have as timber producers, and since 1970s the research interest has shifted to understanding the attitudes, motives and objectives of private forest owners (Egan 1997). Lot of forest owner studies have been done particularly in North America and in Nordic countries (Finland, Sweden, Norway and Denmark). National Woodland Owner Survey and studies based on it regularly produce information in the USA about private forest owners and their management intentions and objectives (Butler et al. 2016). The first forest owner typology study appeared in 1981 by Kurtz and Lewis in the USA. Changes in economic structures, e.g. a decrease in the number of farms in Europe along with urbanisation, among other factors, have changed the ways forests are used and managed. Forest ownership is fragmenting and various forms of co-ownership are becoming more common (Follo et al. 2017). These changes have been seen as challenges for active forest policy and industrial utilisation of forests in Western countries. Behaviour and attitudes towards forests greatly influence how landowners use their forests (Ziegenspeck et al. 2004).

Numerous survey-based studies creating typologies and classifications of forest owners have identified an increasing diversity of objectives and motives for owning forests (e.g. Silver et al. 2015; Ficko et al. 2019). Ficko et al. (2019) reviewed private forest owner typologies from 28 European countries and found the most common typologies to be multi-objective owners, recreationists, investors and farmers, indifferent owners, conservationists, multifunctional owners and self-employed owners. In the USA, Kline et al. (2000) and Majumdar et a. (2008) both identified three groups of forest owners: multi-objective, timber production-oriented and non-timber-oriented or recreationist, with the multi-objective group being the largest. Kline et al. (2000) also recognised a group of passive owners. Feliciano et al. (2017) conducted a survey in seven European countries and found that private forest owners in Western European countries emphasise ecosystem-oriented forest management and the concept of multi-functionality more, while economic aspects and maintaining the good growing condition of forests are more important in Eastern European countries.

In Finland, forest owner studies have been conducted regularly since the 1970s at approximately ten-year intervals (Karppinen and Hänninen 2006), aiming to group owners based on either their socio-economic status and holding characteristics or their timber sales and management behaviours (Järveläinen 1974; Ihalainen 1992; Karppinen et al. 2002). The first Finnish study on private forest ownership, the doctoral dissertation by N. A. Osara, "Small Wood-lot Forestry in Finland" was published already in 1935. More recently, typologies have been built e.g. based on owner values or timber selling behaviours (see e.g. Kuuluvainen et al. 1996; Favada et al. 2009). In addition to large survey studies aiming to generalise over large populations, more detailed typologies have been built based on interviews (e.g.

Lähdesmäki and Matilainen 2014; Takala et al. 2017a), aiming to understand how different issues are connected to each other (Sayer 2000, pp. 19–22).

Globally, women were not recognised as a distinct group of forest owners until the 2000s, and therefore research focusing on female forest owners is also fairly novel (Follo et al. 2017). In the literature, women have been described as "the silent owners", as they have either been mostly invisible in forestry (Strupstad 1999) or have acted as bystanders (Vainio and Paloniemi 2013), whereas men have been regarded by society as the main operators of family farms and forests (Brandth and Haugen 1998). Measuring the share of women as forest owners is problematic in forest owner research based mainly on surveys, because they underestimate the number of women (Karppinen and Ahlberg 2008). In Europe, the share of women as forest owners varies between 20% and 40% by country (Schmithüsen and Hirsch 2010). In the rural context in Finland, women are often considered in relation to men (as wives, daughters or daughter-in-laws) rather than individual actors themselves making decisions about the use of resources (Silvasti 2003). The same also applies to other countries where forest industry is nationally important (Brandth and Haugen 1998; Reed 2003).

Common patterns changing forest ownership, such as urbanising lifestyles and the increase in female owners, are decreasing the level of harvesting and increasing the share of land set aside for conservation (Côté et al. 2016). More forest owners are increasingly interested in forest benefits other than timber production such as recreational and aesthetic forest values (Leppänen 2010; Häyrinen et al. 2015). Non-market forest values may play an essential role when a forest owner decides to utilise their land (Amacher et al. 2002; Conway et al. 2003). Forest owners with strong recreational objectives for their forests harvest less timber (Favada et al. 2009).

3.2. Knowledge types and forms and their management

Bell (1979) describes knowledge as an "organized set of statements of facts or ideas, presenting a reasoned judgment or an experimental result, which is transmitted to others through some communication medium in some systematic form". Davenport and Prusak (1998, p. 5) define knowledge as "a fluid mix of framed experiences, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information".

Several types of knowledge exist in biodiversity conservation and decision-making concerning the use of forests, for example scientific knowledge and local, non-professional or indigenous knowledge (Berkes et al. 2000; Giessen and Böcher 2009; Fortmann and Ballard 2011). Local knowledge is related to local places and people, and is produced and utilised by them (Geertz 2000; Salomaa et al. 2016). A person who has no professional status through education or occupation concerning a certain subject produces non-professional knowledge, and this knowledge is based on their experiences and the social norms for interpreting those experiences (Bamberg 2013). Knowledge types may intertwine at the local level and contain nature-related, cultural or social knowledge (Yli-Pelkonen and Kohl 2005; Salomaa et al. 2016). These various knowledge types may take different forms: some are tacit by nature, others may be codified or encapsulated.

Different knowledge types create different knowledge systems. Several, rather similar definitions can be found about knowledge systems. Cornell et al. (2013) define knowledge systems as being "made up of agents, practices and institutions that organise the production,

transfer and use of knowledge". Foray (1997, p. 64) defines knowledge systems as "a network of actors or entities that assume specific functions for the generation, transformation, transmission and storing of knowledge". For example indigenous and local knowledge creates different knowledge systems than scientific knowledge. Merging and mixing of various knowledge systems create new insights and hence can improve the understanding about the dynamics of social-ecological systems (Tengö et al. 2014).

Knowledge management, including the knowledge lifecycle and different forms of knowledge, takes place within the knowledge systems. Knowledge and technological systems related to knowledge are always dependent on the time, place and people producing them (Blackler 1995; Jasanoff 2004, pp. 12–19). The collection of standardised data and the IT systems supporting their storage, distribution and application are collectively referred to as the *technical knowledge system*. The individual actors and their organisations using and generating forest-related knowledge, the social and societal norms that regulate their actions, and the ways in which they take advantage of the technical knowledge systems, such as information systems, together constitute the *social knowledge system* (Tsoukas 1996; Rametsteiner and Weiss 2006; He et al. 2009). Certain forms of knowledge are more typical for the technical knowledge system and other forms more typically occur in the social knowledge system.

The technical knowledge system is embedded in the social knowledge system: the decisions on how technical knowledge management systems (meaning for example databases and software) are built and what data are collected are socially directed (Jasanoff 2004, pp. 12–19). Technologies are useful for enhancing information flows within the organisation and enabling coordination between relevant operators by minimising human and physical constraints (Bhatt 2001). They are used to bring order and coherency to the world and thus make the world governable (Peltola 2013). The social knowledge system determines how these technologies are used. Effective knowledge management requires an interplay of technical and social knowledge systems in an organisation and at the level of individuals working in and with those organisations (Bhatt 2001). In Western companies and organisations knowledge management efforts have so far emphasised technology-based initiatives and mainly focused on managing explicit knowledge by developing new applications for information technology to support the acquisition, storage and distribution of codified knowledge (Grover and Davenport 2001). Social relationships are a key factor affecting knowledge-sharing behaviour (He et al. 2009). For example, Primmer & Karppinen (2010) found that social professional norms have an even stronger influence than attitudes on how forest professionals judge new information concerning e.g. biodiversity conservation measures. Because knowledge and knowing are always socially determined, they are also a question of power relations. Someone's credibility as a knowledge producer depends on social markers such as education (Fortmann and Ballard 2011). Two knowledge systems and their relationship are presented in Figure 1.

Knowledge management includes systematic processes for producing, collecting, distributing and applying all forms of knowledge (Alavi and Leidner 2001), for the purpose of enhancing organisational performance and value creation, as well as the potential of individual skills, competencies, thoughts and innovations (Dalkir 2011, p. 3). Knowledge management theories mostly build on the understanding that organisational knowledge has several forms or shapes (Evans et al. 2014), which determine how the knowledge may be stored and distributed. These are divided into three categories: data, information and knowledge (Bhatt 2001; Grover and Davenport 2001). Data are considered raw facts, whereas

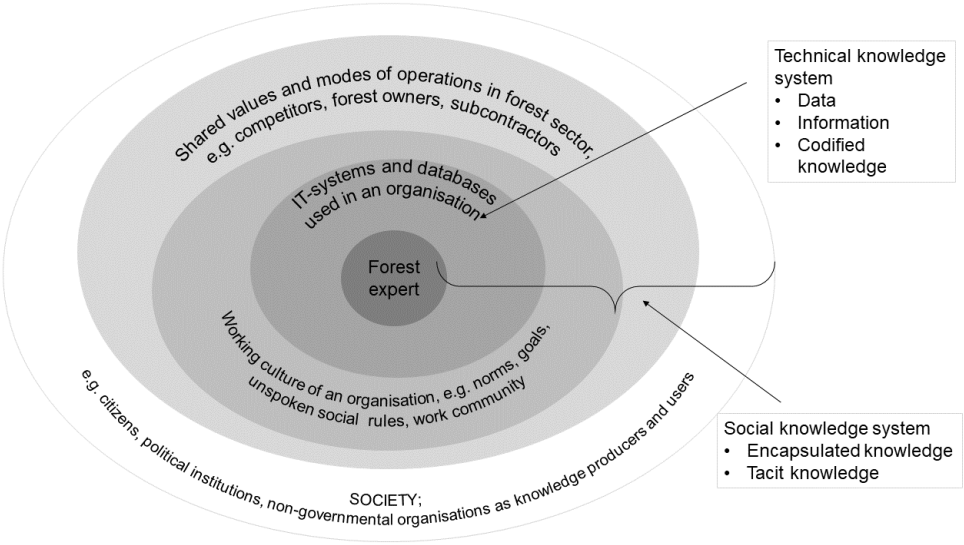

Figure 1. Knowledge systems, their relationship and typical knowledge forms in each system.

information is a classified or summarised set of data within a certain context. Knowledge is meaningful information that always includes human interpretation or processing of that information and hence has the greatest relevance to actions. Knowledge is always dependent on the person using and developing it, and because of this dependence on human contribution to its existence, it is also the most difficult of these three forms to manage (Grover and Davenport 2001). The form of knowledge dictates the cost and benefit of acquiring it and affects the ways it can be transferred (Figure 2) (Van Den Berg 2013). The classification of knowledge forms is required for managing knowledge as an important asset and factor of production (Evans et al. 2014).

Knowledge is commonly further divided into explicit and tacit knowledge (Grover and Davenport 2001). Explicit knowledge is usually defined as easily codified and formally expressed using a system of symbols, such as words or formulae, (Van Den Berg 2013) or as being "describable and tangible" (Wiig 1993, p. 65). According to this definition, explicit knowledge is codified knowledge. Codified knowledge is highly formalised (Van Den Berg 2013) and codified into rules, standards, classification systems and formulae (Choo 1996). Automated forest inventory data or a register with customer contact information are examples of this type of knowledge. The difference between codified knowledge and information is wavering, as they have many common features. Both can be easily stored or written down without losing parts of the content (Evans et al. 2014), because the pattern of formation is commonly known or standardised between sender and recipient (Kogut and Zander 1992, p. 386).

However, not all explicit knowledge is explicit in the sense of being readily observable and standardised between sender and recipient. Encapsulated knowledge consists of the thought, reflection or experience of its creator, and offers the functional value of the creator's expertise to the receiver although the primary expertise stays concealed (Van Den Berg 2013). Typically, the encapsulated knowledge has been transformed into a product that only

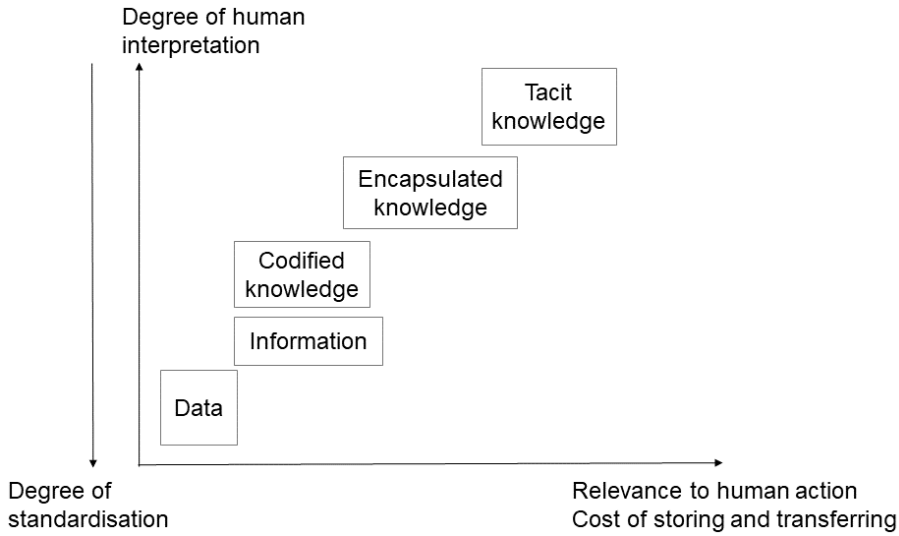

Figure 2. Knowledge forms and their characteristics

requires functional knowledge for its utility (Van Den Berg 2013), e.g. patents or tools (Choo 2006, p. 141), but it can also be instructions or procedures. Software is an example of encapsulated knowledge; the user receives functional benefit from it without needing to know how the code behind it works. Encapsulated knowledge is commonly intra-organizational. A forestry-related example of encapsulated knowledge is the recommendations for forest management: forest owners benefit from the knowledge of how to best manage their forests even if they are not familiar with the scientific reasoning behind the recommendations.

Encapsulated knowledge is similar to tacit knowledge, as they both are difficult or impossible to capture in structured form and require prior knowledge from the recipient for correct interpretation. Tacit knowledge is personal and action-oriented and is typically considered non-conscious or internalised (Wiig 1993, pp. 135–136). It is practical know-how, skill or expertise that accumulates over time through experience or learning (Kogut and Zander 1992). As tacit knowledge is embedded in the human brain (Grover and Davenport 2001), it is expensive to transfer and distribute (Kogut and Zander 1992). Tacit knowledge of an employee is needed to interpret and process codified knowledge or data sets constituting it (David and Foray 2002).

Besides different forms of knowledge, knowledge management includes a process (Dalkir 2011). This knowledge management lifecycle is defined as a chain of knowledge activities that occur after each other (Nissen et al. 2000). In practice, the phases take place iteratively (Nissen and Espino 2000). Fink and Ploder (2009) define the key process phases as the following: In *knowledge acquisition*, an organisation needs to acquire certain forms of knowledge from the outside through generating new knowledge by themselves (e.g. by forest inventories) or through collecting existing knowledge from customers or other knowledge sources (such as official databases). *Knowledge distribution* means sharing an organisation's existing knowledge within itself and its partners, e.g. subcontractors or customers. In

knowledge utilisation, knowledge is applied productively to carry out organisational activities. Despres & Chauvel (1999) add the concept of evolvement to the lifecycle, meaning that knowledge must evolve along when its environment changes for it to remain relevant. This is also known as adaptation. Dynamism of knowledge systems enables them to constantly respond to changes in the operational environment and to adapt to new knowledge (Battiste 2005).

3.3. Knowledge in forest management planning and advisory services

Multi-objective and sustainable management of privately owned forests requires a variety of knowledge types and forms from various sources. Necessary knowledge is dispersed among different local, regional and national agencies and groups (Berkes 2009). Efficient decision-making based on knowledge dispersed among a network of different knowledge sources demands smooth information flows within and between individual actors, actor groups and organisations (Primmer and Wolf 2009; Sandström 2009; Primmer 2011). However, in environmental governance, natural science based knowledge and information on the natural environment have been and still are considered most relevant (Mol 2006). Improving environmental information is often seen as a matter of improving the quality of data sets that contain the relevant variables needed to measure certain environmental characteristics such as biodiversity (Turnhout 2009; Lehtonen et al. 2016). Environmental management has been based on technocratic, exclusionary paradigm (Adams and Sandbrook 2013) and knowledge production has traditionally been led by governmental agencies and conducted by assigned experts. Primmer et al. (2015) call this a scientific-technical approach to the governance of natural resources.

Scientific-technical approach to the governance of natural resources primarily concerns ecosystem structures and functions (Primmer et al. 2015) and hence concentrates on nature knowledge. It places emphasis on the construction of knowledge and support systems with the aim to maximise the effectiveness of implemented measures (Primmer et al. 2015). It relies on scientific knowledge and the assumption of smooth knowledge flows (Primmer et al. 2015) along with the presumption of knowledge objectivity (Jasanoff 2004, pp. 12–19; Fortmann and Ballard 2011). Traditional or local knowledge is required to be scientifically validated in order to be included as usable knowledge (Agrawal 1995). In Finland, forests are governed by the professionals with institutionalised science and technology, and according the best scientifically proven practices of each time (Suopajärvi 2009, p. 344). A great deal of emphasis is put into collecting more forest inventory and nature data and developing databases and systems to automatically update and share the data (Ministry of Environment 2013; Ministry of Agriculture and Forestry 2015). The emphasis on the scientific-technical approach is also clear with the demands on the evidence-based biodiversity conservation approach (e.g. Sutherland et al. 2004) which predominantly builds on western scientific knowledge system (Tengö et al. 2014).

Management of privately owned forests requires at least technical and scientific knowledge about the forest resources and the forest nature, social and practical knowledge about the objectives and resources of the forest owner, and local knowledge about the special characteristics or ways of using the certain forest area. Knowledge is applied by forest management planning and by forest professional advising a forest owner about the possible management of the forest. Integrating biodiversity protection into the management of productive

forests has presented a fundamental change in the knowledge requirements for forest management and hence also challenged the forestry experts, forestry organisations and the knowledge systems used in governing the privately owned forests (Peltola 2013).

Forest management planning is an application of knowledge systems for forests that aims at providing information about the forest to its owner to support the forest related decision-making (Kangas et al. 2015). In many countries forest management plans are rather regulatory instruments than informative (see e.g. Brukas and Sallnäs 2012). The purpose of forest management planning is finding an efficient mix of operations to fulfil the goals set for a specific area, typically one forest holding (J. Kangas and A. Kangas 2005; Kangas et al. 2015). Forest management planning concentrating solely on timber production has been replaced in several countries with planning for multiple uses around 1980's (Pukkala 2002, p. 2). A forest management plan is an information tool that helps forest owners manage their forests according to their individual objectives and the principles of sustainability (Paretti 2003). Traditionally, it has been predominantly based on the technical knowledge system, but nowadays it also contains elements from the social knowledge system. A starting point of a planning process is to set the preferences of the land owner (Pukkala 2002, p. 2), and then choosing the operation alternatives that best fulfil the set goals (Kangas et al. 2015). Preparation (e.g. conducting the inventory work in a forest), compilation and delivery of the plan is referred to as forest management planning (Hokajärvi et al. 2011).

Forest management planning is conducted on strategic, tactical or operational level (Pukkala 2002). Strategic planning is usually conducted for 10-20 years periods to define the objectives of owning and managing a forest area. In tactical planning the means needed to achieve the set goals are defined. In the planning of privately owned forests strategic and tactical planning are usually integrated (Kangas et al. 2015). In operational planning the practical conducting of the individual management or harvesting operations is planned in great detail (Kangas et al. 2015), e.g. delineating and marking in the forest the areas to be saved for biodiversity purposes or defining whether to harvest a stand during winter or summer.

The forest management plan for a single forest holding in Finland contains the forest inventory data (e.g. tree species, basal area, three height and diameter) and information on site factors and possible biodiversity hotspots for every stand, illustrated with figures and thematic maps (Hokajärvi et al. 2009). A plan is usually compiled for a period of 10 years. A forest expert provides treatment suggestions for harvesting and management activities for each stand (Hokajärvi et al. 2011). A forest management plan also contains information on income and management costs (Hokajärvi et al. 2009), and the harvesting suggestions are based on aiming for an even flow of money from timber sales, while maintaining harvesting possibilities over time. The line of thought is usually based on the assumption that the owner rationally maximises their expected utility (Beach et al. 2005) although this approach has been also criticised (Kangas et al. 2015). Depending on the owner's wishes, a plan may focus on timber production, nature conservation or recreation (Tikkanen et al. 2010). However, there may be uncertainty on the preferences of the forest owner with respect to different criteria (Kangas et al., 2015), or the forest owner may not be able to articulate their preferences in a way that can be used in strategic forest management planning (Tikkanen 2006). In earlier studies, having a valid holding-level forest management plan has been connected to conducting harvests (Ní Dhubháin et al. 2010; Hänninen et al. 2011) and pursuing management activities (Ovaskainen et al. 2017).

Advisory services for forest owners have long been based on scientific knowledge on how to maximise timber production (Peltola and Tuomisaari, 2016). The content of advisory

services and management suggestions issued in forest management plans are mostly based on guidelines concerning good forest management. These "Best Practices for Sustainable Forest Management" (Tapio Consulting Services 2016) have been produced for decades and are regularly modified based on scientific knowledge. They are compiled with financing from the Finnish Ministry of Agriculture and Forestry in a multi-stakeholder process and then adopted by forestry actors. Different guidelines for forest management have been produced with different emphasis on for example game keeping, profitable forestry or for close-to-nature management practices. These practices include leaving more retention trees in harvesting, favouring light selection felling, and minimising the removal of dead wood (Bieling 2004).

