Norwegian University of Life Sciences
Faculty of Environmental Sciences
and Natural Resource Management

Philosophiae Doctor (PhD)
Thesis 2019:38

# Forestry and forest management in an uncertain environment – adaptation to climate change in Norwegian forestry

## Skog og skogbehandling når usikkerheten øker – klimatilpasning i norsk skogbruk

Kaja Mathilde Aamodt Heltorp

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# Preface

This thesis is one of the requirements for the degree of Philosophiæ Doctor (PhD) at the Norwegian University of Life Sciences' Department of Ecology and Natural Resource Management. The Norwegian University of Life Sciences funded this PhD project. In addition, Nordic Forest Research (NOFOBE) funded a short secondment with the University of Eastern Finland in Joensuu. My darling husband funded the better part of a longer secondment with the University of Helsinki in the autumn of 2017, with contributions from Skogbrukets Utviklingsfond and NMBU.

The thesis consists of four research papers in various stages of completion, and a synopsis that presents the context of these research papers. The research papers are:

*Do forest decision-makers in Southeastern Norway adapt forest management to climate change?*
(Published)

*Forest management and climate change – forest owner perceptions in Norway and Sweden.*
(In review)

*Quantifying the effect of beliefs, observations, risk perceptions*
*and information on climate change adaptation*.
(Draft of manuscript)

*Who and what to trust: Norwegian forestry decision-makers'*
*interpretations of climate change information*

(Draft of manuscript)

‘

*Fra Landbrukshøyskolens fane:*

Aandens Tugt over Mold
til Foryngende Frugt.

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# Sammendrag

Den overordnede målsetningen for dette doktorgradsarbeidet har vært å studere om, hvordan, og hvorfor (ikke) usikkerhet og risiko påvirker/kan påvirke norske ikke-industrielle skogeieres skogbehandling og dermed også skogen i Norge.

For å kunne besvare denne problemstillingen, ble det gjennomført to data-innsamlinger. Først, en kvalitativ datainnsamling basert på 10 fokus gruppe intervjuer med til sammen 54 deltagere. Deltagerne var enten eiere, forvaltere, eller ansatte (for eksempel skogbruksledere) i de norsk skogeierforeningene på Østlandet. Administrativt ansatte i foreningene hjalp til å finne intervjukandidater.

Intervjuene var semi-strukturerte, slik at rammene for hvert intervju var relativt frie. Intervjuguiden som ble brukt var basert på forskningslitteratur på området. Intervjuene ble tatt opp på lydbånd, transkribert, kodet og analysert og danner grunnlaget for to av artiklene i denne avhandlingen.

Den andre datainnsamlingen ble gjort gjennom en spørreundersøkelse distribuert til tilfeldig trukne medlemmer av skogeierorganisasjonene i Norge og Sverige. Undersøkelsen var relativt omfattende, og inneholdt spørsmål om for eksempel tro på klimaendringer, opplevelser og observasjoner, oppfatninger av risiko, behov for rådgivning og skogbehandling når klimaet endrer seg. Undersøkelsen mottok 1745 svar, noe som utgjorde en svarprosent på omtrent 17.5%. Dataene fra spørreundersøkelsen danner grunnlaget for to av artiklene i denne avhandlingen.

Resultatene fra de to datainnsamlingene, sett i sammenheng, gir ikke grunnlag for å anta at det pågår noen større klima-tilpasning av skogbehandlingen eller skogen i Norge. I fokusgruppeintervjuene kom det frem at endring av skogstruktur og treslag sammensetning var uaktuelt for de fleste deltagerne. Dette var ikke fordi deltagerne ikke kunne gjøre dette, men fordi de ikke så behovet og fordi det ville begrense effektivitet og inntektspotensialet. Men, skogeiere og forvaltere og rådgivere tilpasser seg likevel til endringer. For eksempel snakket mange av skogforvalterne om hvordan de nå var nøye på å alltid planlegge avvirkning fleksibelt slik at alternativ fantes om vær og fremkommelighet skulle stoppe drift i noen områder. Økt fokus på vei-overvåkning og vedlikehold, på oppgradering av kulverter og på robusthet i nybygde veier var også relativt utbredt. Men, dette ble omstilt som et utslag av opplevde behov, heller enn et utslag av et ønske om å tilpasse seg klimaendringene per se.