3.4 Knowledge distribution with innovative web-based services

Web-based services are electronic customer services such as internet banking (de Ruyter et al. 2001; Ariff et al. 2013). They are interactive and content-centred, and integrated with the technologies and systems offered by the service provider (de Ruyter et al. 2001). With online services customers contribute to service delivery by actively using their own effort and time (Bressolles et al. 2014). Governmental services, such as tax administration, are a specific branch of e-services. The Metsaan.fi service platform investigated in article III is one such governmental service aimed at forest owners. E-government uses information and communication technology to effectively provide governmental services and information to citizens, businesses and other governmental agencies (Rose et al. 2015). Trusting the administrative body significantly influences the adoption of e-government services (Alzahrani et al. 2017).

E-service quality refers to consumers' overall evaluation of the quality of a web-based service (Santos 2003). For e-services intended for information delivery or promotional purposes, such as the Metsaan.fi service, quality refers to consumer judgment on the processes and outcomes of the interaction (Gummerus et al. 2004). A review study by Ladhari (2010) disclosed six key characteristics for e-service quality: reliability, responsiveness, usability, security, web design and information quality. Reliability refers to delivering the requested service (Cristobal et al. 2007), responsiveness to the willingness to help customers (Li et al. 2002) and usability means the ability of a customer to locate relevant information and features (Collier and Bienstock 2006). Security and the privacy of a service are linked to protecting the customer from risk of fraud and protection of personal details (Bressolles et al. 2014). Web design or aesthetics refer to the appearance of the webpage, such as the graphics and colours used, and the clarity and precision of the information provided describe information quality (Bressolles et al. 2014).

E-satisfaction can be defined as "a cumulative, attitude-like judgment that is based on customers' past experiences" (Gummerus et al. 2004) or as customer judgment of their experience with a specific service compared to their other service experiences (Anderson and Srinivasan 2003). E-service quality influences e-satisfaction (Wolfinbarger and Gilly 2003). Different customers emphasise different aspects of e-service quality concerning their perceived e-satisfaction (Bressolles et al. 2014). Four website characteristics are of particular importance for e-satisfaction: ease-of-use, information content, entertainment and interactivity (Alpar 1999). Ease-of-use refers to response speed and the logics of navigation; information content refers to quantity, quality and accuracy along with customer orientation of

the content; entertainment is linked to amusement and excitement; and interactivity to functions such as live chats. The majority of customer segments consider ease-of-use to be important in e-satisfaction (Bressolles et al. 2014). The importance of security and privacy are found to be decreasing compared to earlier studies (Wolfinbarger and Gilly 2003; Bressolles et al. 2014). Trust has been found to be equally important in services that involve personal, even sensitive information, than in services that require financial exchanges, where a lack of trust has been the most important reason for not adopting a service (Gummerus et al. 2004).

Innovations diffuse in a process in which they are communicated over time among people in a certain social system (Rogers 2003, p. 35). In this study, Finnish private forest owners are the social system in which the innovation, the Metsaan.fi e-government service, is diffused and adopted. Rogers' (2003) theory on innovation diffusion distinguishes five attributes or perceived properties of an innovation that affect the rate of their adoption: relative advantage, compatibility, complexity, trialability and observability. These attributes explain the majority of the variance in the rate of adoption, which is the speed at which an innovation is adopted in a certain social system (Rogers 2003, p. 221). Some authors add perceived risk as the sixth attribute (de Ruyter et al. 2001). Besides these, the type of innovation-decision, ways to gain information and the social system where the innovation is being diffused, affect the rate of adoption (Rogers 2003, p. 221). The perception of the attribute that the decision-maker has concerning the innovation matters, not the objectively classified attributes themselves.

Relative advantage is the "degree to which an innovation is perceived as being better than the idea it supersedes" (Rogers 2003, p. 229). It can be expressed as economic profitability, social prestige or decrease in discomfort (Scott et al. 2008). It is often linked to characteristics such as ease-of-use and time-saving (de Ruyter et al. 2001). Perceived relative advantage is the strongest predictor for the rate of adoption (de Ruyter et al. 2001; Pannell et al. 2006). *Compatibility* is "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (Rogers 2003, p. 240). A more compatible idea is easier to regard as familiar, or is perceived as fulfilling the adopter's need. Compatibility or incompatibility is linked either to sociocultural values and beliefs (Mascia and Mills 2018), previously adopted ideas or one's perceived needs for the innovation (Wejnert 2002). The innovation's compatibility with the adopter's previous knowledge, such as experience in using web-based services, speeds up or slows down the rate of adoption (Wejnert 2002; Rogers 2003, p. 243).

Complexity is the "degree to which an innovation is perceived as relatively difficult to understand and use" (Rogers 2003, p. 257). Being perceived as complex may create a considerable barrier for the adoption of an innovation. *Trialability* is "the degree to which an innovation may be experimented with on a limited basis" (Rogers 2003, p. 258). It refers to the concrete easiness of trying the innovation out but also to factors affecting learning from the trial (Pannell et al. 2006). Innovations that are perceived as easily trialable before being fully implemented are more readily adopted (Scott et al. 2008). Different incentives can be used to increase the adoption rate of a certain innovation e.g.by facilitating its trial use (Saltiel et al. 1994; Rogers 2003, pp. 236–238): for example the initial user fee of the Metsaan.fi service was removed approximately two years after its initial launch to encourage forest owners to adopt the innovation (Finnish Forest Centre 2015). *Observability* is "the degree to which the results of an innovation are visible to others" (Rogers 2003, p. 258). The rate of adoption increases if the positive outcomes from the implementation of the innovation are

easily visible or communicable to others (Rogers 2003, p. 258; Greenhalgh et al. 2004). *Perceived risk* is "the degree to which innovation performance and psychological (concern regarding others' opinions of one's decision) risks are attributed to the innovation" (de Ruyter et al. 2001). With online services perceived risk may be related to financial, physical or social risks as well (Forsythe and Shi 2003).

An individual's decision to adopt an innovation is a dynamic process occurring over time and consisting of a series of actions (innovation-decision process) (Rogers 2003, p. 169). The process begins with *gaining knowledge* about the innovation, where the socio-economic characteristics, personality and the ways the adopter uses communication channels play an important role (Rogers 2003, p. 170; Scott et al. 2008). Then comes the *persuasion phase*, where the perceived attributes of the innovation itself are of particular importance (Rogers 2003, p. 175). In the decision stage, an individual decides whether to adopt or reject the innovation. Innovation trialability is important in this phase, because trialability helps overcome uncertainties linked to the innovation (Rogers 2003, p. 177). *Implementation* may take quite a long time. Users may postpone deciding about adoption until the innovation develops to replace their current product of service (Szmigin and Foxall 1998). The adoption is confirmed after implementation, as individuals seek to reinforce their decisions to keep using the innovation, but they may also decide to discontinue use (Rogers 2003, p. 217).

Five categories of innovativeness are typically distinguished: innovators (ca. 2.5% of the members of a social system), early adopters (13.5%), early majority (34%), late majority (34%) and laggards (16%) (Rogers 2003, pp. 280–281). Important differences can be distinguished between the typical characteristics of individuals in different categories, although there are no sharp borders between adopter categories (Rogers 2003, p. 282; Greenhalgh et al. 2004). Early adopters typically have longer formal education, higher social status, larger units of adoption and higher income (Rogers 2003, pp. 288–292; Khanal et al. 2019). In their study of Central European forest owners, Rametsteiner and Weiss (2006) found that owners of large properties were often clearly more likely to adopt innovations than smaller landowners. Early adopters seek more information, have wider social networks, including change agents, communicate more interpersonally and seek information about innovations more actively than late adopters (Rogers 2003, p. 291).

4. EMPIRICAL CONTEXT: FINNISH FOREST OWNERS AND FORESTRY

4.1. Small-scale private forest owners in Finland

The beginning of Finnish private forest ownership took place in the late 18th century with the beginning of the Great Partition, i.e. the official demarcation of forests (Karppinen and Hänninen 2006). During Finnish independence, forestland has been redistributed in the 1920s and 1940s, when first tenant farms and then the evacuees of World War II were granted land (Leppänen 2008) for family farming and forestry. Changes in economic structure and urbanisation in the 1960s also began changing the composition of forest owners, and this change is still ongoing (Karppinen and Ahlberg 2008). On average, the shares of women and the

elderly, and hence of pensioners, are increasing, while the share of agricultural entrepreneurs is decreasing. In the future, forest owners are projected to average higher education levels than currently and to more often live in urban areas (Karppinen and Ahlberg 2008; Hänninen et al. 2011). In 2016, there were 620 000 forest owners who alone or jointly own 344 000 forest property entities of at least two hectares of land categorised as forestland, with the average holding size being 30.5 hectares (Natural Resources Institute Finland 2019). Approximately 60% of Finnish forestland is owned by private persons, and 74% of this area is owned by private persons alone or with their spouses, 17% is under joint ownership and 9% is owned by the undistributed estates of a deceased person (Natural Resources Institute Finland 2019).

Finnish forest owners average 60 years of age according to the latest published nationwide survey (Hänninen et al. 2011). In the same study, 32% of forest owners were between 55 and 64 years, 24% between 65 and 74 years, and 19% between 45 and 54 years. The proportions of younger and older forest owners were 11% and 14%, respectively. Approximately one quarter of forest owners in this study were women, but their actual number is greater, because when a forest holding is jointly owned by a man and woman, it is usually the man who manages the forest and hence also responds to the surveys (Hänninen et al. 2011). When Karppinen & Hänninen (2017) calculated the forest estates owned solely by women and those owned by married couples, the share of women was 38%. If jointly managed estates were also taken into account, with the assumption that the gender distribution is the same as in the population in general, the share of women owning forestland would be 44%. In 2008, the share of women as forest owners was estimated to increase between 30% and 40% by 2020 (Karppinen and Ahlberg 2008), and in spring 2019 the share of women among individuals owning at least one hectare of forestland was 41%, according to the Finnish Forest Centre database (Vennesland et al. 2019). A new nationwide forest owner survey was conducted in spring 2019, but no results have been published yet.

Ten years ago, 45% of forest owners were pensioners, which was the largest occupation group at the time (Hänninen et al. 2011). Thirty per cent of forest owners were salaried, 16% were farmers and 7% were otherwise self-employed (Hänninen et al. 2011). The majority of forest owners (64%) lived in the same municipality than at least one of their forest holdings and 35% in another municipality than their forests. About one-fifth, 21% of forest owners were reported to have graduated from secondary school, approximately one-third of forest owners had vocational education, about one-fifth had college-level training or a bachelor's degree and ca. every tenth had a master's degree (Hänninen et al. 2011). In the same survey 22% of forest owners owned less than ten hectares, 26% owned 10 to 20 hectares of forest, 32% owned 20 to 50 hectares, 14% owned 50 to 100 hectares and 6% owned more than 100 hectares of forest.

The same extensive survey study by Hänninen et al. (2011) found those forest owners emphasising multiple objectives (30% of respondents) to be the largest forest owner category, followed by those focusing on recreation (24%), self-employment in forest management activities (20%), economic security (16%) and indifferent objectives (10%). A more recent study by Haltia and Rämö (2017) finds the largest group to be multi-objectives emphasising financial security (43%), followed by two groups of almost equal size: one emphasising forests as an environment for recreational activities (22%) and another emphasising nature and the environment (21%). Indifferent forest owners made up 14% respondents in that study. Takala et al. (2017a) recently grouped Finnish forest owners based on in-depth interviews. They found five discourse types describing owner relationships with their forests and forestry: the forester, who emphasises "good forest management" as defined in the guidelines;

the economist, who emphasises economic benefits and profitability; the distant economist, to whom profitability is important, but who may also feel stressed by the obligations of forest management; the critical anti-economist, to whom forest and nature have intrinsic values and who questions prevailing forestry practices; and a dutiful forest owner, who predominantly owns small estates, and to whom recreation is more important than economy, but who feels obligated to manage their forests for timber production.

Forest owners with strong recreational objectives for their forests harvest less timber whereas multi-objective owners are most active in that sense (Favada et al. 2009; Kuuluvainen et al. 2014). Forest owners emphasising economic profit more likely conduct forest management activities on young stands that are subsidised by the state than forest owners emphasising recreation do (Ovaskainen et al. 2017). Female forest owners tend to consider aesthetics and conservation more (Palander et al. 2009; Häyrinen et al. 2015) and have softer, more altruistic values also in relation to forest ownership (Karppinen and Korhonen 2013) than men do. Women are more likely to consider continuous cover forestry a desired method for forest regeneration (Kumela and Hänninen 2011). Estates owned by women are on average smaller than those owned by men (Karppinen and Hänninen 2017), and women sell slightly less timber and less frequently than men do (Ripatti 1999; Kuuluvainen et al. 2014). However, when women sell timber, the quantities per sale are larger than those sold by men (Kuuluvainen et al. 2014). The oldest forest owners tend to appreciate the economic security offered by forests more than the income generated from timber sales (Häyrinen et al. 2015), and they sell timber in smaller quantities and less frequently than young forest owners do (Kuuluvainen et al. 1996).

However, inconsistencies have been observed between the reported objectives and concrete behaviours of forest owners (Bieling 2004), particularly regarding the high share of multi-objective owners reported by previous studies. Takala et al. (2017a) argued that forest owner objectives reported in survey studies may rather be general appreciations than real objectives, as genuine objectives would be expected to affect practical management decisions. On the other hand, the strong reliance some forest owners show to professional advice (Bieling 2004; Hujala et al. 2007) that emphasises timber production (Häyrinen et al. 2015), and the hegemony of multiple uses in forest discourses in Finland (Takala et al. 2017b) may also distort the understanding of forest owners concerning how they should describe their relationships towards forests. Forest owners may have conscious or unconscious ideas about good forest ownership with multiple values (Takala et al. 2017a). The decision-making process and objectives in real situations may differ from those desired or expressed in a research situation (Tikkanen 2006; Hujala et al. 2007).

The decision support needs of a forest owner depend on their knowhow on forestry and their decision-making strategies (Hujala et al., 2007). Hujala et al. (2007) categorised owners into five groups based on the role they give to professional advice and their willingness to learn about forestry. The groups were forest owners with: substantial trust in professionals, where professional aid is actively sought to substitute the lacking knowhow or interest of the owner themselves; desire to learn self-reliance, which is characterised by an interest to learn more about forests and forestry, and who use professionals as a consultative source of information; sequential, managerial judgements, where decision-making efficiency is important, as the resources allocated for forest issues are limited; balanced, considerate decision-making, where decisions are made after careful knowledge acquiring and weighing up the alternatives, and professional advice is used as a backup; and strong decisions of personal prop-

erty, which is characterised by owners sticking to their own views and experiences, and professionals are mainly used to check for the latest guidelines. Decision-support services are also received in various ways. Karppinen & Berghäll (2015) found that female forest owner intentions to conduct timber stand improvements were more influenced by the norm pressure, i.e. by advice by professionals and less by their own attitudes. According to Takala et al. (2017a), forest owners with low knowhow and self-confidence about forestry are easily convinced to conduct harvesting even against their objectives. Professional advice for forest owners and forest management planning are found to be important for forest owners also when deciding to conduct subsidised forest management activities (Ovaskainen et al. 2017).

4.2. Decision-support services for forest owners

4.2.1 Forest management planning and advisory services

The great number of small-scale forest owners and the financial importance of the forest sector for Finland (Rantala and Primmer 2003) during the past century have created prerequisites for extensive advisory and forest inventory services issued by forest administration and from market-oriented timber procurement and forest management service providers. Finnish forest policy has greatly emphasised securing the long-term availability of timber resources and an even flow of timber for the industry by supporting and incentivising the forest management planning and related forest inventory attempts for private forests (Kotilainen and Rytteri 2011). Forest management planning has been an important advisory tool emphasised by various laws and policy programmes formulated for the implementation of forest policy (Hokajärvi et al. 2011). For example, the national forest programme, compiled in a multi-stakeholder process and accepted by the government in 2008, set a target that 75% of privately owned productive forests should have a forest management plan by 2015 (Ministry of Agriculture and Forestry 2008). Planning has been regarded effective forest policy instrument (Ollonqvist 1998, pp. 214, 247) and an important starting point for other forest professionals for advising owners about management activities needed (Hokajärvi et al. 2009).

Tikkanen et al. (2010) studied the history and development of Finnish forest planning. The practice of "regional forest planning" was established in the 1970s as a task for forest administration (then regional Forest Centres). Forest inventories were carried out in a centralised manner region by region, to ensure the continuity and efficiency of planning work and to enhance holding-level planning. Because the state financed the fieldwork, individual owners only paid half price for their plans compiled based on the regional inventories (Tikkanen et al. 2010). Regional planning was extensively utilised by forest service providers for their advisory and timber procurement work. This model of forest management planning, with some modifications, prevailed until 2010.

In the 1980s, attention shifted to forest owners to activate passive owners to conduct management activities and harvesting. Individually advising forest owners about forest management based on the plan became important (Tikkanen et al. 2010). Sustainability and safeguarding biodiversity alongside timber production were adopted into official strategies in the 1990s. Other functions of forests alongside timber production began emerging both in forest

policy and forest planning, though they were still on the margins while forestry and its favourable preconditions remained in the focus (Ollonqvist 2001). Development of IT systems at the end of the 1990s enabled shifting the focus to discovering special values of forests, such as biodiversity hotspots (Tikkanen et al. 2010). Taking forest owner objectives and other values than economic ones, into account were emphasised, along with the importance of forest management plans as a decision support tool for owners (Hokajärvi et al. 2006). Different focuses of the forest management plan, such as emphasis on nature management or recreation, became available, but did not become widespread (Tikkanen et al. 2010).

Service- and customer-orientedness of planning have gained importance during the 2000s, and producing information that helps forest owners realise their ownership objectives has been an outspoken objective of forest planning. However, at least during the first decade of the 21st century, the starting point of forest planning remained in traditional wood production (Hokajärvi et al. 2009). Values besides timber procurement have been seen rather as constraints to timber production than as valuable objectives themselves (Hokajärvi et al. 2009). Incremental changes, such as consideration of valuable habitats, enhanced protection of water quality and the practice of leaving retention trees in final cuttings, have been included in planning systems (Tikkanen et al. 2010), both in tactical holding-level planning and operational planning for management activity or harvesting sites.

Changes in the Finnish Forest Act (1085/2013) from the beginning of 2014 deregulated forest management and for example continuous cover forestry was allowed. From 2010 onwards, the practice of regional forest planning was gradually replaced with forest inventory conducted with remote sensing techniques. Holding-level forest planning completely shifted to a market-based service produced by service providers to interested forest owners. In 2009 45% of forest owners had an up-to-date forest management plan (Kurttila et al. 2010). The introduction of remote sensing and launching of the e-government service platform Metsaan.fi in 2012 changed the way forest inventories are conducted and the distribution of information to forest owners. Such radical technological innovations creating new infrastructures for knowledge production and distribution are important reasons for forest management planning changing over time (Tikkanen et al. 2010).

In the Forest Act of 1996, small-scale habitats of special importance (e.g. herb-rich forest patches, the immediate surroundings of springs or other small waters) were listed for safeguarding in all forest management (Forest Act 1093/1996, amendments 1085/2013, §10) and this practice of delineating these areas outside management has been tightly integrated into forest management practices (Primmer 2010). Market-based forest certification systems, such as PEFC (Programme for the Endorsement of Forest Certification (PEFC 2019b)) and FSC (Forest Stewardship Council (FSC International 2019)), also guide forest management and felling practices. More than 90% of productive forests in Finland are PEFC certified (PEFC 2019a). The share of FSC certified forests in Finland is about 8% (Forest Stewardship Council 2019).

Certain forest management and improvement measures are supported with state subsidies to promote the management and use of forests for private forest owners. With this cost-sharing scheme, forest owners can gain compensation for part of their costs for conducting or procuring certain forest management activities. The Finnish Forest Centre administers the applications and admission of the subsidies, and forest owners can authorise their service providers to make the application and conduct the work. The purpose of these subsidies is to increase forest growth, maintain road networks for forestry purposes and secure forest biodiversity (Temporary Act on the Financing of Sustainable Forestry 34/2015) by using cost-

sharing to encourage forest owners to conduct forest management activities that are predominantly beneficial for timber production. The scheme includes e.g. tending for seedlings or young stands, remedial fertilisation and road building along with fixed-term forest environment contracts and nature management projects such as wetland restoration. The yearly budget for forestry subsidies has been approximately 50 million euros and ca. 5 million euros for nature management projects and forest environment contracts.

Forest biodiversity decline led to the development of the Forest Biodiversity Programme METSO (later Biodiversity Programme), which aims to halt biodiversity decline in southern Finland (Government of Finland 2014). The Biodiversity Programme is based on voluntary participation of private forest owners, where the owner chooses whether to conserve parts of their forest and how. Forest owners may offer their forest sites for the Biodiversity Programme and receive monetary compensation from the state if the sites are accepted depending on certain science-based criteria for biodiversity values (Government of Finland 2014). The Biodiversity Programme is implemented by forest and environmental authorities, and involves forest service providers and non-governmental organisations (NGOs) as partners to consult and support forest owners with their initiatives to offer their forests for the programme. Service providers have committed to inform forest owners alongside their work about the possibility to enter the Biodiversity Programme when there is a suitable site. Forest and environmental authorities may also contact owners of suitable sites and recommend entering the programme. Both authorities can enter into conservation contracts with forest owners. In principle, forest owners may choose between permanent or fixed-term conservation, environmental subsidy agreements or nature management projects (Salomaa et al. 2016). The programme was launched in 2008 and will continue at least until 2025. By now the Biodiversity Programme covers nearly 70 000 hectares as permanent conservation areas, approximately 40 000 hectares of environmental subsidy areas and 4700 hectares of nature management projects (Hohti et al. 2019). Forest owner willingness to participate in biodiversity conservation has increased as a result of the Biodiversity Programme (Paloniemi and Varho 2009).

Web-based services aimed at forest owners have also been developed concurrently with the development of information and communication technologies. A state-funded e-government service platform Metsaan.fi was initiated to make better use of forest inventory data collected by the Finnish Forest Centre and to help forest owners decide on the management of their forests with easily accessible information (Valonen et al. 2019, pp. 19–20). The service was launched in 2012 and was made free of charge for forest owners in 2015. The very core of the service is the holding-level information about owners' forests: aerial photos, maps of each estate (e.g. a terrain map, a forest stand compartments map), forest inventory data and information concerning nature or cultural-historical values, for example Natura2000 conservation sites (Valonen et al. 2019, pp. 46–48), which are easily available for every forest owner for the first time. Inventory data are mainly collected using remote sensing methods, along with proof measurements and site visits. The service also offers recommendations about forest management activities and harvests that are calculated based on inventory data. Before Metsaan.fi, this information was mostly delivered as forest management plans. The service differs from forest management plans in the sense that recommendations given contain no consideration about owner's objectives, no calculations of income and costs of harvesting and management activities, and no simulation and comparisons of different management or harvesting alternatives. With the service a forest owner can make a statutory announcement in the platform to the forest administration about forthcoming harvests, apply

for subsidies for certain forest management or biodiversity protection works and search for forest service providers to conduct work in their forest (Finnish Forest Centre 2016a). Metsaan.fi is also open to forest service providers, who can use it to search for potential customers and utilise the forest data when negotiating with a forest owner, provided the forest owner has agreed to such contacts.Development of this service platform was implemented with an emphasis on more active timber production, enhancing the profitability of forestry and opening up forest service markets (Ministry of Agriculture and Forestry 2019).

Three largest timber buying companies have developed their own e-services for their loyal customers. Services give information about one's forests and future management needs and contain a digital forest management plan. Initiating harvesting or management services is also possible. As opposed to Metsaan.fi –service company services offer estimations about income from harvests and costs of management work. Each service has also specific features linked to their loyal customer programmes (Vanhatalo 2017; UPM Metsä 2019; Anteroinen 2019). Main feature of the e-service by Forest management associations is a digital forest management plan for mobile phones. Service contains base maps for whole Finland and works as positioning device (MHY Etelä-Savo 2020).

4.2.2 Forest owner advisory and regulatory service providers in Finland

Forest professionals represent various organisations and work as mediators interpreting forest management regulations and hence shape forest policy outcomes while brokering knowledge within their publicly funded or business activities (Lidskog and Löfmarck 2016). Different organisational strategies affect practices and hence the professionals have varying resources and objectives when they meet with forest owners. Forest owners in Finland receive services and information from several actors that operate in a multi-actor network consisting of representatives of the state administration, various market-driven service providers and NGOs, which operate mainly with issues related to nature conservation (Salomaa et al. 2016; Vainio et al. 2018).

Forest and environmental authorities work under the responsible ministries and hence implement forest and environmental policies. The Finnish Forest Centre is the national forest authority. The enforcement of forestry legislation, promotion of sustainable forest use, strengthening the competitiveness of the forest sector and contributing to regional development are its responsibilities. The Finnish Forest Centre produces and provides information to forest owners and service providers about forest resources and their management through training, informing and contributing to regional development. It also implements state funding schemes for sustainable and profitable forestry (e.g. financial support for construction of forest roads) and for biodiversity conservation through nature management (e.g. restoration of forest springs or other valuable habits). In 2012, the Finnish Forest Centre shifted from 13 regional forest centres into one national organisation with regional offices. Regional environmental authorities are responsible for the production and provision of environmental information and implementation of biodiversity conservation measures such as Natura2000 and more currently the Forest Biodiversity Programme. Both authorities work at the regional level, and their co-operation with each other and with forest service providers and forest owners is usually rather successful (Rantala et al. 2011).

The work of forest service providers is still largely driven by traditional roundwood market needs (Mattila et al. 2013) and hence concentrates on timber production and procurement

(Peltola and Tuomisaari 2015). Forest Management Associations (FMAs) are local service organisations that forest owners themselves administer as an association. FMAs provide professional assistance in forestry issues to their members, but the membership is not mandatory for using their market price services. FMAs employ foresters and forestry engineers to advise forest owners on how to use their forests, and produce information about them by compiling holding-level forest management plans and assist owners in conducting timber sales e.g. by making the operational plans and instructions for harvesting or management activities. FMAs also conduct forest management activities for forest owners by employing or contracting out forest workers. FMAs make their revenues mainly as a percentage of the timber sales they facilitate and by selling other forest management services, but lately they have made efforts to also develop multi-objective services, e.g. they forward proposals for potential Biodiversity Programme sites from their customers to forest and environmental authorities. Until 2014 (Forest Management Association Act 20.12.2013/1090), FMAs had a statutory task to offer forest owners training, guidance and professional assistance in forestry matters, and therefore each forest owner, excluding the smallest holdings (Lillandt 2001), was obligated to be a member of a certain FMA and pay a membership fee. During the last decades, many FMAs have merged into larger organisations to increase their profitability and competitiveness against timber purchasing companies (Hokajärvi et al. 2011) and to serve the differentiated needs of forest owners. Hence the number of FMAs has decreased from 369 in 1990 (Juntunen 2013) to 65 in 2019 (Forest Management Associations 2019). In 2018, 72 per cent of forest owners were members of an FMA (Kjellberg 2018).

Timber purchasing companies concentrate on procuring timber effectively. However, they are also committed to a wide range of environmental programmes and their formal strategies feature multi-objectivity. These companies also offer owners forest management and other expert services. New actors have entered the forest service field, but these enterprises are still small and local and in many cases work in co-operation with the FMAs.

In their advisory position, the professionals who prepare operational plans for harvesting and forest management activities for privately owned forests play a significant role in executing biodiversity or habitat conservation (Primmer and Wolf 2009). These professionals usually represent FMAs or timber procurement companies. In practice, they carry the landowner's responsibility of safeguarding the natural value of the management site (Peltola 2013). Incorporating biodiversity conservation and multiple forest uses into forestry has required considerable changes in the expertise and knowhow of forest professionals and in how the organisations work. These changes have not been easy or straightforward, as securing biodiversity and maximising timber production require opposite measures in forests, and integrating them requires compromises (Peltola 2013). Changing the advisory services to acknowledge biodiversity conservation has been riddled with reluctance (Primmer 2010). This also applies to recognising other multi-use objectives or forest owner-orientedness (Pynnönen et al. 2017).

5. MATERIALS AND METHODS

5.1. Data

Four different data sets were utilised for the empirical analyses: two surveys, a large focus group discussion data and field notes from three training workshop days. Three data sets (reported in articles I and II) were collected as a part of a large practice-oriented research project about the Biodiversity Programme, funded by the Finnish Ministry of Agriculture and Forestry. One data set (reported in article III) was collected in a project conducted by Pellervo Economic Research PTT and funded by the Finnish Forest Centre. In addition to these, register data from the Forest Centre concerning Finnish forest owners were utilised in article III. An overview of the different data sets is presented in Table 2.

5.1.1 Postal survey for forest owners (article I)

Data for this study were collected using a postal survey in the North Karelia region of Finland (Figure 3) in the spring of 2014 as part of a larger survey also targeted at other regions in Finland (Paloniemi et al. 2018). North Karelia was chosen as the target region because it has both an active forestry sector with high felling rates and has been forward-looking in enhancing forest biodiversity (Finnish Forest Centre 2016b). Sampling consisted of two parts. Subsample 1 consisted of all forest owners in the target region who have established a private forest conservation area (PFCA) (N=86) contract within the Biodiversity Programme or who have a forest environmental management contract (EMC) (N=109) signed between 2004 and 2013. Subsample 2 was a representative sample of all forest owners in North Karelia, excluding forest holdings smaller than two hectares and those in Subsample 1. Subsample 2 (N=103) was generated with systematic sampling in which the holdings in the target population were arranged from smallest to largest by forest area and alphabetically with the last name of the owner within each holding size class. Weighting of the classes was done based on the Forest Statistical Bulletin by Leppänen ja Sevola (2014). The sampling interval was determined so that the targeted sample would be as proportional to Subsample 1 as possible within the budget resources. The first mailing was followed by a reminder letter and a new questionnaire ca. two weeks after the first mailing. The total number of questionnaires for the analysis was 298, and the response rate was 29.2%.

Survey questions were formulated partly based on earlier research carried out in Finland (e.g. Paloniemi and Tikka 2008; Paloniemi and Vainio 2011; Primmer et al. 2014). The study examined questions about forest ownership objectives and information needs. One question concerned the importance of forest ownership objectives and included ten statements. A five-point Likert scale ranging from very important to not important at all was employed. Another question concerned forest management styles and included variables describing alternative forest management practices. Respondents were asked how likely they would apply each practice in the next five years on a five-point scale. Respondents were also asked how useful (very useful–not useful at all) they found various services and information related to biodiversity conservation, for example maps, photos or meetings with an expert. Finally, the agreement level with statements about forest management planning and related advisory services

Table 2: Overview of the data

Data set	Mail survey for forest owners (FOs)	Group discussions with a multi-actor stakeholder network	Field notes from workshops with professionals	Web survey for FOs and register data
Article	I	II	II	III
N	298 (sample 1: 86+109,sample 2: 103)	60	35	5170
Sample type	1: all FOs with private forest conservation area contracts AND all FOs with forest environmental management contracts, signed 2004 – 13 2: systematic sampling in the North Karelia region	Based on local key informants' suggestions and purposive sampling for heterogeneity	Forest management associations in two regions, open invitations in relevant networks	Survey: All registered users with an email address Register data: All FOs with at least 2 ha of forest, who own at least 50% of the holding
Coverage	North Karelia region in eastern Finland	3 different locations in southern Finland, participant from several neighbouring regions	3 different locations in southern Finland, participants from nearby regions	National
Organisations represented		Environmental administration Forest Centre Ministry of Agriculture and Forestry Forest Management Association Nature conservation NGO National landowner organisation Regional Council Forest consulting company Tapio Finnish state forest organisation Communications entrepreneur Independent consultant	Forest management associations Finnish Wildlife agency (Suomen Riistakeskus)	
Key parameters	Forest owning objectives Preferred style of forest management Satisfaction with information services	Forms of knowledge Knowledge use, distribution and validation	Forms of knowledge, Knowledge use, distribution and validation	Characteristics of e-service users FO views concerning service attributes
Evaluation of non-response bias	Data compared with a study of Finnish forest owners in 2010 (Hänninen et al. 2011)			Survey respondents compared with survey sample and register data, comparison of early and late respondents
Generalisability	Results represent Finnish FOs in general	"Moderatum generalisation", limited generalisation, describes phenomena that are more generally recognisable than only during this occasion		Represents users of the e-service, careful generalisations over the Finnish FOs. The service attributes describe a one-of-a-kind service.

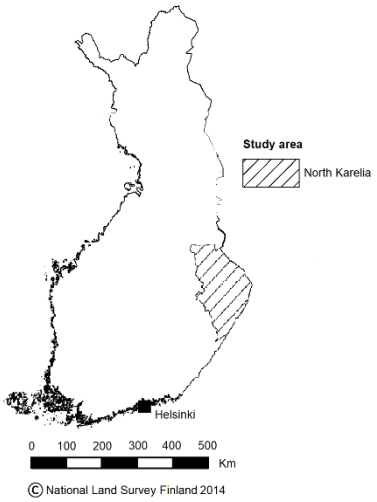

Figure 3. Study area in North Karelia in article I.

was questioned. The statement sets were tested with landowner representatives before the questionnaire was sent to landowners. Demographic background information (age, gender, education level, place of residence and household income level) and key variables about forest holdings (form of possession of the holding, duration of forest possession and annual income derived yearly from the forest) were requested.

Representativeness of the data was assessed by a comparison to the previous nationwide forest owner survey (Hänninen et al. 2011). Differences for certain variables within the whole distribution were tested with Chi square –tests and if significant differences occurred, differences between individual shares were tested with z-tests. In this study, 76% of respondents were male, which corresponded well with results from Hänninen et al. (2011) concerning the gender division of forest owners. More respondents were born between 1940 and 1949 (35% compared to 24%) in the present data and fewer between 1960 and 1969 (14% compared to 19%) than in the reference material, with the former difference being significant.

The survey respondents included more pensioners (51%) and salaried persons (36%) than the nationwide forest owner survey data – their respective shares were 45% and 30% – but these differences were not significant. The shares of farmers (7%) and other self-employed (4%) were smaller than in the control data (16% and 7%). For this comparison, the X^2 –test indicated significant differences ($p = 0.000$) but conditions were not fulfilled for calculating the z-test (less than 30 observations) for a more accurate analysis. In these data, a significantly higher share of respondents lived in a different municipality than where their forest is located (44% versus 35%). Hänninen et al. (2011) did not separate groups that own their forest areas alone or with their spouses into their own categories. However, the combined sum of those groups (55% and 21% respectively) in these survey data corresponded well with their results. The share of jointly administered properties was somewhat larger in these data (16% compared with 13%) and that of the estate of heirs was somewhat smaller (8% compared with 12%).

Because the data were collected as part of a wider survey with questions on voluntary conservation measures, the sampling was biased towards those experienced in voluntary con-

servation. These forest owners did not necessarily answer questions about forest management, as it may not have concerned them. Similarly, respondents in a random sample may have refrained from answering conservation-themed questions. The use of two differently targeted subsamples ensured the acquisition of more varied knowledge from forest owners with differing forest ownership objectives.

5.1.2 Group discussions with the multi-actor stakeholder network and field notes from workshops with forest professionals (article II)

The data of this study were drawn from two sources: focus group discussions and notes from training workshops. The focus group discussions and training workshops were conducted in the spirit of participatory action research, emphasising the participatory character of the data collection and enhancing communication and co-operation between research participants. The first part of the data consisted of nine focus group discussions. Focus groups are discussions by a group of people, organised to explore a particular set of issues (Kitzinger 1995). The aim of the focus groups was to initiate dialogue among a varied group of stakeholders that possessed multifaceted forms of knowledge. These were organised at three locations in May and November 2014, each location hosting three parallel sessions (Figure 4).

A total of 60 participants represented forest and environmental administration, landowners, forest professionals and other stakeholders such as environmental NGOs and the regional council responsible e.g. for regional land-use planning. The assembly of the groups is presented in Table 1 in Appendix 1. The selection of focus group discussion participants was based on key informants' knowledge of relevant conservation and forestry actors in each area. The participants represented different actors that play a role in forest owners' forest-related decisions by e.g. advising, supervising or operationalising the decisions. The progress of the data collection is presented in figure 5.

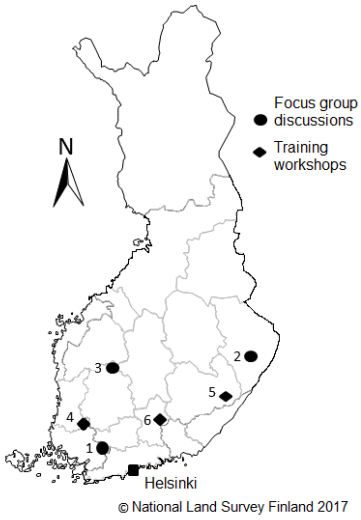

Figure 4. Locations of the focus group discussions (1 Somero, 2 Joensuu, 3 Virrat) and training workshops (4 Huittinen, 5 Savonlinna and 6 Vierumäki) for article II.

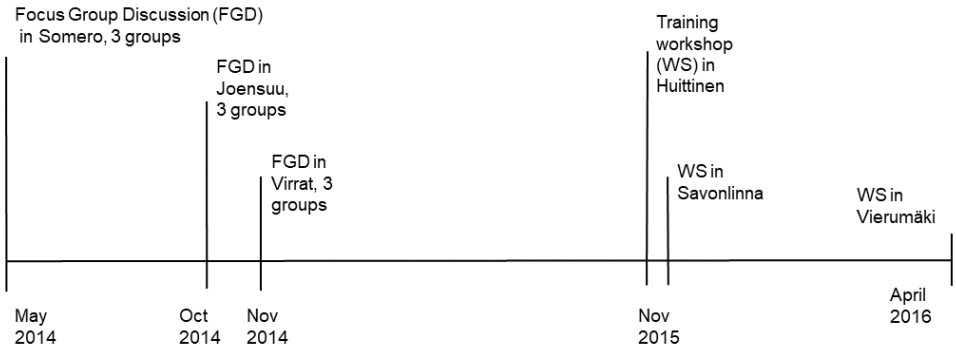

Figure 5. Progress of the data collection for article II.

The discussions lasted approximately two hours each, they were facilitated by a researcher with a set of predefined statements relating to knowledge practices and they were thematically relevant to the area. The statements were compiled with the help of Mickwitz's (2003) policy evaluation criteria. The organisation of the focus group discussions is described in detail by Salomaa et al. (2016) and Paloniemi et al. (2018). Each discussion was recorded and transcribed verbatim. The author acted as a secretary in one discussion without participating in the discussion, and as a scientist in the other group. This contribution to the discussion has been left out from the analysis.

The second part of the data consisted of field notes from three training workshops for forest professionals. The workshops were organised in three locations in southern Finland with altogether 35 participants in November 2015 and April 2016 (Figure 4). They were organised in co-operation with the umbrella organisation of FMAs and hence the participants mainly represented FMAs. However, one participant represented a regional wildlife management organisation. Participants came from more than ten independent FMAs, representing forest advisors working daily with forest owners, forest planners who conduct field inventories for holding-level forest management plans and personnel with managerial duties for FMAs. The participants of the workshops are presented in Appendix 1, table 2. Comments from forest professionals were included into the data because they can identify the needs for change by discussing their experiences and practices (Hokajärvi et al. 2009). FMA professionals are the most influential in forest owner decision-making concerning the management of their forests (Karppinen and Berghäll 2015), and hence their contribution in the multi-actor network of decision support for forest owners is of particular interest for research.

The aim of the workshops was to encourage participants to identify bottlenecks in biodiversity conservation in their work and find effective solutions for their operational environment. The workshops were structured using themes that emerged from the focus group discussions. Two workshops consisted of three sections dealing with different themes. The first theme asked participants to discuss why considering multiple forest uses and conservation measures in production forests is important. The second theme highlighted the practices of knowledge distribution, acquisition and production in forest owners' decision-making. The last theme encouraged participants to plan a micro-experiment concerning the discussion themes, to be conducted in their own work. Each section began with a short introductory presentation by researchers and continued with small-group discussions, with a set of questions defined by the researchers. The sections finished with joint discussions.

The third workshop was organised as part of a national two-day in-house training for FMA forest planners. It focused on the first and second themes of the other workshops. It began with an introductory presentation followed by facilitated group discussions. The workshop ended with a plenary discussion involving all participants. All training workshops were followed by field trips on the same afternoon or following day, where the themes were discussed with examples from actual forests. Representatives from the state forest administration took part in the field trips, bringing their expertise about the topics into the discussions. The participants were offered the possibility to discuss their experiences about the micro-experiments a few weeks later in a Skype meeting.

The researchers offered scientific insights and facilitated constructive discussions during both phases of data collection. The aim of combining two different data sets is to illustrate the different levels of knowledge flows in the process of deciding on forest use, and to explore how more general views of knowledge use presented in the focus group discussions were visible in discussions with practical examples and planned experiments.

5.1.3 Web-based survey for forest owners (article III)

Data were collected in an Internet survey during August and September 2016. The Finnish Forest Centre provided the email addresses from their customer register. A link to the survey was sent via email to those forest owners who had registered or logged into the Metsaan.fi service between March 1st 2015 and the beginning of August 2016 (period when the service had been free of charge) and left their email address into the system, excluding forest owners whose aggregated forest area is two hectares or less. Before sampling, Finnish Forest Centre also checked that each person still owned forestland and was alive at the moment of sampling. The survey was conducted in both Finnish and Swedish, and the language version was chosen based on the language the forest owner had indicated as their preferred language according to the Finnish Forest Centre. The survey was tested with a random sample of 500 users before the actual survey was sent to recipients. Based on the test sampling answers, some technical changes were made to the survey website. After the initial invitation email, two reminders with a link to the survey were sent to those who had not responded. A survey was sent to altogether 35 139 recipients and 5 742 responses were received; hence the response rate of the survey was 16.3%. The responses from the test sample were analysed together with the other responses. Some respondents (572 participants) had not used the service after initial registration, and they were excluded from the data.

The survey consisted of multiple-choice questions, statements to be answered on a five-point Likert scale, and open-ended questions. The multiple-choice questions dealt with the frequency of service use and considered the importance or usefulness of service features. The preferred means of dealing with forest issues (e.g. e-services, by phone or face-to-face with a service provider) and previous experience with utilisation of the service as decision support were also inquired about. Statement questions dealt with user experiences of the service and respondents' objectives for their forest ownership. The last set of statements presented possible new features that could be developed for the service. Demographic background information (age, gender, education level and place of residence) and key variables concerning forest holding (form of possession of the holding, duration of forest possession) were requested. In the open-ended questions, respondents were asked to describe in their own words what elements in the service are particularly good and what need improving.