Resultatene fra spørreundersøkelsen underbygget inntrykket fra fokusgruppene: få hadde sterke meninger om klimatilpasset skogbehandling, og det mest utbrede svaret når respondentene skulle ta stilling til om de ville vurdere 12 konkrete skogbehandlingsforslag var «ingen mening». Den store andelen «ingen mening» gjør det vanskelig å konkludere om fremtidig skogbehandling, da respondentene jo hverken i særlig stor grad utelukket eller bekreftet at de foreslåtte skogbehandlingene var aktuelle.

Deltagerne i fokusgruppeintervjuene hadde en rekke grunner til at de ikke ønsket, eller opplevde at de kunne, endre skogbehandlingen elle skogen. Først og fremst pekte de på økonomiske hensyn og effektivitets og teknologi-hensyn. Men de var også usikker på om det var noe behov for endring, og de var usikker på om eventuelle tiltak ville ha noen positiv effekt.

Resultatene fra spørreundersøkelsen viste at respondentene, selv om de trodde klimaendringene kom til å forårsake økte skogskader, ikke trodde dette ville ha særlig betydning for inntekts potensiale og fremtidige eiendomsverdier. Det er derfor ikke unaturlig å anta at den opplevde økonomiske risikoen forbundet med klimaendringer kan være relativt lav, og at dette påvirket det opplevde behovet for å iverksette tiltak negativt. Videre hadde en stor andel av respondentene i undersøkelsen forsikret skogen sin, det er derfor mulig at de opplevde at de var finansielt sikret mot økonomiske tap gjennom dette.

# Summary

The overall objective of this thesis is therefore to study whether, how, and why (not) risk and uncertainty related to climate change may (or may not) influence the forest management strategies of forestry decision-makers who own or manage non-industrial private forest holdings in Norway.

To reach this objective, we collected data through focus group interviews and a questionnaire. The 10 focus groups constituted of altogether 54 participants who owned or managed forests or advised owners and managers on forest management in Southeastern Norway. The participants were requited with the assistance of administrative staff in forest owner associations operating in the area.

The interview-guide we used was based on published research articles on climate change adaptation. However, because of a semi-structured design, the frames were still very open and allowed for the participants to discuss rather freely. The interviews was recoded, transcribed, coded and analyzed and this data underlies two of the research papers in this thesis.

The second data-collection was a questionnaire distributed to randomly drawn members of forest owners association's in Norway and Sweden. The questionnaire was relatively comprehensive, with questions about for example climate change beliefs, experiences an observations, risk-perceptions, need for advice and adaptive climate management. The questionnaire received 1745 replies, which constitutes a response rate of approximately 17.5%. The data from the questionnaire underlies two of the research papers in this thesis.

Taken together, the data collected through this thesis does not much reason to assume that Norwegian forests and forestry at present are undergoing any large-scale proactive adaptation process. In the focus group interviews, most participants signaled that they were rather opposed to changing tree-mixture and forest structure. However, they were still reactively adapting to changes. The managers for example talked about how they now, because of the conditions (i.e ground moisture) emphasized flexible harvest planning so that there always were alternative if conditions in some stands did not allow harvest to continue. Increased focus on road surveillance and maintenance, upgrading of culverts, and increased focus on robustness when building new roads were also relatively common, at least among the managers. The implementation of these practices were however driven by experienced need, rather than motivated by wanting to adapt to climate change per se.

The results from the questionnaire supports the results from the focus groups: few respondents had any strong opinions about adaptive management and the most frequent reply when asked to consider 12 adaptive practices was "no opinion". The large proportion of "no opinion" makes it challenging to conclude on how climate change is likely to impact forestry in the future, since few respondents neither rejected nor confirmed most practices.