In addition to the survey data, a register data set describing Finnish forest owners in general was used. The data were produced by the Finnish Forest Centre. The register data consisted of altogether 385 269 records, representing all Finnish forest owners who own at least two hectares of forestland alone or together with one other person (e.g. their spouse or sibling). Hence these register data exclude forest owners who are co-owners in an estate of heirs or in joint administration of a property with more than two persons. These owners were excluded from the register data and hence from the comparison, because the decision-making situation in such joint properties differs from situations were ownership is individual or divided with only one other person. This limitation was also due to the technical difficulties in gathering the sample from the register, because the intertwined characteristics of Finnish forest owner patterns causes overlapping of the observations in the sample, as one person may own forestland in several ways. The register data contain demographic variables (gender, age, place of residence) and information concerning the owners' forest holdings (e.g. duration of forest ownership, number of holdings, aggregated area of forest holdings). It provides more accurate background information about the survey respondents' forest properties and was also utilised for comparing the respondents and the sample with forest owners in general to see how the respondents represent Finnish forest owners.

The representativeness of the data was evaluated by comparing survey respondents with the survey sample, and the survey sample with the register data. A comparison between early and late respondents was also conducted. The significance of the differences was calculated with two-tailed t-tests. Comparison is based on the register data also for survey respondents and the survey sample. However, information on respondents' education and occupation are based on the survey data and hence only available for survey respondents.

Age-wise the registered users of Metsaan.fi differed significantly from Finnish forest owners in general, as the sample included clearly less forest owners over 71 years of age (11.4% vs. 26.6%). However, users over 71 years and users from age class 61–70 years responded more often to the survey than their overall share of the sample. The share of 23–40-year-old users was somewhat larger in the survey sample than their share of all forest owners; however, they answered the survey clearly less frequently, and are underrepresented in the data. There are clearly less women registered in the service than their share in the register data (19.5% vs. 39.1%) and even fewer women answered the survey (17% of all respondents).

Owners of forest holdings larger than 50 hectares were clearly overrepresented and owners of the smallest holdings were underrepresented in the survey data compared to forest owners in general. However, compared to registered users of the service, the distribution in the area classes was quite similar. Forest owners whose forest holdings lie elsewhere than in the municipality they live in answered the survey somewhat more often than their share of registered users or forest owners in general. Comparison of early and late respondents showed statistically significant differences (all $p < 0.05$) in shares of women and men; within age classes 51-60 and 61-70; within forest area classes 10.1-20 ha and over 200 ha; and within the share of salaried persons.

A bachelor's degree or equivalent (36%) and vocational education (31.1%) were the most common education levels of the survey respondents. The majority of respondents (59.8%) indicated having a higher education level. Compared to the latest wide survey of Finnish forest owners by Hänninen et al. (2011), our data included more salaried persons (35.3% vs. 30%) and less pensioners (39.6% vs. 45%) and agricultural or forest entrepreneurs (12.7% vs.16%).

5.2. Methods

5.2.1 Theoretical assumptions behind the methodological choices

This thesis is foremost a study about people and their societies, and hence the methodological choices and inferences made from the results rely on the principles of social constructionism rather than more positivist views of science or the world. Social constructionism is an orientation in the philosophy of science insisting that reality and its structures and phenomena are constructed in social and verbal interaction and hence also the scientific knowledge we gain about the world is rather a product of social negotiations than an absolute truth (Cozzens and Woodhouse 2011). In contrast to this, positivism claims that trustworthy knowledge about the world can be only gained through observations and measurements analysed statistically and interpreted objectively. The main idea of social constructionism is that it takes a critical approach to knowledge being taken for granted. Social constructionism is foremost concerned with how knowledge is constructed and understood and places great emphasis on everyday interactions between people and how they use language to construct their realities (Andrews 2012). Social constructionism has its roots in sociology and has been connected with post-modern qualitative research (Andrews 2012).

This study adopts a view of critical realism, i.e. that reality, or the external world, exists independently of our knowledge or representations about it (Danermark 2002). Although our understanding about reality does not necessarily reflect it precisely as it is, our understanding is bolstered by the reality and hence human beings can gain knowledge about the reality (Burr 2003). Adapting from Andrews (2012), social constructionism accepts that forests can and do exist in the independent reality, but what we understand as forest and call forest is a different matter, and that may be socially constructed. Thus, we can gain knowledge about reality through scientific inquiry, but when doing so, we need to be aware of the assumptions we make as our starting points. Instead of gaining knowledge about reality directly from itself, social constructionism assumes that we construct our versions of knowledge among ourselves through daily interactions in the course of social life (Burr 2003). Therefore, the social practices engaged by people and their interactions with each other are core research interests of social constructionism (Burr 2003). According to critical realism, the focus of the research process should be the relation between the real world and the concepts we form of it (Danermark 2002).

The distinctive factor within social constructionism is not the use or denial of certain methods or empirical analysis, but the questioning of universalistic claims about truths linked to them (Gergen 1999; 2001 as cited in Burr 2003). This thesis also employs statistical methods that are founded on a positivist understanding of the world. However, more important is that the data sets used dealt with the views and opinions of people. Data collection included other people as survey respondents or participants of discussions as objectives of the research. They have made their own definitions and formed their own concepts about the issues inquired about (Danermark 2002). Hence I do not claim that the data represent any objective truth, but rather reflect the ways in which forest owners think about the issues asked, within our common historical and cultural context. Social constructionism takes a critical position towards the accustomed way of thinking about the world and ourselves, and hence challenges the view about conventional knowledge being based upon an objective, unbiased observation of the world (Burr 2003). Social constructionism makes visible how different actors ascribe some knowledge as facts or objective truths through social processes (Knorr-Cetina 1982).

Our ways to understand the world around us are always historically and culturally relative and dependent on the prevailing social and economic systems; scientific knowledge in particular is rooted in social practices, identities, norms, discourses and conventions (Jasanoff 2004, pp. 12–19). What we call "truth" is rather a currently commonly accepted way of understanding the world, negotiated between the people in social processes and interactions (Burr 2003). Empirical evidence about nature or reality can help us evaluate the phenomena and their effects, but whether the phenomena are considered "good", "bad" or "desired" is a question of social negotiations and value-giving (Saarikoski 2007). For example, research can identify forest owners who conduct harvesting in their forests, and others who do not, but labelling the first as "active" and the latter as "passive" is a social construction. Social constructionism cautions us to question our assumptions about how the world appears to be. This means that the ways in which we classify things to comprehend the world do not necessarily refer to real divisions or classes of things (Burr 2003).

Social constructionism takes into account that the different possible understandings, i.e. social constructions, about the world we live in enable or produce various actions from individuals. What one individual considers untended forest may to another appear as a natural phase of succession. These differing views about the world sustain certain patterns of social action and exclude others and have implications for what different people are allowed to do: power relations play a role in our ways and possibilities to shape reality and further our interests (Burr 2003). Macro-orientation of social constructionism acknowledges the meaning of material or social structures, social relations and institutionalised practices in the construction of realities and as restricting the actions of individuals (Burr 2003).

Social constructionist research starts from the thinking that our understanding about truth can also change, and social constructionism allows this change because there is no one absolute truth or objective fact. According to Berger and Luckmann (1966, pp.134), as our understanding of the reality is always socially constructed, it can also be socially changed by human activity. For example, in their critical discourse analysis study about the discourses of forest owner types, Takala et al. (2017b) identified marginalised anti-economic discourses that may slowly widen the common understanding about what is good forest ownership and forest management. Social constructionism invites us to think whether the current reality is the best possible or the most desired one, and if not, to look for the means to change it (Burr 2003). Thus, it is also well suited to this study, which looks for the means to develop practices to better acknowledge the versatility of forest management alternatives. It realises that knowledge is always partial, derived from looking at the world from one perspective only, and serves some interest rather than others (Burr 2003).

According to (Habermas (1971, pp. 191–213) the ways we search for knowledge of reality are always dependent on the knowledge interests (also cognitive interests or knowledge-constitutive interests), which are cognitive strategies that guide how we conduct research. This is because society has various demands for research, as it has for other activities as well. According to Pietarinen (2002), Habermas argues that scientific research always aims to meet the demands of some knowledge interests, because there is always a purpose for that knowledge and for producing it. Meeting the demands for a knowledge interest does not distort the results or diminish their validity, and the scientific methods do not aim to eliminate the effects of knowledge interests. Knowledge interests describe the objectives of the knowledge production and the attributes of reality the research focuses upon (Pietarinen 2002).

Habermas distinguishes three knowledge interests: technical, practical and emancipatory. Technical knowledge interest aims for knowledge production about the natural resources and technologies to utilise the physical world and most often relies on a positivistic idea of science (Zining and Sheffield 2006). However, it also guides the research about causal explanations and patterns in social phenomena. Practical knowledge interest concentrates on interpretation of language and intersubjective communication and relies on constructionist understanding in meaning as it is interpreted, understood, and shared (Zining and Sheffield 2006). It aims to ensure and enhance the possibilities of shared understanding and fulfilling of inner needs. Emancipatory knowledge interest guides the critical knowledge that advances emancipation from restrictions of societal power structures (Pietarinen 2002). These power structures are conscious and unconscious and may rule over individuals in a restricting way. Emancipatory knowledge interest provides a dialectical synthesis of and a self-reflection on the technical and practical approaches (Zining and Sheffield 2006). This current thesis implements practical and emancipatory knowledge interests, as it searches for means to enhance forest owners possibilities to fulfil their objectives in forest ownership along with easing up the structures in forest owner decision support services that have been perceived as suppressing certain forest uses.

Questioning the current understanding of the state of affairs, and searching for emancipatory knowledge to lead to a change for the better are also key elements of transformative research. As an emerging trend, transformative research contributes to solving societal problems, and its key characteristic is the explicit aspiration to become involved, to influence society by producing robust knowledge regarding real-world problems and to engage stakeholders into the research process to ensure the transferring of the created practical solutions into action (Soini et al. 2018). This thesis acknowledges the principles of transformative science, as the sub-studies of this thesis originate from practice-oriented research projects that were conducted in close contact with forestry professionals. The research questions have their origin in the identified problems of current forest management and decision support services and as the sub-studies produce new understanding about them using scientific methods, they also suggest solutions to these problems. The thesis involves a normative note, as the research questions are based on joint understanding about forestry practices that require enhancement. The data collection for article II included interventions that aimed to enhance the networks of forest and environmental professionals and the participants co-created possible solutions to identified problems during the training workshops.

Having a social constructionist background for the research does not restrict the research methods to any particular set, but qualitative methods are naturally used because of an emphasis on language and social interaction at the core of constructing and understanding the world (Burr 2003) that allow the revelation of social interactions and the different understandings. Social constructionist research makes certain assumptions about its aims and about the nature and status of the data collected (Burr 2003). All three data sets in this thesis consist of people's perspectives, perceptions and opinions and hence already create multiple understandings about the phenomenon at hand, as a contrast to objective measurements of the truth.

5.2.2 Overview of the methods used

Thesis employs several methods to produce diverse knowledge about the phenomenon of interest. Using several methods helps to overcome the weaknesses of individual methods, and hence qualitative and quantitative methods should be seen as complementary rather than competitive (Jick 1979). The methods employed in the sub-studies are explorative and data-driven. Qualitative methods in articles II and III were used to allow the researchers to understand meaning and context along with identifying unanticipated phenomena (Maxwell 2008) and to grasp the inner experiences of participants and ascertain how meanings are formed through and in culture (Corbin and Strauss 2008:12). As qualitative research rather discovers facets of variables than tests them (Corbin and Strauss 2008:12), it is well suited for examining new and emerging phenomena. Statistical procedures were utilised to discover latent, unobservable patterns from the data in article I, indicating possible associations between several variables e.g. opinions or behavioural models (Fabrigar and Wegener 2012). Logistic regression in article III was used to explain the relationships between a variable of interest (level of using the service) and predictor variables such as characteristics, opinions or behaviour of people (Peng et al. 2002).

In article I, the amount of data available limited the choice of methods, and explorative process was hence used to find the best possible solutions within the technical boundaries of statistical analyses. The quantitative analysis in article III was also conducted in an exploratory manner to test how different variables behave with each other. Data-driven methods were chosen for the qualitative analyses in articles II and III, to ensure the conveyance of participant viewpoints and thoughts in all their versatility. Article III employs a mixed-methods approach, where quantitative and qualitative research techniques, methods and approaches are combined in a single study (Johnson and Onwuegbuzie 2004). Employing the mixed-methods strategy in article III by first examining the phenomena with a logit model and then deepening the analysis with a qualitative content analysis of the open-ended questions allowed studying the uptake of the e-service from two sides: the possible differences in the background of the respondents and the influence of the service attributes on the uptake of it. An overview of the methods used is represented in Table 3.

Table 3. Overview of the methods used for the different sub-studies

Data set	**Mail survey for forest owners (FOs)**	**Group discussions with multi-actor stakeholder network**	**Field notes from workshops with forest professionals**	**Web-survey for forest owners (FOs) and register data**
Reported in article	I	II	II	III
N	298 (sample 1: 86+ 109, sample 2: 103)	60	35	5170
Method type	Quantitative	Qualitative	Qualitative	Mixed methods
Analysis methods	• Factor analysis • Cluster analysis • Sum variables • Cross-tabulation and comparison of means	•Data-driven analysis with grounded theory •Theory-driven analysis according to the theories of knowledge management	• Data-driven analysis with grounded theory • Theory-driven analysis according to the theories of knowledge management	• Logit model • Content analysis of the open-ended questions

Triangulation has been used on two levels in this thesis: between the three sub-studies examining the same phenomena from different viewpoints, and in the article III, where the combination of quantitative modelling and qualitative content analysis was employed to achieve a more multifaceted and deeper understanding of the factors affecting the use of the e-service. Based on a review study, Thurmond (2001) defines triangulation as "a combination of at least two or more theoretical perspectives, methodological approaches, data sources, investigators, or data analysis methods". The idea is to see one issue from multiple viewpoints to achieve greater accuracy, validity and reliability of the results (Jick 1979). Triangulation also helps to capture a more comprehensive view about the object of interest and allow new and deeper insights to emerge (Jick 1979).

Denzin (1970 pp. 472) identified four basic types of triangulation: data, investigator, theoretical and methodological. Data triangulation takes account of time, space and person (Denzin 1970). Data sources may vary based on the time they were collected, the location of the data collection and the type of data or persons from whom the data are collected (Thurmond 2001). Investigator or researcher triangulation involves multiple researchers in the data collection, analysis and interpretation processes to ensure accounting different views (Denzin 1970). In theory triangulation, several theoretical schemes or perspectives are used in the interpretation of a phenomenon (Denzin 1970). Methodological triangulation involves using more than one method to gather data, such as surveys, group discussions and observations (Denzin 1970) and it enables cross-validation of data collection and interpretation (Jick 1979). Two types of method triangulation exist: the within-method and between-method (Thurmond 2001). With within-method, a researcher uses at least two different procedures for data collection from the same study design approach (Kimchi et al. 1991), but all implemented methods are either quantitative or qualitative, not both (Thurmond 2001). In contrast, both quantitative and qualitative methods are used in the same study in the between-method (Denzin 1970; Kimchi et al. 1991).

5.2.3 Quantitative methods

Thesis exploited a set of statistical analyses (article I) and a logit model (article III). Article I combined two typologies to examine forest owner motivation and behaviours. One grouping was based on the ownership objectives of forest owners and the other grouping was based on their forest management styles or preferences. The aim of combining two typologies was to explore the relationship between objectives and preferred management decisions, and to see whether this knowledge would be useful for creating improved decision support tools. The article applied factor and cluster analyses to group the respondents.

The statistical analysis for article I was conducted in four phases. The phases of the analysis are presented in figure 6. First the factors were formed using exploratory factor analysis for two typologies. Secondly, clusters were calculated based on the factors. Thirdly, the frequencies of groupings were cross-tabulated with each other to explore the associations between owner objectives and forest management styles. They were then tested with sum variables of forest owners' preferred tools for information acquisition. Lastly, both typologies were cross-tabulated with socio-economic background variables to rule out the possibility that observed differences between groups were due to respondent backgrounds. Sum variables were formed for biodiversity conservation tools and forest management planning services. Missing data were handled with pairwise deletion in all analyses to minimise data loss.

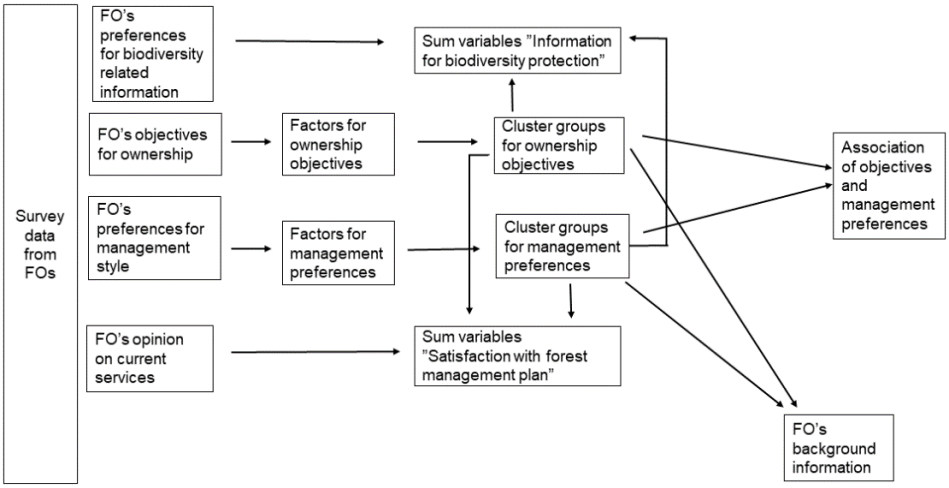

Figure 6. Analysis phases for article I.

All analyses were conducted using IBM SPSS Statistics, Version 24.0.

Factor analysis with maximum likelihood and Kaiser-Varimax rotation was applied. Factor analysis is a multivariate method used to determine the number of distinct constructs assessed by a set of measures and to provide information about the number of common factors underlying them (Fabrigar and Wegener 2012). Although the communalities in the chosen solutions were consistently low, the number of factors was, however, small (only two in both cases) and each factor mostly had a rather high number of indicators (five to six). Communalities can be interpreted as the proportion of the variance accounted for by the common factors (Fabrigar and Wegener 2012). Despite the rather low number of responses, the statistical prerequisites were fulfilled and a good factor solution was achieved (MacCallum et al. 1999).

For both typologies, all alternative solutions from one to four factors were tested and the two-factor solutions best fulfilling the statistical preconditions were chosen. The solution was improved for forest ownership objectives by deleting two variables with low communalities, the final result including eight out of 10 variables. Method appropriateness for the data set was checked with the Kaiser–Meyer–Olkin test for sampling adequacy (value 0.703) and Bartlett's test of sphericity ($p < 0.001$ (Metsämuuronen 2011, p. 671). Forest management style was studied using a set of 12 variables, from which one variable was left out because of low communality (lower than 0.2). The Kaiser–Meyer–Olkin test for sampling adequacy (0.855) and Bartlett's test of sphericity ($p < 0.001$) once again gave adequate values.

Factor scores were used to cluster the respondents with a k-means algorithm. The best solutions with three clusters was selected by testing all solutions from two to four clusters and then choosing the best based on a subjective estimation of their interpretability (Jain 2010). Groups were named based on final cluster centre information. Clustering was used to create forest owner groups, within which the respondents are expected to display similar behaviours and decision-making while displaying dissimilarities with individuals in other groups (Kaufman and Rousseeuw 1990).

Three sum variables were formed based on means for receiving information concerning ecologically valuable spots in individual forests and three sum variables were based on satisfaction with the forest management plan and related advisory services. The internal consistency of the sum variables was tested using Cronbach's alpha (Cronbach 1951). All constructs exceed 0.7 (Gruen et al. 2000). One-way ANOVA testing was used to compare the means of sum variables between ownership objective clusters and forest management style groups to analyse which information tools were most preferred by various forest owner groups. Post-hoc tests were carried out using Tukey HSD and Games–Howell tests. The Pearson's Chi squared test was applied for cross-tabulation of typologies with socio-economic background variables.

Before the analysis in article III the data were classified into seven groups based on respondents' activity levels in using the service. Activity level was determined based on six questions that indicate how much and in what ways a respondent had used the service. Activity classes range from 0 (uses the service less than weekly or monthly, and has not used the service for gaining information for decision-making or licensing various forest uses) to six (uses the service weekly or monthly, takes advantage of the information provided when planning forest management and harvesting activities and uses the service functions to apply for licences). The questions or statements used for the classification are presented in Table 4. The frequency of each activity class is presented in Table 5. Most respondents belong to activity class 2 (1580 respondents, 30.6%) and 3 (1212 respondents, 23.4%). 10.1% (524 respondents) belong to the most narrow activity class 0, and 3.3% in total belong to the most versatile activity classes 5 and 6 (160 and 9 respondents respectively).

Table 4. Survey questions or statements used for activity classification in article III

Survey question	Value	Activity point
How often do you use the Metsaan.fi service?	Weekly/ Monthly	1
Have you taken advantage of electronic forest inventory data when planning forest management work or timber sales?	Yes	1
Based on the forest management and felling recommendations delivered via the platform I plan how and when forestry operations are carried out in my forest	chosen	1
I leave an electric forest use declaration to authorities	chosen	1
I check the ecologically valuable sites of my holding	chosen	1
I have electronically applied for support for forest management work	chosen	1
	Total	**6**

Table 5. Frequency and share of each activity class in data in article III. Difference in total percentage is due rounding the figures.

Activity level	Frequency	%
0	524	10.1
1	1031	19.9
2	1580	30.6
3	1212	23.4
4	654	12.6
5	160	3.1
6	9	0.2
Total	**5170**	**99.9**

A binary logit model was used to analyse usage activity in the Metsaan.fi service (e.g. Greene 2003). The logit model was specified as follows:

$$ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2, \quad (1)$$

where p was the probability of the dependent variable, β was a coefficient and x was an explanatory variable.

The activity level was indicated in a binary format. In the activity variable, forest owner was active if their activity level was three or above (39%). Forest owners with two activity indicators or below were classified as narrow activity users (61%) as they use only very few features of the service if any.

The set of possible explanatory variables for modelling was chosen based on earlier literature concerning forest owners' forest management activities and on research concerning the adoption of new internet-based services generally. The variables included forest owner characteristics (age, gender, education, forest ownership objectives), forest area and a stance concerning the Metsaan.fi e-service. Stepwise procedures in IBM SPSS statistics 25 were used to select the final models. Both stepwise methods, i.e. forward and backward estimation, produced similar final models.

5.2.4 Qualitative methods

The core of qualitative research is to recognise patterns from texts or words to gain a meaningful picture concerning a phenomenon of interest, while maintaining its richness and multiple dimensions (Leung 2015). The purpose of the analysis in article II was to understand the meanings and roles accorded to knowledge in forest use and to understand structures that determine and steer how knowledge is used or bypassed. The two data sets were analysed together, applying the same principles. The analysis followed the methodology of grounded theory and was implemented in three consecutive steps. Grounded theory is a qualitative research method applying a multistage analysis to develop an inductively derived theory grounded in the data (Strauss and Corbin 1990). Grounded theory was chosen as the main analysis method because it allows the data to dictate the direction of the analysis and ensures the visibility of the contributions by the focus group participants. The evolving – grounded – theory is a construct of concepts that are confirmed and saturated (Glaser 1978, pp. 62–65 as cited in Holton 2010) by conceptualising the underlining patterns or individual happenings of the data into a more abstract description of the phenomenon (Holton 2010). The analysis process is a continuum where the incidents of the data are firstly conceptualised into descriptive analyses categories, continually compared against each other and the given concept and then abstracted into a theoretical level.

The first step of the analysis was to identify the main categories in the open coding of all the data. After identifying the core category (knowledge) and categories mostly related to it, the analysis proceeded to selective coding (Holton 2010). At this stage, the coding was divided into two segments, as part of the core categories were further conceptualized based on the theories of knowledge management. This line of analysis was theory-driven, focusing on the technical knowledge system. Another line of analysis was data-driven and focused on the social knowledge system. The concise analysis categories created in the selective coding (step 2 of the analysis) were then abstracted into more theoretical, higher-level concepts in

the third step of the analysis. In this phase, the two lines of analysis were kept parallel. The third line of analysis identified solutions and positive developments from the open coding. All analyses were conducted using the Atlas.TI programme, version 7.5. The phases of the analysis and main categories used at various stages of the analysis are presented in Figure 7.

During the analysis, the same themes and similar examples describing them were found repeatedly in the focus group discussions and training workshops at all locations. This implicates saturation of the data and the universality of these themes. The discussions are assumed to not replicate, but rather reflect the actions taken by stakeholders in real-life situations (Bazeley and Jackson 2013) and hence describe the various understandings concerning the realities of the multi-actor network in the multi-objective management of privately owned forests in Finland. The interpretation of data and naming of the concepts were discussed with all authors with multi-disciplinary backgrounds to increase the credibility and validity of the interpretation.

In article III, the analysis was conducted as an inductive content analysis, drawing analysis categories from the data. Content analysis is an empirically grounded method that is exploratory by nature with the intent of making inferences (Krippendorff 2013, p. 1). Content analysis as a research technique delivers a systematic and objective means to make valid conclusions from verbal, visual, or written data for describing and quantifying specific phenomena (Downe-Wamboldt 1992), increases a researcher's understanding of the phenomena at hand and informs practical actions (Krippendorff 2013, p. 24).

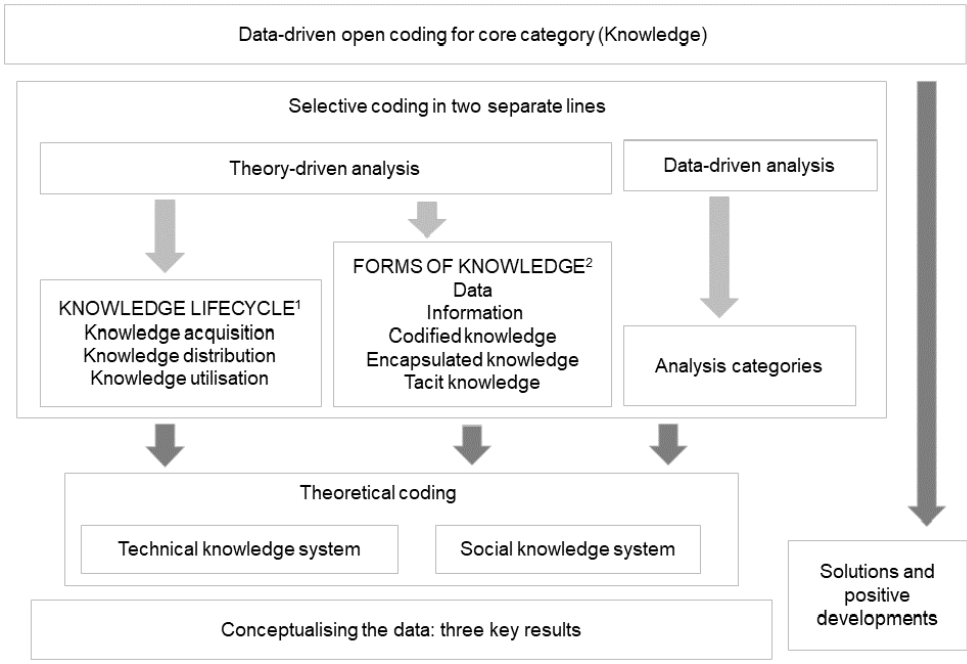

Figure 7. Stages of analysis and categories used in the theory-driven analysis if article II. [1] e.g. Evans et al. 2014, Fink & Ploder 2009, Bhatt 2001; [2] e.g. Evans et al. 2014

Content analysis was first mainstreamed as a method for studies concerning mass communication (Krippendorff, 2013, p. 13–14), founding their inferences on quantifying analysis of so-called "manifest content", which is easily identifiable in the text data. Since then, the method has been used in many fields such as management, political science and sociology (White and Marsh 2006). It can be used for several types of data, e.g. transcribed interviews, documents or for analysing open-ended survey data (Krippendorff 2013, p. 25). For example, White and Iivonen (2001) used a qualitative content analysis on brief questionnaire responses to questions inquiring about the reasoning behind decisions on how to search for specific issues on the Internet. Individual responses to the question "what is good" or "what should be enhanced" were used as units of analysis.

The analysis aimed to describe and quantify the phenomenon of interest (Downe-Wamboldt 1992) and to search for factors explaining the varying activity levels in the use of the service. As the data consisted of a large number (approximately 4600) of individual responses, but single responses were mainly very short (usually a few words) or lists of separate issues, the analysis concentrated on the manifest content of the data, with a rather low level of interpretation. Manifest content describes the visible, obvious components of the text used as data (Downe-Wamboldt 1992).

Responses to the open-ended questions were divided according to the activity classes and every analysis class was analysed separately. After analysing one activity class, the analysis categories created were copied to the other classes to keep the classes as comparable as possible. However, new categories were added when needed. Once completed, the analysis was checked to make sure it was consistent throughout all the activity classes. The analysis was conducted by hand using a spreadsheet programme by the author of this thesis and was discussed among the authors at different phases to ensure its reliability. The categories were then organised into the Rogers' model of five attributes of innovation. Examining the open-ended questions within this framework ensures that the transmission of respondents' own perceptions is carried out in a straightforward manner.

6 RESULTS

6.1. Summaries of the article results

6.1.1 Article I: Recognising the interest of forest owners to combine nature-oriented and economic forest uses

Two factors were extracted for ownership objectives and management style preferences. The first factor was characterised especially by the availability of berries and mushrooms along with recreational values, and was hence named "recreation and nature". The factor explained 35.1% of the total variation. The second factor described economic forest values and explained 16.0% of the total variation. It was named "timber production and economy". For management style, the first factor described willingness to shift towards multi-objective forest management practices and was named "diversifying forest management practices", explaining 40.7% of the variation. The second factor was characterised by the willingness to

apply nature management practices and was named “emphasis on nature”. This explained 12.7% of the variation.

The largest cluster group for ownership objectives (44.7% of respondents) was those emphasising economic forest use. This group had a rather strong negative loading for recreation and nature and a positive loading for timber production and economy. A group having multiple objectives (32.8%) valued both recreation and nature and timber production and economy. The smallest group (22.5%) emphasised nature values and they were characterised by opposing timber production and economic profit maximisation. Diversifying management practices (45.6%) was the largest group for the management style clustering. They found diversifying management practices important and also emphasised nature values. The timber production group (35.5%) only aimed at timber production, having neither the intention to diversify their management nor to place any additional effort on nature friendliness. The smallest group (19%) was again those who aimed to manage their forests to actively add nature value there. Both clusterings formed similar groups despite one being based on ownership objectives and another being based on forest management style.

Grouping frequencies were cross-tabulated to explore the associations between owner objectives and forest management styles. Large shares of both the economic (39%) and multi-objective (60%) groups are classified into the diversifying management style group. In total, these represent 37.3% of all owners. The group emphasising economic objectives actually exhibits two kinds of management preferences: managing their forests solely for timber (51% within group) or diversifying the forest management practices used (39% within group) to enhance other forest functions alongside timber production. Respondent with nature management preference are rather evenly distributed within all the objective groups.

Both typologies were cross-tabulated with socio-economic background variables and subsamples. Of the tested variables, gender caused statistically significant differences in the way the respondents were grouped. In the objective typology, multi-objective was the largest group for women and timber production for men. Emphasis on nature was the smallest group for both women and men, with a slightly higher share for women. In the forest management style typology, women had a clearly higher share (55%) than men (44%) in the diversifying group. Women also more often want to manage their forests for nature (25%) compared with men (17%). Significant results were also obtained between subsamples for forest management style: $p = 0.038$. However, the respondents were distributed so evenly in all cluster groups that the difference is assumed to not affect the results.

Three sum variables were constructed for both information services on biodiversity protection and forest management planning and related advisory services. Comparison of means between forest owner groups’ opinions concerning information tools for biodiversity protection were calculated based on both forest ownership objectives and forest management style. For all sum variables, statistically significant differences were observed between the objective groups, varying from $p < 0.001$ to $p = 0.014$. Comparisons between forest management style groups had significant differences varying from $p < 0.001$ to $p = 0.022$. In both typologies, the groups that emphasised nature values considered information services for biodiversity protection the most positive. Those emphasising timber production in both typologies considered co-operation over forest holding the least necessary.

In comparison with forest management planning and related advisory services and forest ownership objectives, statistically significant differences were observed between the groups for all tested sum variables, varying from $p < 0.001$ to $p = 0.044$. Comparisons between forest management style groups had significant differences between the groups for sum variables

"experience of restrictiveness of advisory services" ($p = 0.009$) and 'decision support from forest management plan' ($p = 0.008$). Decision support offered by forest management plan was considered very positive in all groups and in both typologies. The highest means for both typologies were in the group that emphasised timber production. Available advisory services were not considered restricting the forest management by any group, however those emphasising timber production disagreed the most with the statement. The means of the individual sum variables for grouping were very similar despite the typology used for comparison. The means were more unanimous between objective and management style typologies for forest management planning related services than for biodiversity-related services.

6.1.2 Article II: Technical and social knowledge discontinuities in the multi-objective management of private forests in Finland

The results of this article were classified under three headings: i) Knowledge (data, codified, encapsulated or tacit) remains under-utilised, ii) Gaps in knowledge distribution, and iii) Perceived validity of the knowledge is dependent on the person producing it. Each of these describes the phenomena with several examples. Some examples appeared from the focus groups, others from workshops and some were found from both data sets.

The under-utilisation of the existing data became apparent in six ways. The first three examples were more linked to the technical knowledge system. Firstly, substantial amounts of codified knowledge that have been collected and stored in authority databases are not necessarily available to other authorities or to market-oriented forest and environmental sector organisations due to privacy regulations. Forest service providers do not automatically have digital access to this information (e.g. biodiversity hotspots, relics of cultural-historical areas spots).

Secondly, collected data may be inefficiently converted into information and further knowledge. Forest inventory data are not used to the fullest in biodiversity conservation planning. Authorities also hesitate to capitalise on Zonation, a GIS-based conservation area prioritisation programme that would calculate the most promising spots for biodiversity protection based on forest inventory and other nature data (see Moilanen et al. 2014). Data are not utilised because the resources for implementing new conservation measures are inadequate, some data are outdated or because of insufficient skills or tools for analysing the data and converting the results into information.

Thirdly, codified or encapsulated knowledge is not transferred correctly in the operation chain within and between organisations. Examples of this include maps that may display incorrectly when transferred to another organisation's system and the structure of software systems where part of the information may be hidden or displayed incorrectly. Information that is considered additional, e.g. proposals for measures enhancing multi-objectivity remains encapsulated when the software is not developed to include them in a codified form. Organisations do not automatically transfer all available details about e.g. biodiversity or game management measures on a felling site to the subcontractor conducting the work.

The fourth example is more linked to the social knowledge system, and it came up in the training workshops. Participants noted that the organisations had no habit of asking and checking for nature-related information from their colleagues or from the forest authorities' office if the information is not automatically available in their systems, even when their databases are known to not necessarily be up-to-date. The problems are due to a lack of IT

systems supporting (encapsulated) knowledge sharing and because there is no organisational habit of passing on or seeking for the information within the operation chain.

The last two examples about the under-utilisation of existing knowledge are linked to the mismatch of knowledge systems. Organisation's databases, or those available to them, are not necessarily checked for codified (or partly encapsulated) knowledge, because there is no habit of searching for or checking information. The mismatch of knowledge systems emerges when the information is available in the database but the user does not use it because of the organisations' social norms. Last, resistance to change and suspicion towards new ways of working are common, for example reluctance to use new tools such as Zonation, which illustrates the importance of social acceptance when new practices are introduced.

The second headline concerned gaps in knowledge distribution. How forest advisors skip advising forest owners about conservation possibilities was a commonly noted problem with knowledge distribution. Three reasons were identified: employees' lack of competence, employees' negative attitudes towards forest conservation and the timber procurement targets of organisations and pressure to make better profits. The same problem with employee competence was acknowledged in workshops too but somewhat differently. Instead of advisors not discussing conservation issues with a forest owner at all, the main problem identified was that the forest owners' wishes concerning conservation or nature management measurements are not passed on to the next person in the operation chain. This information is often part of an advisor's tacit knowledge. Another example illustrated the mismatch between the technical and social knowledge systems. It showed a misconception, to where all information in the databases is codified, and hence standardised between the sender and the recipient. In reality, part of that knowledge is encapsulated and would need certain background information to be understood. This means that the information may be interpreted differently from how the original producer meant it.

The last headline concerned acknowledging the validity of produced knowledge and represents problems that are mainly linked to the social system of knowledge use. Non-professional or local knowledge was received with mixed expectations in the focus group discussions. It was claimed to be less trustworthy or valid, and in some cases even ideologically loaded. The role of officials as primary information producers was emphasised by some discussants. Another way to emphasise the role of professional knowledge over non-professional or local knowledge was to demand that the information be of high quality. Despite the reservations towards non-professional knowledge, the knowledge of forest owners about their own forests was considered valid and worth taking into account, though it is also mostly non-professional knowledge. Concurrently, forest owners are generally considered (by their peers and by forest and environmental professionals) not well-informed enough to know about important biodiversity spots in their forests, and the responsibility for producing and sharing biodiversity information is held by the forest professionals (both service providers and authorities).

6.1.3 Article III: The digital forest information platform as a service innovation: Finnish Metsaan.fi service use, users and utilisation

Results of the third article are two-fold: the logit model was used to explain the level of activity in the Metsaan.fi e-service, and responses to questions concerning e-service attributes were used to examine factors pushing the owner to adopt or reject the service at some point of their innovation decision process.

In the logit model for all respondents, age was not a statistically significant explanatory variable for activity level in the Metsaan.fi service. To examine the connection of age and adoption of Metsaan.fi e-service in more detail, we estimated the separate models for all respondents, respondents aged 60 years or less, and respondents over 60 years old. The forest owner's age group impacted how certain explanatory variables were associated with the activity in the Metsaan.fi e-service. All three models are statistically significant according to the likelihood ratio (LR) Chi2 test, but the very low pseudo R^2 (between 0.060 and 0.061) imply that the explanatory variables in the model rather poorly explain the variation in the dependent variable. Nevertheless, the models provide insight on whether certain variables are connected to Metsaan.fi service use or not.

A forest owner's strong timber harvesting motive increased the probability of them being an active user of Metsaan.fi. If a forest owner had multiple objectives for forest ownership, including timber harvesting but also recreation and environmental aspects, they used the Metsaan.fi service more actively. Activity was also higher if they felt that the management recommendations were in accordance with their own forest management objectives. This result was similar regardless of the age group. Agricultural or forest entrepreneurship increased the usage activity of owners above 60 years of age. Forest area had a statistically significant but very low positive impact on usage activity within both age groups. Women were less active users of the Metsaan.fi service in both age groups. Distant ownership did not have an impact on activity. High education increased the probability of Metsaan.fi service use among older forest owners. The characteristics of the service as pulling and pushing factors were organised among the Roger's attributes for the diffusion of innovations (Table 6).

Table 6. Characteristics of the Metsaan.fi –e-service as pulling and pushing factors, organised according Rogers' (2003) diffusion of innovation theory.

Attribute	Pulling factors	Pushing factors
Relative advantage	- Independency of time and place, accessibility - Existence of a web service - Service being free of charge	- Problems of linking the service to other operators and services - No added value perceived from the service - Low rate of service offerings from service providers
Compatibility	- Neutrality, credibility, reliability, independence from certain service provider - Versatility of the information available	- (Lacking) features for other forest uses than holding timber production level - Poor reliability, credibility of the forest inventory data - Discordance with forest owner's - values or objectives - Discordance with the service needs
Complexity	- Ease of use - Technical implementation	- Usability, service too technical
Trialability	- service being free of use - Ease of use - Technical implementation	- Usability, service too technical
Observability	- Existence of a web service - Up-to-dateness of information - Availability of maps and aerial photos for every FO - Availability of forest inventory data	- Missing or low quality of one's forest data - Problems with technical functioning of the service

When classifying respondent activity, 60% of respondents were categorised into narrow activity classes where they barely use the service. No specific characteristics either in their background or forest holding or in their perceptions concerning the service attributes were found to explain this lack of activity. Comments about the features and functioning of the maps and forest stand information in the more active classes indicate a more versatile way of using the service for decision-making. In the more narrow activity classes, responses emphasised more the up-to-datedness of the information. In all activity classes, respondents asked for new functions related to better acknowledgement and management of nature values. The perceived low quality of forest inventory data was found to be very central for improvements. The perceived low quality or missing forest inventory data was also most often mentioned as an individual reason for somebody not using the service. The sheer existence of the service was perceived as a positive aspect, and the continuous development implemented with the service was additionally praised.

According to the results, many forest owners want to use the service as their primary decision support tool for their forests. They wished the service to replace the forest management plans in the future and now want to use both as complementary tools, although the service is not intended to replace forest management plans. Many users perceived that the accuracy and adaptability of the service is not yet good enough to replace the plans, though on the other hand the service was considered good because it offered at least some information for those forest owners with no plan. The disparate numbering and demarcation of the forest stands in the service and in respondents' own forest management plans were often mentioned as problems. This inconsistency also prohibits using these two services as substitutes or complementary to each other. Many respondents wish for more illustrative information with pictures and graphs, along with more alternative management recommendations. Functions helping co-operation between owners of neighbouring forest holdings were also desired. Information and forecasts for timber prices were frequently requested to support the decision-making process. A web-based service also makes it easy to convey forest information to family members who have previously not been interested in or are incapable of visiting the forest, for example because of long distances.

6.2 What decision support services do forest owners wish for to support their multi-objective forest uses?

The results indicate that forest owners expect decision support services to acknowledge their diverse and multiple objectives for owning and managing forests. Information services are needed for the management of nature values and integration of various objectives, most often economic objectives with biodiversity protection or recreational targets. Although a great share of forest owners still aims for income from timber selling, they are increasingly interested in accomplishing this only while concurrently maintaining and not compromising other forest functions such as recreation and biodiversity protection (article I). Two different management preferences can be found from the group emphasising economic use: managing their forests solely for timber (51% within the group) or diversifying forest management actions (39% within the group) to enhance other forest functions alongside timber production. Those

preferring nature management as their management objective were found within all objective groups in rather even proportions.