The focus group participants gave a number of reasons for not wanting or feeling at liberty, to change their forest management. Many of these reasons were associated with income, efficiency, or technology. They were however also uncertain whether there was an actual need for change, and about the positive effect of changing their forest management.

The results from the questionnaire showed that many respondents, even though they believe climate change would increase the damages in their forests, did not envisage this having a negative effect on their forestry income potential and holding value. It is thus not unreasonable to assume that they experienced the financial risk associated with climate change and therefore also the need for adaptation as relatively low. A large proportion of the respondents had also insured their forests, it is thus possible that they felt they already had secured themselves in the events of damage and loss.

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# SYNOPSIS

# 1. Introduction and thesis objective

Forests provide a range of goods and other services to forest owners, forest communities and society in general. Forests are carbon sinks (Pan et al., 2011), and a significant proportion of the accumulation of carbon takes place in boreal forests (Sarmiento et al., 2010), which is the biome with the largest carbon stock in the world (IPCC, 2000). Researchers have called for the adaptation of forestry and forests to challenges posted by climate change, motivated by a range of needs, including mitigating economic risk, ensuring ecological sustainability, continuing the provision of various ecosystem services and preserving forests as carbon sinks (Seidl et al., 2016; Lindner et al., 2014; Kolström et al., 2011). In Norway, non-industrial private forest owners (NIPF) own 79% percent (Statistics Norway, 2019) of the approximately 86620 $km^2$ productive forested land in Norway (NIBIO, 2018). These owners are free to manage their holdings according to their own objectives, within the frames of relatively liberal national regulations (LOV-2005-05-27-31, 2005) and voluntarily certification schemes (PEFC Norway, 2015). Thus, adaptation of forests to climate change in Norway is therefore contingent on non-industrial private forest owners, their employees and their managers.

I am not aware of any research-based studies on climate change adaptation among NIPFs in Norway prior to the studies underlying this thesis. There are, however, examples of studies from Norway that touch upon related elements. Størdal et al. (2007), for example, studied risk perception and risk-coping strategies among non-industrial private forest owners without especially focusing on climate change. Sjølie et al. (2016) studied owners willingness to adjust their management, although not for climate change adapting but for bio-energy purposes.

## 1. *Overall objective*

The overall objective of this thesis is to study whether, how, and why (not) risk and uncertainty related to climate change may (or may not) influence the forest management strategies of forestry decision-makers who own or manage non-industrial private forest holdings in Norway.
I will strive to answer this objective through four research papers:

Paper I explores adaptation, climate change perceptions, and perceptions about adaptation based on in-depth interviews with 10 focus groups consisting of 54 forestry decision-makers. The paper contributes to answer both “whether’, ‘how’ and ‘why/why not’.

Paper II is based on a quantitative survey forestry-decision makers intentions to adapt, with the goal of answering the ‘whether’ and ‘how’ regarding these intentions. In addition, Paper II presents findings for a number of other variables previously linked to adaptation (e.g. belief in climate change, having observed climate change, having knowledge about climate change).

Paper III further explores the ‘why’, by first testing whether there were differences between those prone to adapt and the others in their responses to a number of variables and next by developing generalized linear models based on previous literature and testing these for prediction.

Finally, Paper IV addresses aspects related to both the ‘how’ and the ‘why/why not’, by exploring how the focus group interviews interpret and is affected by the social discourse on climate change.

This thesis will not debate whether forestry decision-makers *should* adapt to climate change, or recommend adaptive strategies, measures or policies. Instead, it will hopefully contribute to the understanding on how forestry decision-makers perceive climate change related risks and adaptation, and provide an indication of whether, and to what extent, a process of adaptation is taking place in Norwegian forestry.

The thesis is structured as follows. The next chapter provides an introduction to the contextual background of the thesis. Then comes a review of the literature on forest owners’ perceptions and adaptation. Chapter 3, contains an overview of the methods used, ontological and epistemological considerations and case study areas. Results, organized as summaries of the research papers, are presented in Chapter 4. Finally, Chapter 5 provides a discussion of the findings. The four research papers with supplementary material underlying this thesis may be found in Appendices I–IV.

# 2. Context and background

## *2.1. Climate change*

In their fifth assessment report, the IPCC (2014) states that humans' influence on climate change is clear, that the recent years emissions of greenhouse gasses, which are the key-drivers of global warming, are the highest in history; and that climate change already has impacted both human and natural systems. For example, the combined land and ocean surface mean annual temperature has increased by 0.85 ˚C between 1880 and 2012, and the last 30-year period between 1983 and 2012 was arguably the warmest in 1400 years in the Northern Hemisphere. The ocean has warmed and pH-levels have decreased, and the worlds' glaciers and the Greenland and Antarctic inland ice sheets are melting. In response to climate change, many species (terrestrial, freshwater and marine) have shifted their geographical range, seasonal activities and migration patterns. According to the IPCC, "… continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems." Even if policymakers worldwide should succeed in limiting the warming to 1.5 ˚C, the impacts on human and natural systems (e.g. forests) will be serious (IPCC, 2018).

Global development (i.e. population growth, socio-economic development and subsequent demand for and consumption of energy and other goods, land use, technological development and innovation) and policy (e.g. the Paris Agreement) will determine the magnitude of future emissions. The projected climate changes presented in the IPCC reports are based on a bundle of scenarios that are, in turn, based on assumptions about global development called 'representative concentration pathways' (RPCs) (van Vuuren et al., 2011), which are entered into general circulation models (GCMs) (Hong & Kanamitsu, 2014). The results are used by climate modelling groups worldwide (i.e. the Coupled Model Intercomparison Project), who provide climate-projections for the IPCC reports.

Global climate models operate on coarse scales (e.g. 100 × 100 $km^2$), so local climate change projections are (empirically or dynamically) based on downscaling using regional climate models (RCMs) that operate on a finer scale (e.g. 12 × 12 $km^2$ or 50 × 50 $km^2$) that can account for regional topography and weather patterns (Hanssen-Bauer et al., 2009). The results from such models are then used as input in impact studies, for example to project impacts on human and natural systems.

### 2.1.1. The cascade of uncertainty

As the future course of the world is uncertain, so are the assumptions underlying climate impact studies regarding the level of future emissions. Moreover, there is variability in the results from different climate models, and between model runs using the same model (Taylor, 2012). Even when the spread in emission scenarios is accounted for, the (quantified) uncertainty associated with the model projections that formed the basis for the fifth IPCC report were nearly identical to that associated with the previous report (Knutti & Sedláček, 2013).

The uncertainty embedded in the chain of climate models, starting with a bundle of uncertain scenarios based on unverifiable assumptions and ending with projections of impacts is sometimes called a "cascade of uncertainty" (Reyer, 2013; Lindner et al., 2014). The "cascade" refers to the fact that the uncertainty associated with outcomes increases for each model in the chain. In addition to the uncertainty associated with the initial input variables (i.e. the scenarios), there is structural uncertainty related to the relationships between variables or with the underlying model assumptions. There is also statistical uncertainty in model parameters due to inaccuracy, sampling errors and measurement errors, and finally uncertainty associated with the results of previous imperfect models used as inputs (Reyer, 2013; Walker et al., 2003).

### 2.1.2. Impacts on European forests

The literature on climate change-related impacts on forests and forestry include reviews and documentation of ongoing changes and trends, for example in productivity, tree species shifts, disturbances and forest health (Lindner et al., 2014; Seidl et al., 2016; Schelhaas et al., 2003). Such studies suggest that plants are responding to changes in the climate (Menzel et al., 2006; Lenoir et al., 2008; Delzon et al., 2013), growth rates are changing (Kauppi et al., 2014; Babst et al., 2013; European Forest Institute, 2012; Piao et al., 2011), and drought-induced mortality has increased (Allen et al., 2009).