Current information and decision support services were generally considered useful, but differences were found between objective groups (article I). The group emphasising nature values in both typologies considered biodiversity-related information about their forests more necessary than other groups. They were also less satisfied than the other groups with the usability of the forest management plan and the decision support it provides related to the use and management of their forests. However, forest owner in all objective and management preference groups wished for advisory services and management plans to provide more information on the nature values in their forests such as photos or management recommendations. Especially those with multiple objectives found such information lacking, which may indicate their need to integrate several, partly even conflicting objectives in their forest use (article I). The need for more multi-faceted advice became obvious also in the results of article III, with requirements for alternative management recommendations than the even-aged timber production recommendations offered in the Metsaan.fi e-service. Services promoting co-operation between neighbouring forest owners were found useful by multi-objective and nature conservation groups, both as objective and management preferences, and rather useless by those emphasising timber production (article I). Such services or functions were also desired for the Metsaan.fi e-service, to increase the profitability of timber harvests on small properties and to permit assessing the effects of harvests more widely in the landscape (article III).

Decision support offered by forest management plans was generally considered positive by all groups and in both typologies, but the group emphasising timber production found them to be the most positive (article I). Forest owners with nature objectives or management preferences found the usability of the forest management plan weaker than the others. None of the groupings agreed with the statement that the available advisory services were considered to restrict forest owners in their forest management. However, statistically significant differences were observed between the opinions of groups, as timber producers felt the least restricted and nature conservationists felt the most restricted. The Metsaan.fi e-service was generally received in a positive manner as a new alternative information service for forest owners. However, many forest owners had expected it to replace or complement their forest management plans as a decision support tool and source of information (article III), but the service has not fulfilled these expectations very well. The perceived poor quality of the forest inventory data and the one-sidedness of the management recommendations in the service were the most commonly mentioned reasons for this, along with difficulties in comparing information in the e-service with forest owners' other decision support tools. However, Metsaan.fi is not intended to replace forest management plans that are produced as a market-priced service.

Women and men showed differences in management and information service preferences. The largest share of women was aligned in the multi-objective group, whereas timber production was the largest objective group for men. Women also more often preferred diversifying management practices or nature management purposes than men did (article I). Results from the logit model (article III) showed that women were less likely to actively use the Metsaan.fi e-service. Timber production or multiple objectives increased the activity probability. Likewise, finding the e-service's management recommendations to be in line with a

user's own management preferences increased the probability. According to results from article I, women tend to appreciate nature values more than men do, and this may also be reflected in the logit model results.

The mechanism of a decision support service is also important in addition to its content. Results from article III reveal that many forest owners find web-based decision support services a very useful and practical way of taking care of their forest practicalities. The independence of time and place, accessibility to digital information, gratuitousness and finding the service easy to use increased the use of the e-service. On the other hand, the lack of forest inventory data for forest holdings or perceiving the service to be difficult to use caused forest owners to refrain from using it. The sheer existence of the service was perceived as a positive, which indicates that a web-based service is perceived as an easier way of dealing with forest issues compared to traditional ways of contacting forest service providers and finding the relevant data from many places. On the other hand, some forest owners still prefer meeting their service providers in person, and the service is not an appealing option for them.

6.3 How is knowledge used in the management of private forests in Finland?

A technical knowledge system and codified knowledge compatible with it dominate the forest management and decision-making processes (article II). Knowledge production is also concentrated around codified, standardised forest resource data that dominate the knowledge content of the Metsaan.fi e-service (article III). Information related to biodiversity protection, nature management and forest owner objectives and preferences was more often considered additional and burdensome. The role of the social knowledge system and the importance of its functioning have not been fully recognised by forestry organisations (article II). Because the functioning of the technical knowledge system is in many ways dependent on the social system it is built on, the underrating of the social knowledge system not only affects the distribution of tacit and encapsulated knowledge but also the use of codified knowledge. It also causes mismatches between the two knowledge systems, which then lead to gaps in the knowledge flows.

Massive investments have been made to collect forest-related data and build IT systems to enable knowledge distribution and utilisation (article II), but part of the collected information remains unused. Nature-related knowledge is not used e.g. due to problems with distributing the codified knowledge from the official databases into the IT systems of the service providers or because of insufficient data conversion into usable units of information with different planning tools. Organisations' databases concerning biodiversity hotspots or other important forest characteristic are not necessarily kept up-to-date. These were found to be problems explicitly in the technical knowledge system. Encapsulated and tacit knowledge are more difficult to store and share in IT systems that create the core of the technical system, and hence they may remain unused or unseen (article II). They usually contain information on forest owner's management preferences and other locally bound knowledge that is considered additional to technical forest resource data or tactical harvesting or management activity information. Hence the decision-making concerning the management of someone's forests and implementation of those decisions is conducted mainly based on forest resource data. Encapsulated and especially tacit knowledge are best shared in a social knowledge system,

between people and mostly informally within organisations. Acknowledging this would help to balance the use of different knowledge forms and hence produce better informed decisions.

The Metsaan.fi e-service (reported in article III) offers forest owners and service providers access to codified knowledge about individual forests. Information there is based on automated calculations of forest inventory data and the data available in other databases such as biodiversity hotspots or spots of cultural-historical values. During data collection for article III, the majority of the information in the system was based on forest inventory data and e.g. forest owner objectives and management preferences were not taken into account. The recommendations for management activities and harvesting are based on forest inventory data and only aim for even-aged timber production.

6.4 What knowledge-related discontinuities occur in decision support services?

Several knowledge-related discontinuities were identified in the decision support services in the sub-studies of this thesis. The insufficient distribution of knowledge related to biodiversity protection appeared in all three sub-studies. Information and advisory services for other forest uses than even-aged timber production are lacking to a large extent. Thus, the advisory services or forest management plans have met the needs of timber production-oriented owners notably better than of those who aim to enhance nature values or who want to integrate recreation or biodiversity protection with timber production (article I). Metsaan.fi, the e-service for forest information, only offers management recommendations that are based on methods for even-aged timber production. It is therefore perceived most useful by those whose objectives include even-aged timber production, but risks estranging forest owners who, for example, want to manage their forests for biodiversity or recreation (article III). The lack of biodiversity protection advice was also noted both in the focus group discussions and by the forest professionals during the workshops (article II). Three possible reasons for this lack were suggested: employees' lacking competence, their negative attitudes towards biodiversity conservation and the organisations' financial targets that emphasise timber procurement efficiency.

Knowledge concerning forest owner objectives is not transmitted correctly between owners and professionals or within and between operating organisations. As a result, forest owner's decisions are not implemented in the operational chain as they should be, e.g. chosen nature management practices are overlooked. This is partly a problem of the advisory and management planning practices, which do not provide such information in the forest management plan (article I) and partly a defective flow of encapsulated or tacit knowledge in an organisation (article II), where this "additional" info is not transferred or taken into account. The results from article I show that enquiring about the objectives only in an abstract manner for forest management planning may result in overly simplified answers concerning management preferences. If a forest planner suggests alternative recommendations for a forest stand, for example nature management measures, those are often written down into the IT system as additional information. The forest advisor or timber procurement expert making the operational planning for the management activities or harvesting does not necessarily check for additional information, and so additional management preferences are easily not transferred as work instructions into the forest worker's IT system (article II).

Yet another discontinuity is linked to the protection of biodiversity that is required by the Forest Act and forest certification systems (more than 90% of productive forests in Finland are PEFC certified (PEFC 2019a)). The databases on biodiversity hotspots or other valuable forest characteristics are not available digitally for all service providers, and the IT systems of various organisations are not necessarily compatible to transfer the information (article II). Hence the information in the databases remains unused. However, according to further results in article II, the knowledge missing from the technical knowledge system (an organisation's database) is usually available in a social knowledge system by asking the forest or environmental authorities, the forest owners themselves or a colleague. Activating this social knowledge system may demand changes in the social norms and practices within organisations. Hence this is also a problem of the social knowledge system. The organisations have no habit of asking their colleagues for more information about local conditions (tacit knowledge) or checking with the authorities for more information about a specific area (article II).

Codified and encapsulated knowledge is not transferred correctly within or between organisations. The maps may display incorrectly when transferred to another organisation's system or the encapsulated knowledge is not automatically transferred because it is considered additional and unimportant. The software have been built around codified forest resource data and management of timber production, and hence adding information or planning management activities for other objectives is more difficult than for timber production. In the IT systems, knowledge may be considered codified although it is actually encapsulated and then the content received is not the same as the content inserted into the system. The use of map symbols concerning nature information is an example of this: an organisation has no commonly agreed upon practices for storing nature information, but appropriately interpreting this information requires common understanding. This is an example of the mismatch between technical and social knowledge systems.

The problem with encapsulated knowledge remaining unseen in the organisations' IT systems is a problem caused by the human habit of not checking for information that may be considered additional or that needs more work for interpretation (article II). The mismatch of technical and social knowledge system emerges when information is available in the technical system, but the user is not in the habit of using it. Also, I identified an organisational habit of relying almost solely on the technical knowledge system, meaning the IT system and databases of an organisation, whereas asking colleagues or forest administration for more information was identified as a practice that needs to be learnt. Distribution of tacit knowledge requires the employees to ask each other about their work, and this habit of sharing individual knowledge within the organisation or operational chains seems to be lacking (article II).

The knowledge produced by non-professionals is sometimes claimed by forestry actors to be less trustworthy or valid, or in some cases even ideologically loaded, because prejudices exist against non-professionals as knowledge producers (article II). This weakens the production on new nature knowledge. This applies particularly to species observations produced by nature hobbyists, but to some extent also to forest owner views. The role of professionals as knowledge producers was emphasised by some participants in the focus group discussions. However, non-professionals in knowledge production were also considered an important resource, and co-operation between forest administration and nature hobbyists and hunters has increased in recent years. Another way to emphasise professional knowledge over non-pro-

fessional or local knowledge was to require storing the information in technically high quality, meaning it must be compatible with GIS databases. This allows the actor to ignore observations stored by others than forestry actors or environmental administration.

The forest resource data are not necessarily up-to-date when transferred between forest and environmental authorities, and hence the planning of potential conservation areas is not efficient. The production of conservation-related knowledge is also weakened by resistance to change or lack of human resources to introduce new tools, such as the Zonation conservation planning software, and the inadequate resources for implementation of new biodiversity conservation measures. Also, by nature these are problems in the social knowledge system.

In addition to lacking information for other forest uses than even-aged timber production, the quality of information offered in the Metsaan.fi e-service was considered insufficient to be used for decision support. Forest owners expected the information in the e-service to be usable for complementing their other decision support means and even substituting them, but the perceived accuracy of the information does not support such use. The service is not meant to replace forest management plans, which are produced for forest owners by market oriented service providers, but the differences in the information content between the service and a proper forest management plan have not been able to be communicated sufficiently to the users.

7 DISCUSSION

7.1 Assessment of the validity, reliability and limitations of the studies

To some extent, assessing validity and reliability is different for qualitative and quantitative studies and for social and natural sciences. In quantitative research in the natural sciences, reliability refers to exact replicability of the study process and results (Leung 2015), but that is not possible if the research deals with human beings and their views and communities. Even if the studies were repeated with same respondents, their views may have changed over time or due to new understanding gained by participating in the study (Carcary 2009). Qualitative research deals with non-numerical information and the phenomenological interpretation of it, and thus the human senses and subjectivity are an inevitable part of the qualitative research (Leung 2015). However, in quantitative, replicable studies, the choices made by researchers about their questions and assumptions may also be value- or interest-loaded, and making those visible e.g. with the social constructionist view, is needed to assess the objectivity of a study (Cozzens and Woodhouse 2011). These are particularly important in forest-related research in Finland, where timber production and the forest industry have been prioritised in policy formulation concerning forest use (Ollonqvist 2002). The objectivity ideal may be used by groups in power to legitimate only one interpretation as value-neutral facts and to suppress other interpretations (Code 1993).

Validity in qualitative research depends on choosing the tools, processes and data to be appropriate in detecting the phenomena of interest and interpreting it correctly in its cultural context (Lewis and Ritchie 2003; Leung 2015) and the comprehensiveness and depth of the data (Remenyi et al. 1998, p. 180). Using a constant comparative method and making sure to also recognise deviant cases in the analysis improve the internal validity of a study (Lewis and Ritchie 2003) as well as thorough reporting of the different phases of the study (Payne

and Williams 2005). External validity is dependent on data richness and transparent reporting of its collection (Leung 2015), and is enhanced through triangulation (Lewis and Ritchie 2003). Reliability can be improved with the use of consistent and systematic work processes that transparently reflect and outline the analysis phases and the evidence collected leading to the results and interpretations, by ensuring equal participation of all informants, basing the inferences firmly on the evidence, and offering a balanced perspective (Lewis and Ritchie 2003).

Because qualitative research is usually tightly connected to its context, generalisability is not expected as such (Leung 2015). In the context of qualitative research, some researchers rather assess the transferability of the findings into another context than the generalisability of them (Carcary 2009). A thorough description of data collection and analysis provides the reader with enough information to decide to which extent the results can be transferred to other contexts (Payne and Williams 2005; Leung 2015). Assessment of the generalisability of a qualitative study can be conducted based on the same criteria as the assessment of validity (Leung 2015). Qualitative research has limited generalisability, i.e. ”moderatum generalisability”, which equals moderate, pragmatic generalisations drawn from personal experience of which occurrences can be transferred to other contexts (Payne and Williams 2005).

Result validity achieved in this dissertation is enhanced with triangulation in data collection and with the methods used along with co-operation with a multi-disciplinary team of researchers at various phases of the research. Four quantitative and qualitative data sets were collected and a large register data set was used for non-response evaluation of one survey data. The representativeness of one forest owner survey data set was evaluated against the most recent nationwide forest owner survey. In order to achieve an overall picture about the phenomenon of interest, i.e. of the decision support services and knowledge used in them, the services were examined both from the viewpoint of the service users and from the perspective of the multi-actor network producing those services and the knowledge needed in them.

Data collection for articles I and II were conducted in a large multi-disciplinary research group, which helped ensure that all concepts used in the surveys were explained well enough to be understood in the same way, and that the invitation of participants in the focus group discussions was not biased due to e.g. one-sided networks of stakeholders. The qualitative data from the focus group discussions and training workshops were saturated, as the focal themes were repeated similarly in different groups and locations. This reinforces the generalisability of the results more widely in the Finnish forest sector. Three sub-studies employ quantitative and qualitative methods to ensure comprehensive and multi-faceted understanding concerning the phenomenon of interest. However, several limitations of these studies exist despite our attempts to overcome them.

The analyses were mainly conducted by the author of this thesis, but the co-authors discussed them at different phases of the analysis. Interpretations of the results were also discussed among the authors to ensure the even consideration of all possible explanations and to ensure the tight linkage of the inferences to the evidence from the data. The rather long research process from the initiation of this thesis to the analysis of data, and working experience and knowledge gained with different stakeholders during the thesis process have ensured a more comprehensive and balanced perspective for interpreting the results. As stated in the Introduction, this thesis has two aims: enhancing the owner-orientedness of information services and enhancing the ecological sustainability of forest use. Hence the data collection and analysis emphasise these two themes, and other themes may have been left out.

Respondent and discussion participant expectations on expressing socially desirable opinions and views rather than their real opinions may have decreased the internal validity of the studies. This positive response style is a common bias in survey studies (Ficko and Bončina 2014). Besides this, the typologies created based on surveys only capture the most salient motivations for ownership, while more nuanced understanding remains hidden and their ability to predict owner behaviour is limited (Ficko et al. 2019). In article I, this well-known method flaw was at least partly overcome with our strategy of also inquiring owners about their desired ways to manage their forests in upcoming years, and these two typologies were combined in the analysis to create more concrete understanding about forest management preferences. In article III, the forest owner survey employed open-ended questions to explore the views about the decision support service to overcome possible misunderstandings of the statements (Stanislovaitis et al. 2015). The probability of participants censoring their speech in the focus groups and training workshops to ensure social acceptability was evaluated as small because most participants knew each other already prior to data collection and the atmosphere in the discussions was relaxed and open. Conflicting opinions were also expressed and the discussions did not aim for any consensus about the topics at hand.

The survey data used in the studies I and III were clearly dominated by males, although the share of women as forest owners is estimated to be between 30% and 40% (Follo et al. 2017; Karppinen and Hänninen 2017; Vennesland et al. 2019). Women were clearly underrepresented in the data for article III when compared to the register data that was used for non-response analysis. The repeated under-representation of women in data became evident only during the analysis of the datasets and hence its possible consequences are reflected on in this summary more than in the research papers. The picture gained concerning the objectives and values along with the use of decision support services may be distorted in a sense that regardless of the formal ownership of the forest holding and the possibly differing opinions of women, men are more likely to take care of forest management together with a male professional and they also tend to answer surveys. The socially accepted space for women to take agency in forest-related issues is narrower than that of men (Vainio and Paloniemi, 2013) and hence as respondents they may feel more pressure to provide answers that are expected from women, regardless of their real opinions. Enough women were presented at the focus groups to avoid tokenism (ca. 40% of all participants), and the discussions were facilitated to ensure everybody equal say, but the discussions were nevertheless dominated by men, and particularly by men in their expert roles. Phenomenon has been identified in the literature that describes forestry as a hegemonically masculine context that offers marginal positions to women (Brandth and Haugen 1998; Vainio and Paloniemi 2013). The majority of the comments from female participants also came from individuals representing their expertise or occupation, whereas women forest owners were mainly silent.

Besides the underrepresented voices of women in the focus groups, the representatives of timber procuring companies were absent. This is clearly a weak point of the study, as according to their public communications, forest industry companies are at the forefront in proactive nature management practices and their contributions to the discussions would have been valuable. The participants may have had more positive outlooks toward biodiversity conservation than average professionals, because participation required some time and effort. However, the majority of participants participated during their working hours as a part of their work. This also applies to the training workshop participants.

The practice-orientedness and attempts to produce knowledge for developing work practices in forestry makes this research more normative than descriptive. The thesis not only

gathers facts about the phenomena it examines but also evaluates the present state and points out how to improve the current practices (Routio 2007). The thesis attempts to provide recommendations and advices for further development of forest-related decision support services. The research problems have been discussed in co-operation with representatives of forestry, and hence there is a common understanding concerning the problems that the thesis offers solutions for, as well as about what the desired state of affairs is. On the other hand, the stakeholders have ensured freedom of research with no interference at any phase of the research.

7.2 Need for user-oriented decision support services is evident

My findings show that to be useful, decision support services should acknowledge forests owners' diverse and multiple objectives for owning and managing forests and be easily available and illustrative. They should help integrate several objectives alongside timber production and compare various alternatives. Forest owners wish for more services related to biodiversity conservation and nature management, and these are particularly important for nature-oriented forest owners. In general, forest owners desired more illustrative and practice-oriented information, for example photos and graphs, to enhance the usability of forest management plans and the Metsaan.fi-service, both for timber production and for maintaining the biodiversity.

The findings show that forest owner preferences for forest management are more versatile than they appear based on objective typologies. When I compared the typologies for ownership objectives and forest management preferences, two different management preferences were found within the group emphasising the economic use of forests: half of the group prefers managing their forests only for timber production as they are used to do, while the other half wants to diversify management e.g. with continuous cover fellings, or conduct nature management measures. The result shows the importance of inquiring about forest owner preferences for forest use in concrete management situations, as abstract-level objectives may instead reflect general-level appreciations than genuine objectives, as Takala et al., (2017a) argues. Enquiring about the objectives of every operation by presenting alternatives during consulting situations would ensure the knowledge transfer from a forest owner to the professional, and also make it easier for a forest owner to make informed decisions about the integration of various objectives and their consequences (Höglund et al. 2012). Having alternatives to choose from could also intrigue the forest owner to specify their goals or preferences and hence take agency in the decision-making (Hokajärvi et al. 2009).

The over-simplification of forest owner characteristics by typologies has also been criticized by Ficko et al. (2019). My results from both surveys show that decision support services are most commonly used or most commonly considered useful by those who aim for timber production as their principal objective. This is understandable, as the majority of forest planning and management services still aim to maximise timber production (Mattila et al. 2013). The interest felt towards biodiversity-related information and the large share of owners from the economic group willing to diversify their forest management alongside the multi-objective and nature-oriented forest owners indicate, however, that the majority of owners want to produce timber only alongside other forest values, not at a cost to them. This result is in line

with Takala et al. (2017a), who concluded that for a forest owner to be multi-objective, respective emphasis is essential for both economic and non-monetary objectives. This finding is encouraging from the viewpoint of shifting to ecologically more sound forestry that maintains more nature-like elements also in productive forests.

Adding biodiversity-related information to services may help multi-objective forest owners fulfil all aspects of their ownership objectives, as combining various objectives requires information concerning all of them. Multi-objective owners have been found to be most active in conducting loggings (Kuuluvainen et al., 1996; Favada et al., 2009) but it is unclear whether these loggings have been done respecting the forest owners' other objectives or to what extent the norm pressure caused by professionals to conduct loggings has influenced their decision-making (Takala et al. 2017a). According to my results, multi-objective forest owners found that decision support services did not cover all aspects of their objectives. Forest owners emphasising nature values were less satisfied with current service offerings. Decision support services are more effective at influencing harvesting decisions and biodiversity conservation when directed at forest owners in line with their objectives (Favada et al. 2009). More research is needed on the versatile preferences of multi-objective owners, especially with the current developments of many service providers placing more emphasis on nature management (see e.g. Metsäteollisuus Ry 2016; Metsä Group 2017) and adopting the FSC forest certification system in addition to PEFC certification (see e.g. UPM 2017).

According to the results, services promoting co-operation between neighbouring forest owners were desired by some owners both for enhancing the efficiency of nature-management measures and for increased profitability of fellings in the small holdings. Co-operation between neighbouring landowners was encouraged with the regional forest inventory and planning approach in the 1970s (Tikkanen et al. 2010). It did not gain popularity in the timber trade, but some management activities, such as ditching and forest road building, are still often carried out as joint projects between several landowners (Tikkanen et al. 2010). Co-operation was tested within the Biodiversity Programme using agglomeration bonuses for private conservation areas stretching over several estates, but the practice was discontinued (Rantala et al. 2011). Despite past experiences, such services should be reconsidered, boosted by the open availability of the forest inventory data. However, more research is needed concerning the best ways to facilitate this e.g. within the Metsaan.fi e-service.

The methods used in decision support services are important, in addition to their content. The Metsaan.fi e-service was praised for its availability regardless of office hours and for its ease-of-use. Independence from market-based service providers or from service providers at all was also considered important. For the increasing share of forest owners living further away from their forests and being employed elsewhere (Hänninen et al. 2011), the possibility of supervising their forests when they have free time may be the only way to manage their forests at all. In an earlier study the possibility to produce illustrations has been found a reason for interest in internet-mediated decision support services (Hujala and Tikkanen 2008). On the other hand, the trend of forest decision support services moving to the Internet may challenge forest owners who are incapable of using such services or who prefer meeting service providers in person. They may become further alienated from forest management. Finding a balance between face-to-face advising and internet-mediated decision support services is important. Advising FOs in person potentially constructs shared knowledge and promotes learning (Virkkula and Hujala 2014). Successful advising generates trust and respect between FO and forest professional and strengthens one's conception of themselves as forest owner

(Hujala and Tikkanen 2008), which may help estranged or less interested forest owners to take initiative about their forests.

The majority of respondents had barely used the Metsaan.fi e-service. From this, I conclude that these users are still at some point in their innovation-decision process. Late adopters wait until they have proof about the performance of an innovation (Rogers 2003, p. 294). The results show that bad performance, meaning a lack of reliable forest inventory data, has been the main reason for many owners in the lowest activity classes to wait before proceeding with their innovation-decision process. This means that they have not yet made up their minds about adopting or rejecting the service. There are many ways to influence the process, for example through change agents or opinion leaders, or by removing barriers hindering its adoption (Lin 1998). Interest towards the service naturally grows when more inventory data are available. Forest extension experts may serve as change agents guiding forest owners towards adopting the service (Rogers 2003, p. 370), and the advance of their service was also noted in the results by forest owners as helping with adoption of service. However, special attention must be given to personal advice being allocated to those who need it the most (Rogers 2003, p. 383), such as owners of smaller properties or owners with other than timber production objectives. In addition to professionals acting as change agents, diffusion could be enhanced through opinion leaders that are peer forest owners who have already adopted the innovation and can influence their social networks by their example. Information provision through forest owners' social networks is more effective than e.g. through mass media (Brook et al. 2003), as people are more likely to consider information from the sources they trust (Arbuckle et al. 2015). Using peer opinion leaders could particularly help with introducing women to the service, as the worlds of IT and forestry are still considered masculine (Suopajärvi 2009; Galyani Moghaddam 2010; Vainio and Paloniemi 2013). Strengthening forest owners networks, both with each other and by means of extensionists, may also enhance the adoption of an innovation (Hubbard and Sandmann 2007).

The desire to be independent from service providers may express the dissatisfaction or mistrust felt by forest owners towards the service providers, e.g. due to a lack of owner-orientedness when previously dealing with service providers. According to a study by Mattila and Roos (2014), Finnish and Swedish forest service providers have difficulty in reaching forest owners with other than timber production objectives due to the rather one-sided service supply that disregards the diversity of forest owner objectives.

Results from article III showed that having other objectives than timber production lowered a forest owner's probability of using the Metsaan.fi e-service, and the one-sidedness of the codified knowledge in the Metsaan.fi e-service caused certain forest owners to reject the service. Having strong nature or other non-monetary objectives seems to be impossible to integrate with timber production (Takala et al. 2017a), and hence services emphasising timber production, such as Metsaan.fi, may alienate these forest owners, as they feel they cannot combine their objectives with the service. Developing the service to also meet other objectives than timber production is important, as initially the service mainly contained information of forest resources for even-aged management. The emphasis placed on forest resource information rather than on balanced forest knowledge may steer the decision-making to become excessively one-sided. To ensure the owner-orientedness of the service, the information offered and the management recommendations produced should also contain nature information and suggestions suited for alternative forest management preferences. After data collection for this thesis, the e-service has already been supplemented with more nature-related knowledge such as potential spots for the Biodiversity Programme.

Women and men showed certain differences in their use and preferences for management and information services. In article III, women were found to be less likely to use the Metsaan.fi e-service, and in article I they more often belonged to the multi-objective group and preferred diverse management practices or nature management purposes than men did. These results are well in line with earlier studies about women appreciating nature conservation more (Lidestav and Ekström 2000; Häyrinen et al. 2015). The probability of actively using the Metsaan.fi e-service was higher for those forest owners whose objectives were in line with timber production-oriented management recommendations the service produces. The more common disaccord of the service with women's more typical nature-oriented objectives may be one explanation for the lower probability of women using the e-service. Another explanation may be the women's weaker agency in forestry in general. This is manifested by the by-stander position that women are offered and easily adopt in the management of the family forests (Vainio and Paloniemi 2013) as a result of forestry traditionally being a masculine practice (Baublyte et al. 2019; Larasatie et al. 2019). In families, the man more commonly takes care of forest management even if the woman formally owns the forest (Vainio and Paloniemi 2013), and hence the man is also more likely to use the Metsaan.fi e-service.

Forest sector and especially forestry has gained strong masculine sphere during its history, still dictating the mindsets and practices also wider in the Finnish society (Kuisma 2006, p. 539). The gendered sphere of forestry has been assumed to limit women's involvement and participation as active forest owners (Brandth and Haugen 1998; Vainio and Paloniemi 2013), which was also evident from the gender distortion in my data. According to previous studies, women also participate less in forest extension activities (Ripatti 1999) and nature conservation within the Biodiversity Programme (Paloniemi et al. 2010). However, when they participate, women are more likely to utilise advisory services than men are. Ripatti (1999) found women to be more likely to sell timber than men were after participating in extension activities, and women's plans for forest management are more strongly influenced by norm pressure from professionals and family than men's are according to Karppinen and Berghäll (2015). Karppinen and Ahlberg (2008) show the share of women forest owners to be as high as 30% to 40%, and therefore women's lower participation may hinder the realisation of forest policy goals of active forest use, although women's lower participation also in policy formulation may have distorted the policy towards more masculine targets. The masculine culture of emphasising economic forestry may also hinder the realisation of female forest owner's nature-related objectives (Vainio and Paloniemi 2013) or alienate them from forestry if advisory services do not acknowledge them as equal actors in forestry, who nonetheless may have other goals besides timber production. The active participation and agency of women in forestry can be enhanced with gender-specific activities and peer-learning (Hamunen et al. 2015), but more important is normalising women's status as forest owners and forest sector actors (Brandth et al. 2004). Gender consciousness is important to consider in future research, to ensure the validity of results and comprehensive understanding of forest owner composition.

Contemporary decision support services are founded on the idea of "good forest management" and maximum timber production achieved with it. They are dominated by the economic use of forests, where "a well-tended, cultivated forest is a normal forest" (Vainio and Paloniemi 2013) and "good forest management" with healthy and well-growing forests is described to also benefit nature and the landscape (Takala et al. 2017a). Forest professionals may stick to this production-oriented discourse as a part of their profession and experience

(Selby et al. 2007), but also because of their organisational environments. However, this discourse has been found to cause stress or pressure to comply with it regardless of whether a forest owner's objectives are non-monetary or a forest is only a minor part of a household's responsibilities (Takala et al. 2017b), and hence it risks alienating forest owners from the services and forest management. Because alienated or indifferent forest owners are considered problematic for active forest management and hence meeting policy goals (Follo 2011; Hamunen et al. 2015), it is important for forest professionals to recognise different owner motivations and adapt the decision support services accordingly (Takala et al. 2017a). Owner-oriented planning and advisory services related to it are guided by forest owner needs, aims and resources (Hujala et al. 2007; Hokajärvi et al. 2009).

To be able to adapt the services according to individual forest owner needs, organisations must continuously interact with their customers and then mould the most appropriate service from a segmented product pallet to fit the needs of an individual customer (Tikkanen et al. 2010). This is a mass-customised service. To achieve genuine owner-orientedness, co-configuration of the service between the service provider and the customer is needed (Tikkanen et al. 2010). The distinctive characteristics of joint development are a product or a service with a long lifespan, even one which will never be finished; continuous adjustment to a user's actions; "client smartness" embedded in technological solutions; and the requirement of continuous re-configuration between the user, the producer and the product itself (Engeström 2004). The Metsaan.fi e-service can be seen as one version of this co-configuration, as the forest owner is the initiator of the information service by seeking the information from the service (Bressolles et al. 2014).

7.3 Discontinuities in knowledge use impede the realisation of owner objectives and biodiversity conservation

My findings show that discontinuities in knowledge flows predominantly occur with the knowledge related to forest owners' objectives other than timber production or with biodiversity conservation-related knowledge. This result underlines the dominance of economic forest use along with codified forest resource data used for efficient timber production. New objectives and nature knowledge challenge the established interests and the distribution of benefits from the use of natural resources (Saarikoski et al. 2018). The technical knowledge system and codified knowledge compatible with it dominate the processes of forest management and decision-making. Knowledge production is also concentrated around codified, standardised information, with forest inventory data being the most obvious example of data that dominate the knowledge content of the Metsaan.fi e-service. This worked fine as long as the only forest use objective was timber production and decision-making concerning forests was mainly based on knowledge about timber resources (Hokajärvi et al. 2009). Because the technical knowledge system and codified knowledge dominate currently, encapsulated and tacit knowledge may be left out of the consideration for decision-making.

Massive investments have been put into the technical knowledge system, meaning the collection of forest-related data and the building of IT systems to enable the distribution and utilisation of this codified knowledge. Notwithstanding, a part of this knowledge remains under-utilised because of problems with distributing the codified knowledge in the IT sys-

tems. Databases on biodiversity hotspots or other valuable forest characteristics are not digitally available for all service providers, and the IT systems of various organisations are not necessarily compatible for transferring the information. Interface development between IT systems would solve a part of the problems in the technical knowledge system by ensuring the transferral of codified knowledge between organisations. In their study on ecosystem knowledge, Saarikoski et al. (2018) found a lack of cross-sectoral co-operation between government agencies to be one of the barriers for effective knowledge use. This also became apparent in my results concerning the knowledge distribution between forest and environmental authorities. Some identified problems with the availability of certain data are more of a legal question dealing with the protection of personal information or similar, and solving these requires political processes. The production of conservation-related knowledge is also weakened by resistance to change or lack of human resources to introduce new tools such as the Zonation conservation planning software (for Zonation see Moilanen et al. 2014). However, the use of nature information databases has already intensified with implementation of the Zonation–software by regional forest and environmental administrations and with increased use of the Metsaan.fi service where forest owners can transfer biodiversity and other information about their forests to their service providers. This reduces the under-utilisation of existing knowledge and hence enhances technical knowledge management. New organisational procedures and management structures, such as cross-sectoral networks, are also needed for administrations to break the "silo" effect between the implementation of forest and environmental policies (Saarikoski et al. 2018).

The insufficient distribution of knowledge related to biodiversity protection was apparent in all three sub-studies. The service provider does not inquire about forest owner management preferences or the forest owner is not informed about possibilities for biodiversity conservation. The negative attitudes towards biodiversity conservation may originate from professional emphasis of economic forest use as part of their profession (Selby et al. 2007) and by professionals feeling like their authority is being challenged by new actors and new knowledge (Maier and Winkel 2017), which changes the fundamentals of their work as biodiversity policies intervene in the institutionalised management ideal of good forest management (Peltola 2013). According to our results, the financial burden of the extra work required for the consideration of biodiversity was an important reason why these issues are not presented to forest owners. The pressure to operate in an owner-oriented way when organisational preconditions, e.g. financial targets, go against it (Hokajärvi et al. 2009) may also cause frustration and enforce resistance to change ongoing practices. Established professional norms, competencies and codes of conduct cause professionals to rely on traditional solutions and prevent the uptake of new knowledge (Saarikoski et al. 2018). Biodiversity conservation has not been an area of strategic specialisation for Finnish forest service providers (Primmer 2010), albeit new enterprises having emerged that concentrate particularly on other than even-aged forest management (see e.g. Metsäpalvelu Arvometsä Oy 2015).

Results from article II showed that regular training and working with conservation issues is strengthening the expertise level of forest professionals, and the attitudes of organisations and individual forest professionals are slowly becoming more positive towards more diversified forest uses and biodiversity protection. This leads to accumulation of tacit knowledge concerning biodiversity conservation and widening of the social norms about good forest management implementation in organisations. Both social and technical knowledge systems have been adapted to better accommodate biodiversity-related practices and values.

A gap in the knowledge flow may also appear within and between operating organisations. A forest planner may suggest alternative recommendations for a forest stand, for example nature management measures, but the forest advisor or timber procurement expert making the operational planning for management activities or harvesting does not necessarily look for any additional information, which is then not transferred to the forest worker's IT system as work instructions. The distribution of work between forest planners and advisors has been found to be unsatisfying for the planners, as they do not see the results of their work implemented in the forest (Hokajärvi et al. 2009), and closer co-operation between the planner and advisor would also enhance the transfer of encapsulated knowledge.

This problem with encapsulated knowledge remaining unseen in IT systems is a problem of the mismatching knowledge systems: the social knowledge system guiding the behaviour of individual professionals prohibits the knowledge flow supported by the technical knowledge system. This usually refers to encapsulated knowledge related to forest owner objectives and management preferences or potential spots for nature management measures that were marked as "extra" or "additional" and needed to be added, transferred and looked for with greater effort than codified forestry-related knowledge. This indicates a lower perceived importance of such knowledge for decision-making. This result is in accordance with Rekola et al. (2010), who found that timber production was valued more highly than nature conservation by professionals working with timber procurement. Maier and Winkel (2017) observed discrepancies between the state enterprises managing public forests in parts of Germany and the public opinions about the importance of forest conservation and timber production. As a result, forest owner decisions are not always implemented in the operational chain as they should be, e.g. chosen nature management practices are overlooked.

According to the results, experts in organisations are not in the habit of asking colleagues for more information about local conditions (tacit knowledge) or checking with authorities for more information about a specific area, and hence the knowledge missing from the technical knowledge system (an organisation's database) remains unused despite it usually being available in the social knowledge system when asking forest or environmental authorities, the forest owner themselves or a colleague about it. The distribution of tacit knowledge requires employees to ask each other about their work, and this habit of sharing one's knowledge within the organisation or operational chains seems to be lacking. Activating this social knowledge system would enhance knowledge flows, but this may require changes to social norms and practices within organisations. However, the underestimation or negligence of social knowledge system not only affects the distribution of encapsulated and tacit knowledge but also the use of codified knowledge. With biodiversity hotspot databases this may be partly due to the data in the databases not being considered reliable (Peltola and Tuomisaari 2015). It also causes mismatches between the two knowledge systems, which causes gaps in knowledge flows. On the other hand, Primmer (2010) found that tight networks of service providers advance biodiversity conservation by circulating the information among forestry actors, albeit modestly.

The production of new nature knowledge is weakened, as the knowledge produced by non-professionals is sometimes not considered valid due to prejudices against the validity of non-professionals as knowledge producers. Insisting professional validation of knowledge may lead to exclusion of valuable local knowledge from the decision-making in forest management (Fortmann and Ballard 2011). The emergence of new actors challenges the more traditional actors in natural resource management and their accustomed relationships with each other (Mol 2006; Soma et al. 2016). The role of authorities in contrast to hobbyists as

primary information producers was emphasised in the focus group discussions. Two explanations come to mind: firstly, biodiversity protection and planning of natural resource use is still predominantly based on scientific knowledge, although local knowledge is increasingly recognised as valuable (Joa et al. 2018). Secondly, emphasis on scientific knowledge production and underlining the importance of formal expertise in the objective interpretation of that knowledge has reinforced forest professionals' authority in the use of forests in contrast to lay persons (see e.g. Maier and Winkel 2017). Hence, disputes between different knowledge producers are actually not about conflicting evidence but about contradictory interests of parties, masked as evidence issues (Voß and Bornemann 2011). Claims about objectivity can also be used to justify the technocratic approach to management of environment, where the complicated policy choices should be left to "objective" experts alone (Fischer 2003). However, the knowledge production system has inevitably changed to include new actors and new practices (Soma et al. 2016), which undermines the old authority of professionalism. The perception of expert-driven knowledge production as objective in contrast to other knowledge production disregards the view that all knowledge is partial and affected by the social and historical context in which it is created (Haraway 1988; Fortmann and Ballard 2011). Ignoring a certain part of the knowledge and its producers decreases the quality of decisions and increases the risk for disputes (Tengö et al. 2014). Access to knowledge creates differences between actors (Peltola 2013) and limiting somebody's access to certain knowledge can be used to maintain power structures.

Professionals had two attitudes towards the forest owners as knowledge producers. On the one hand, the forest owner is considered the best expert concerning their own forest and its management, while on the other hand, forest owners were not considered to understand the characteristics of their forests or how they should be managed. Forestry actors tend to protect their decision-making power concerning forest-related issues by shutting others outside (Maier and Winkel, 2017). This explains why the knowledge of forest owners about their own forests is sometimes considered valid although forest owners generally are considered not well-informed enough to know about important spots for biodiversity. Timber production-oriented forest owners, in contrast to biodiversity-oriented ones, may be considered "one of us" by forestry actors, and hence their knowledge is also worth taking into account. Gootee et al. (2010) made aligned observation. In their study, well-informed forest owners were treated as respected stakeholders in issues concerning their forests by forest professionals, whereas less active forest owners were considered less-informed and were approached with a more hierarchical expert-layperson relationship. To achieve owner-orientation in the decision support services, the actual knowledge level of the forest owner about their forests is not essential, but the transfer of the knowledge about FO's objectives. Distribution of that knowledge should be supported and provision of the information to FO matched with their objectives as well as with their knowledge levels. Aiming to understand and appreciate the views of a FO rather than simply transferring knowledge is a key to effective forest management advice (Vanclay 2004).

Non-professional knowledge production and co-operation between various organizations to collect and store nature-related data have also been gaining acceptance, which indicates changes in the social norms concerning socially accepted actors in forestry. The social acceptance of new actors as knowledge producers enhances the knowledge production and use, as greater part of the nature knowledge is produced by environmental NGO volunteers or by crowdsourcing e.g. species observations from hobbyists. Such knowledge production may

rely on so-called policy champions, i.e. individuals who take an active role in bridging different actors (Saarikoski et al. 2018). A project mapping the nests of predatory birds conducted by the Finnish Forest Centre is one example of this. Acknowledging and sharing various sources of data from the forest owners themselves, from forest professionals and from local stakeholders increases the information flow (Fortmann and Ballard 2011).

The Metsaan.fi e-service is an example of the domination of the technical knowledge system and scientific-technical approach (see Chapter 3.3) in forest management, as it is a technical system that combines codified knowledge from several technical knowledge management systems (e.g. databases from different authorities) and makes them available for forest owners. In the system, the codified, timber resource-related knowledge and management suggestions dominate and there is only little space for other types of knowledge and forest values. As Metsaan.fi was developed to encourage forest owners to manage their forests and make informed decisions about them (Valonen et al. 2019, p. 21), the emphasis placed on information concerning forest resources rather than balanced knowledge about forests may steer the decision-making to be excessively one-sided or it may pose a threat to the policy goals of more active forest management and use by alienating forest owners who do not aim for timber production (Häyrinen et al. 2015). Development of new tools for decision support services is important and desirable, but they should better meet the diverse needs of current forest owners.

It also raises the question of whether this approach of recommending only certain kinds of management is suitable for a governmental organisation that is supposed to offer the service equally for all forest owners, independent of their objectives. The strong emphasis on promoting timber production and harvests may also jeopardise the legitimacy of the service in society at large. All in all, it does not appear to be a neutral or balanced premise for developing an information and decision support tool for pluralistic groups of forest owners. Because the Metsaan.fi e-service is a state-funded service for forest owners, it should help maximise the societal benefits gained from forests. In the light of current societal discussion, the benefits for the entire society are not maximised by maximising harvesting, but maximising the provision of multiple ecosystem services, including timber along with carbon sequestration, biodiversity protection and maintaining high water quality, just to name few.

As important as it is to invite more and new forest owners to register to the service, it is equally important to ensure that already registered customers can implement the service in their forest management regimes and hence become active users. Many forest owners found the discontinuity between their forest management plans and the service content as a barrier of active usage of service. This distinct discrepancy between the information offered in the service and the expectations of forest owners to use the service as a substitute for their forest management plans diminishes the efficiency of the service. Using the rather one-sided information of the service for decision support, without simulating and comparing between possible alternatives as in forest management plans, may decrease the possibilities to plan for and strengthen the sustainability in total. The service should better communicate the forest owners the differences between its content and forest management plans. Besides that, special effort should be paid to ensure the providing of relevant information for multi-objective and sustainable forest uses for all forest owners.