Projected physical climate change impacts on European forests include changes in growth and productivity, species suitability, and frequency and intensity of extreme events such as fires and drought, wind- and stormfelling, and insect or pest outbreaks (Lindner et al., 2014). Examples of impact studies includes wind-simulation studies (Blennow et al., 2010; Peltola et al., 2010), fire regime studies (Adams, 2013; de Groot et al., 2013; Liu et al., 2010), and studies of drought (Neuner et al., 2015), pests (Keane et al., 2011; Jönsson et al., 2007), and a combination of several factors (Seidl et al., 2017). Impact assessments focusing on climate change effects on forest ecosystems and the forest sector have also been conducted (e.g. Keenan, 2015). Climate change may also affect market demands, for example through policies promoting replacement of fossil-based with bio-based solutions in industry or wood-based bioenergy, or increased use of wood in construction (Keenan, 2015). Policies designed to for example promote carbon storage, or protect forest ecosystems, species, or water resources which would, if implemented, limit forest owners autonomy are neither not unlikely. Finally, there are a number of studies projecting forest growth and development under climate change. Results from such studies projects increased forest growth in Scandinavia where growth is restricted by temperatures and growing season (e.g. Bergh et al., 2010; Pussinen et al., 2009; Bergh et al., 2003) if growth remains unrestricted by water deficiency (Briceno-Elizondo et al., 2006). Other examples of growth and development studies includes Alam et al. (2008), Kellomäki et al. (2005), and Koca et al. (2006). Such growth and yield studies are often conducted using process-based growth models ,which predict forest growth and development by modelling eco-physical processes (Mäkelä et al., 2000) ,or gap-type models (Bugmann, 2001). Typical for these models, is that the behaviour of a system is derived from a set of functional components and their interactions with each other and with the system environment through physical and mechanistic processes occurring over time (Bossel, 1994; Godfrey, 1983). The eco-physical models project growth as a causal response to a system of eco-physical processes, e.g. photosynthesis, respiration and carbohydrate allocation (Sun et al., 2007; Landsberg, 2003). Thus, such models can describe how these processes may interact given changes in the physical environment (Sun et al., 2007). Traditional growth and yield models derived from data obtained from regular repeated measurements of forest plots or experimental forests on the other hand, are most likely to produce reliable results if future growth-conditions are similar to those under which the data was collected (i.e. not if the climate changes).

Like all models, those used for simulating possible consequences and responses to climate change are imperfect descriptions of the processes they mimic. In addition comes input uncertainty, statistical uncertainty, natural variability, and the cascade of uncertainty associated with the previous models in the chain  (Reyer, 2013; Walker et al., 2003). It is furthermore important to note that most impact studies focus on a limited selection of climate scenarios, and that underlying scenarios vary between studies (Lindner et al., 2014). Model structure can also affect projections. Lindner et al. (2014), for example, show how projections of forest growth (i.e. net primary production) in Europe based on process-based models differ, particularly between models with different assumptions about the effect of atmospheric $CO_2$ levels, by contrasting Reyer et al. (2014) study with Reyer's (2013) review. Due to all the mentioned elements and more, results from studies differ. However, it is, according to Lindner et al. (2014) "clear that uncertainties are inherent to the system we are trying to forecast and thus unavoidable. (….) Decision makers in forest management have to realise that they must take long-lasting management decisions while uncertainty about climate change impacts are still large."

### 2.1.3. Adaptation of forest management

Many have emphasized the necessity for forestry decision-makers to adapt forests and forestry to climate change and increasing risk and uncertainty. For example, Schoene and Bernier (2012) argue that management and conservation "must embrace planned adaptation and mitigation", to be sustainable. Kolström et al. (2011) emphasize that developing adaptation strategies is a matter of urgency, since "… trees regenerated in forest stands today will have to cope with climate conditions that are projected to change drastically throughout their lifetime." They contextualize the necessity of adaptation within the role of forestry in the global biogeochemical cycle and its influence on the climate. Seidl et al. (2016) write that climate change puts pressure on the provision of ecosystem services, and that the potential impact of changes in intensity and frequency of disturbances on ecosystems is of particular concern: the authors advocate for the implementation of management that may increase resilience towards these changes.