7.4 Role of organisations in creating change

Lack of owner-orientedness in the service offerings and many of the discontinuities in the knowledge flows by service providers implementing forest owners' forest management decisions can be traced to organisational norms and practices, and the institutionalised conventions of the forest sector (Maier and Winkel 2017). Changes in way decision support services are produced require changes in the knowledge structures and instructions that organisations follow, along with actual willingness to take forest owner objectives and societal demands for biodiversity conservation into account (Hokajärvi et al. 2009). Changing the practices for multi-objectivity is impossible if timber production or procurement remains the dominating goal of the organisations (Ollonqvist 2001; Keto-Tokoi and Kuuluvainen 2010). Increasing knowledge about biodiversity alone does not change the behaviour of the companies that aim to maximise timber yield (Peltola 2013).

Organisations are characterised by predetermined goals, rules and regulations and an authority structure, and hence the chances of an individual employee changing an organisation's behaviour is relatively limited with the prescribed roles and informal patterns (Rogers 2003, p. 433). One example of this is the lack of advice given to forest owners about biodiversity conservation. Skipping the biodiversity related advising was reasoned among others with the timber procurement targets of service providers and pressure to make better profits. The performance targets given to the employees in an organisation usually reward for maximising the hectares planned or cubic metres purchased (Peltola and Tuomisaari 2016). Inquiring about forest owner preferences may be considered a burden that hampers a forest planner from achieving their "real goals", meaning the daily amount of hectares inventoried (Hokajärvi et al. 2009). The forest professionals in my data recognised the need to operate in an owner-oriented manner, but organisational structures, meaning the financial targets of the organisation and the IT systems developed for timber production and procurement did not support this. Hokajärvi et al. (2009) made the same conclusion. Organisations systematically underperform on goals that are hard to measure, such as providing advice about biodiversity measures or targets that conflict with more easily measured goals, such as cubic metres of procured timber (Biber 2009). When an organisation rewards an employee for achieving set targets, the hard-to-measure goals in the decision-making will be consistently abandoned in favour of easily measured goals (Biber 2009). Balancing the financial targets of an employee with targets concerning customer satisfaction and biodiversity conservation measures would ensure that individual professionals have the possibility of genuinely advising and planning for those objectives as well. However, although organisations are also able to measure other types of performance besides timber production, the organisation's missions, historical inertia and the employer's professional orientation hamper any practical changes (Biber 2009). The problem is in no way distinctive solely to the forest sector. For example, in his study concerning a Finnish logistics company, Stenberg (2012) found similar factors hindering knowledge distribution as were found in this study. These factors relate to focusing performance rewarding, staff attitudes and resistance to change as well as to challenges due to cooperation and knowledge gaps.

Primmer (2010) identified organisational inertia as one barrier preventing the implementation of biodiversity conservation practices in the operations of forest service providers. Biodiversity conservation has been approached with a hierarchical order and standardised approach, where professional norms may also create pressure for uniformity (Primmer 2010) and cause friction when adopting a new concept (Saarikoski et al. 2018). The inertia may

originate from the sector's disinterest towards the social demand for conservation (Maier and Winkel 2017) or be a result of the low value given to biodiversity within the organisations (Primmer 2010). Waylen et al . (2015) describe institutional inertia as "stickiness" that arises from legacy effects of social-ecological system. Legacy effect is the influence of the past on current ways of operating (Waylen et al. 2015), and when the constraint caused is strong, they are typically referred as path dependency (North 1991), or lock-in. Three kinds of sticking points can be differentiated: institutional, cognitive and political (Waylen et al. 2015). Institutional sticking points are formal rules and informal norms that arise from previous ways of working, cognitive sticking points derive from pre-existing ways of framing problems and knowing, and political sticking points arise from the prevailing power relations and tendency of those powerful to defend their prevailing interests (Waylen et al. 2015).

Prevailing interests and accustomed ways of thinking can produce strong resistance to change (Waylen et al. 2015). In addition to these cognitive sticking points, the burden of day-to-day commitments and responsibilities lead the professionals to stick to their routines and established practices and hence increase organisational inertia (Saarikoski et al. 2018). New ideas and practices may be risky and require experimentation before they can be incorporated into business models (Saarikoski et al. 2018). The choice of practices may also be already limited by the lock-in of certain goals over others due to history, organisational culture or economic pressure, even if they are against the current outspoken agenda of an organisation (Biber 2009). Organisations ruling over land management are commonly perceived as reluctant to participate in new initiatives for environmental management hence new approaches may require changing their plans (Waylen et al. 2015). Organisations are generally worse at adopting and implementing innovations than individuals are, as stable organisational structures may resist the implementation (Rogers 2003, p. 179). Larger organisations are in general more innovative, although smaller companies have the benefit of flexibility and low level of bureaucracy (Rogers 2003, pp. 409–410). In Finnish context the consolidation development of forest management associations into larger units can release resources for innovativeness and developing the working practices as the social norms and practice are anyway in flux when organisations are amalgamated. Developing markets for other forest uses and products than timber would encourage companies to invest on services related to those. State-driven services such as Metsaan.fi could play a stronger role in establishing knowledge base for such services. Understanding biodiversity knowledge as a strategic company asset that can be used to gain competitive advantage (Grant 1996) would help change organisational goals. Enhancing knowledge flows could also financially benefit the companies and increase their competitiveness. This could also encourage them to invest in enhanced management of encapsulated and tacit knowledge.

The need for better knowledge management and utilisation has been acknowledged and new practices have already been introduced in service-providing organisations. In my data, examples of these practices include checking biodiversity hotspot locations from the forest authority office or from the organisation's own database, and enquiring about the forest owner's preferences well before forest planning begins. This indicates changes occurring in the social knowledge system and the organisational norms about how the work is conducted. Hokajärvi et al. (2009) also identified the potential for change and adaptability for more diverse forest management, although they observed the potential for conflicts within the process too. They may also implicate changes in the domination of the technical knowledge system and codified knowledge, as the importance of searching for information from various

sources is acknowledged. The functioning of the social knowledge system could be reinforced by informal communication channels like e-mail, intranet and coffee table discussions (Bhatt 2001). Implementing organizational structures and practices that encourage knowledge exchange and learning between employees, would also enhance the flow of encapsulated and tacit knowledge (Stenberg 2012) and hence balance the utilization of different forms of knowledge. This could be approached, for example, via intra-organizational knowledge-sharing software, dedicated knowledge-co-construction events, employee exchange programmes, and informal work-unit cross-pollination practices.

Organisational practices and social norms can be changed with education and training that help to develop new knowledge and create new mindsets to transcend the established professional norms. It is important that the uptake of these new practices is supported within the organisation (Saarikoski et al. 2018), because an individual employee cannot adopt a new idea or work practice until their organisation has adopted it (Rogers 2003, p. 402). External aid is useful and even necessary to conduct such transformations (Hokajärvi et al. 2009). Continuous in-house training should be offered not only on substance of the work but also aiming to develop organisations' ways of working.

Diversification of forest uses should be stimulated through learning and innovation within local networks, and by fostering co-operation and collective structures (Primmer and Wolf 2009) within and between organisations. Shifting to an owner-oriented work mode and multi-objective forest management can be considered a radical innovation representing a new paradigm in an organisation that has mainly operated with the goal of producing and procuring timber in the most efficient manner. Such radical changes require the acquisition of new knowledge by an individual and new knowledge management practices by an organisation. The more new knowledge is needed for a new practice, the more difficult its adoption is (Rogers 2003, p. 426). Implementation of a new practice in an organisation requires changes foremost in the social knowledge system as new ways of working need to be socially formed and jointly accepted (Rogers 2003, p. 428). Establishing practices that enhance the flow of encapsulated and tacit knowledge and add interconnectedness of employees are beneficial also for innovativeness, as the level of knowledge exchange affects the level of innovativeness (Hansen et al. 2006). However, more research is needed concerning the ways to reduce the organisational inertia in implementing new practices.

The forest sector culture in Nordic countries has historically been male-dominated, and the forestry end of the value chain seems to have remained the most masculine (Larasatie et al. 2019). Currently women make up 21% of the salaried personnel in FMAs and 35% in the Finnish Forest Centre (Vennesland et al. 2019). The share of women by the large companies is similar (e.g. 21% at UPM whole concern (UPM 2019) and 26% of all employees at Stora Enso (Stora Enso 2019)). The share of women working with forest owners is expected to be lower than their share of all personnel as the share of women from the members of the Forestry Expert Association (trade union for forest engineers) is 17% (Vennesland et al. 2019). Homogeneity and formation of gendered practices participates in setting the social norms and practices in an organisation and thus they may hinder institutional change (Baublyte et al. 2019). Herring (2009) found that homogeneity of the workforce may lead to less adaptability and innovation in his study about US for-profit businesses, whereas gender and racial diversity is associated with more customers, increased sales revenue, larger market share and larger relative profits. Women as forest owners may be more prone to do business with another women, as consumers are found to have firm in-group preferences for interaction between customers and workers (Black et al. 1996). Suopajärvi (2009, p. 265) found that female

professionals were considered to better understand the needs and interests of female forest owners in her study about Finnish forest professionals. Women are in general associated with characters considered feminine such as better communication skills, which are utilised e.g. in resolving conflicts (Suopajärvi 2009, pp. 263–265). Growth and innovation in an organisation are dependent on its employees with diverse backgrounds working together and capitalising on their differences (Herring 2009), resulting in better resources for problem solving (Cox 2001). With increasing diversity in the background of forest owners the business may benefit from diversity in the workforce, even when the changes in the organisation's composition make the incumbent members uncomfortable (Herring 2009). For adapting to future needs more diverse company culture is evidently required in all organisational levels and concerning not only gender (Baublyte et al. 2019). More research is needed about the effects of diversity and inclusion with expert level on the profitability of companies, as the research interests has focused mainly on top level management (see e.g. Larasatie et al. 2019).

7.5 The road ahead - how to respond to societal changes?

Finnish forest policy is built predominantly on the idea of intense forest utilisation. Progressive timber management and economic sustainability of forest use have dominated policy formulation until 1990s, when international commitments on ecological sustainability emerged (Ollonqvist 2002). The multiple-use principle was adapted into forest policy during the Forest 2000 –programme (Metsä 2000 ohjelmajaosto 1985) in 1985 (Ollonqvist 2002), and since then it has been the most influential policy paradigm in Finnish forest policy and forest management. However, the continuing prioritisation of economic profit through timber production and the collective power of traditional forestry stakeholders to preserve their benefits are still prevailing and have made the shift towards wider policy objectives a struggle (Selby and Karppinen 1998; Keto-Tokoi and Kuuluvainen 2010; Schulz et al. 2014).

The dominance of profitability and timber production as priority forest use methods has been veiled in the paradigm of multi-objective forestry (Takala et al. 2017a, b). The integration of biodiversity conservation into forestry practices has been carried out in a way that has subsumed it into mainstream forestry (Primmer 2010). The 2019 updated version of the National Forest Strategy 2025 emphasises active forest use, active forestry and activating forest owners to use their forests (Ministry of Agruculture and Forestry 2019). Three strategic goals of the strategy all aim at better utilisation of the forests. Forest conservation is mentioned in a footnote as being included in the active use of forests. In contrast, the intrinsic values of forest ecosystems or forest nature are only mentioned once ["Metsäluonnolla on itseisarvoa"] (Ministry of Agruculture and Forestry 2019, p. 61). Forest biodiversity is considered the foundation for utilising forests, but not really important as such. The strategy recognises the versatility of forest owner objectives, yet it aims at activating all forest owners to use their forests for making business, preferably timber production. In the same manner, Holmgren and Arora-Jonsson (2015) identified the Swedish discussion about an "active forest owner" meaning predominantly owners that take measures needed for timber production and harvesting.

Several studies have identified the prevailing hegemonic discourse about "good forest management" aiming for timber production describing the normal and appropriate forest use (e.g. Vainio and Paloniemi 2013; Takala et al. 2017b). The activation discourse in the policy

is part of this discourse as well. For example, the Finnish Forest Centre annually reports on forest management backlogs that emerge when a forest owner does not conduct young stand clearance in their forests according to the guidelines for good forest management. That discussion presumes that all forests are managed for timber production and does not take into account other ways to own forestland. Prioritising one forest use over others in a hegemonic manner restricts certain forest owners' possibilities of realising their objectives for their forests, and creates social tensions in regions where forests have socio-economic importance (Takala et al. 2017b). Hence, society in general should be more open to different ways of owning and managing forests (Takala et al. 2017b). As the demands from individual forest owners and society on forest use versatility are inevitably growing, the forest sector sticking to old goals risks jeopardising the acceptability of forest use and alienating those forest owners who do not prioritise timber production. The professionals working with private forest owners are in a key position in maintaining or restructuring forest discourse and forest management practices (Takala et al. 2017b).

As the sustainable management of natural resources is a complex question with conflicting goals and intertwined interests, solving these questions requires collaboration and compromising from all parties. Natural resource governance should be outlined to foster cooperation and collective structures that support adaptation to changing environment, and to stimulate diversification of action based on local initiatives, knowledge and networks (Primmer and Wolf 2009). Mutual acceptance of diverse knowledge bases and understandings of the world, and respecting each other's legitimacy as actors are needed for collaboration that enhances the decision-making and implementation of sustainable use of natural resources (Tengö et al. 2014). Knowledge exchange with other forest service providers and forestry actors is also good for the business: Rametsteiner and Weiss (2006) found communication with the customers and suppliers or sub-contractors to support the innovativeness of the companies. To ensure the sustainability of use of private forests, enhancing co-operation for better knowledge use is still needed within and between forest service providers and forest and environmental administration as well as with forest owners and local representativeness of civil society and scientists (Primmer and Wolf 2009).

The hegemonic position of even-aged timber production as the most prioritised forest use seems to slowly be giving way. Takala et al. (2017b) found discourses that challenge the timber production and ethos of good forest management among forest owners. Häyrinen et al. (2017) reported forest owners being frustrated with the services only focusing on intensive timber production. The legitimacy of clear cuttings has been loudly questioned both by forest owners and by the wider society (Valkeapää 2014; Hölttä et al. 2018). Socio-cultural values have traditionally been overlooked in Finnish public forest policy (Keto-Tokoi and Kuuluvainen 2010, pp. 272–274), but the current increase in discussion and research concerning forest or nature relationships (see e.g. Pynnönen et al. 2018) and the versatile understandings individuals have about forests is expected to also be reflected in the wider forest policy agenda. More research is needed about the socio-cultural understanding and emotional aspects of forests by urbanised, new forest owner generations along with the wider society facing the threats of climate change and diminishing biodiversity. Further on this positive note, forest discourses can be changed by actors who consciously or unconsciously challenge the notions about forest owners and forest use, and these can be forest owners themselves or other actors (Takala et al. 2017b).

To maintain the social acceptability of forest utilisation for timber production and to enable the involvement of forest owners with multiple objectives in timber sales, the multiple-

use principle of forests should materialise from political rhetoric into action (Takala et al. 2017a). The future viability of the forest sector has been connected to the ability to fulfil the expectations concerning multi-objective forest uses (Häyrinen et al. 2017). As current forest practices called multi-objective forestry have not been capable of halting the loss of biodiversity in production forests, the credibility of the sustainability of Finnish forestry has been questioned. The long history of forestry in boreal countries, such as Finland, has created a well-established system of and accrued expertise in forest management, with which the development and implementation of management practices promoting diverse benefits and biodiversity is possible (Moen et al. 2014). The forest sector is considered to have a broad range of opportunities for renewing its businesses. However, capitalising these opportunities requires radical new thinking and a mindset change for the entire forest sector, including forest policy formulation (Häyrinen et al. 2017).

Also research plays on important role in renewal of the forest sector and to better contribute to solving the future challenges more research and theory development is needed. Development of survey methods is needed to overcome current challenges with declining response rates. Mail surveys can be made more complete with phone interviews (Paloniemi et al. 2018) although it requires resources. Underrepresented groups may be reached with special sample arrangements (see e.g. Gretschel and Myllyniemi 2017). Development of statistical methods to better deal with missing data are needed. Triangulation of data, analysis and methods (Denzin 1970) reduces bias as it involves several perspectives into the research. Research about the functioning of social knowledge system in a more digitalised communication environment, possibilities of e-service platforms in development of co-operation over holding levels, and how organisations overcome inertia and shift their services towards owner-orientation should be conducted. Because forest companies are an important service provider to forest owners, their participation in future research would be beneficial. In forest related research particularly taking the gender into account more thoroughly as possible source of bias is needed. When research is expected to be involved in development of practices in society, as in transformative research, reformulation of the role of a researcher as active participant rather than objective outside observer is needed.

8 CONCLUSIONS

I have studied the decision support services and the knowledge used for them in Finnish privately owned forests. The interdisciplinary research employs theories from knowledge management and the diffusion of service innovations, and the analysis has been framed into forest owner studies and forest management planning studies.

My findings show an evident discontinuity between forest owner needs for information and advice about their forests and the service offered by the forest sector organisations. The decision support services, i.e. forest management planning and more importantly the advice provided on the implementation of forest owner's decisions, have not been renewed at the same pace as changes have occurred in the objectives and management preferences of forest owners and the expectations placed on the forest sector by society by large. The decision support services serve the needs of timber production considerably better than those of other forest uses such as biodiversity conservation or recreational objectives. Further results show that the technical knowledge system and forest resource data dominate in the decision making

about and implementation of forest management activities, whereas other knowledge forms and types, most clearly the biodiversity-related nature knowledge and local knowledge concerning forest owner's management preferences are often considered additional and not equally important. Organisations are found to disregard the importance of the social knowledge system and thus the importance of encapsulated and tacit knowledge are also misunderstood.

Based on my results, I can assume that the management decisions concerning Finnish privately owned forests may too frequently be made based on rather one-sided or not the best possible knowledge. Forest sector organisations play the most important role in the renewal of forestry practices and in achieving owner-orientedness in the decision support services. In order to support the organisations in restructuring their activities and knowledge management practices a practice-oriented yet scientifically rigorous research is needed. Based on the results of this thesis and previous literature, acknowledging the willingness for close-to-nature management of forests and conservation of biodiversity will also distinctly enhance the state of biodiversity conservation in Finnish forests.

Forest service providers, both the administration and market-oriented actors, play an essential role in altering the information services offered to forest owners and then forest management practices. Shifting to genuinely owner-oriented and ecologically sustainable forest management requires a change in the mindset and internal practices of organisations. Unless forest owner's objectives besides timber production are acknowledged as equal with timber production targets, it is unlikely that they will be fully recognised in the decision support services and consequently implemented in forest management activities and timber harvesting.

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Appendix 1

Table 1. Focus group participants. Three parallel groups were organized in each location. (Table modified from Salomaa et al. (2016)).

Stakeholder	Somero	Joensuu	Virrat[3]
Scientist	3[4]	3	3
Landowner	3	7	3
Environmental administration (ELY Centre for Economic Development, Transport, and the Environment)	2	1	1
Forest administration (Forest Centre or Ministry of Agriculture and Forestry)	3	4	2
Forest Management Association (Forest owner association)	3	4	3
Nature conservation NGO	3	-	1
The Central Union of Agricultural Producers and Forest Owners	1	-	1
Regional Council	1	1	-
Tapio (consulting services) [1]	2	-	-
Metsähallitus[2]	1	1	-
Communications entrepreneur	-	-	1
Inventory maker/consultant	2	-	-
Total of participants 60	24	21	15
of which female (excluding the scientist facilitating the discussion)	10	10	4
of which male (excluding the scientist facilitating the discussion)	14	11	11

[1]Tapio consulting services provides solutions for efficient and sustainable forest management and bio 829 economy both for public and private sector.

[2]Metsähallitus administers the state forests; it runs business activities but is also responsible for public services of protected areas

[3]In Virrat one of the local organizers has taken part in one of the discussions and hence the number of participants differs from (Salomaa et al. 2016). The first author has participated in one discussion: the author is listed as a scientist in the participant list, but their contributions have been left out of the analysis.

[4] The last author has participated in one of the Somero discussions: the author is listed as a scientist in the participant list, but their contributions to the discussion have also been left out of the analysis.

Table 2. Training workshop participants (excluding the scientist and local organizers)

Participants	Huittinen	Savonlinna	Vierumäki[1]
Forest advisor (advisory services for forest owners)	3	5	-
Forest planner (field inventories and forest management plans)	5	5	--
Managers (managerial tasks within the FMAs)	1	2	-
Number of represented organisations	8	4	-
Total number of participants	9	12	14
of which female (excluding the scientist facilitating the discussion)	2	1	
of which male (excluding the scientist facilitating the discussion)	7	11	

[1] The Vierumäki workshop was organized as part of a larger training event for forest management planners. There were participants from every part of country, all working with the tasks of forest management planning (FMP). This part of the data is from two discussion groups, to discuss same issues of motivations to take multi-objectivity better into account in the planning of forest use and practices to enhance knowledge use in forest management. Before the group work there was an introductory presentation about the themes for the entire group of event participants. Each of these two discussion groups had about seven participants, both men and women. Other event participants took part in other group discussions with other FMP related themes (e.g. use of remote sensing data as source data for FMP). Researchers facilitated the discussions and took notes. After the group work the results were discussed in plenary. All training days were followed by field trips (in the afternoon or the following day) where the themes were further discussed in the more concrete cases.