According to Bernier and Schoene (2009), forest owners have three main choices in the face of climate change: they can stick to the business-as-usual strategy and base decisions on historical and current climate information, rely on reactive measures when changes that need to be addressed become apparent, or choose to adapt proactively in anticipation of change. Yousefpour et al. (2012) contrast proactive adaptive strategies with business as usual forest management as follows. While adaptive management can involve the specification of a set of decision-making rules dependent on observed trends and beliefs that will (most likely) realize good enough results under likely scenarios, business as usual strategies are designed to handle known variability in growth and hazards and function as long as conditions remains the same. Yousefpour et al. (2017), operate with four adaptation-categories. First, there are two proactive strategies: i.e. trend-adaptive and forward-looking adaptive. The most important difference is that the forward-looking strategy includes constant updating of knowledge and learning. Proactive adaptive actions may entail adjustments in the prevailing forest management regime, or changes that are more radical. Strategies include actively promoting change through, for example, the introduction of new species or by deliberately letting natural adaptive processes unfold; management strategies to increase the robustness of the forest towards impacts; and strategies that may enable the forest to rapidly return to its prior state after disturbances (Bolte et al., 2009; Millar et al., 2007). The condition, value and vulnerability of the stand or forest to expected climate change and the objectives of the forest owner and other stakeholders, i.e. whether the stand is managed for timber production or production of other goods or services, determines the strategies and actions that would be useful in each case. Other authors who have outlined how forests and forestry could be adapted to climate change include Ogden and Innes (2007) and Spittlehouse and Stewart (2004).

Finally, there is studies who focus not on adapting to change, but rather on whether, how and to what extent the use of forests may mitigate climate change. Some focuses on bioenergy (Raymer, 2006; Gustavsson & Madlener, 2003). Others focuses on management for carbon sequestration (Nabuurs et al., 2007; Lemprière et al., 2013; Goodale et al., 2002). Others again focuses on quantifying the effect of substituting fossil-based products with wood-based alternatives (Gustavsson et al., 2006) or on mitigation economics, policy or a combination of these (Sjølie et al., 2013; Hoen & Solberg, 1997; Creutzig et al., 2015).

## 2.2. *Theoretical perspectives on uncertainty, decision-making and adaptation*

The theoretical perspectives presented here have made an implicit rather than explicit impact on the thesis work: they are a backdrop from which have helped interpret, contextualise and hopefully understand the material while working with it.

### 2.2.1. Risk and uncertainty - concepts and definitions

Despite scientists' decades-long interest in uncertainty, there is no scientific consensus on how to define or classify it (Kangas & Kangas, 2004). A common distinction is that between situations where the probability of outcomes are quantified or quantifiable, and situations where outcomes are known but probabilities are not known (Yousefpour et al., 2012; Hildebrandt & Knoke, 2011; Kangas & Kangas, 2004; Knight, 1964). If the probability of possible outcomes is known or may be approximated objectively (e.g. using historical data) or subjectively (e.g. based on expert opinions), this is characterized as situations with risk (Andretta, 2014). A situation where outcomes are known but probability distributions are not, is characterized as a situation with uncertainty or Knightian uncertainty (Knight, 1964). However, after reviewing the literature on risk and uncertainty in forestry, Yousefpour et al. noted that authors have a tendency to use the term "risk" only when there is a possibility of downside events. Brumelle et al. (1990) note that if there is a risk of receiving more of something beneficial than initially expected, this is framed as an opportunity rather than a risk.

Some authors distinguish between types of uncertainty based on the origin of the uncertainty. Such distinctions could for example be between ignorance and uncertainty (i.e. lack of information due to quality of information and beliefs) and random variability (Begg et al., 2014; Ferson & Ginzburg, 1996). Others differentiate between uncertainty due to subjective beliefs and uncertainty due to limited, conflicting, ambiguous or abundant information (Zimmermann, 2000). Different types of risk and uncertainty are associated with different probability theories and decision-making rules (Pasalodos-Tato et al., 2013; Hildebrandt & Knoke, 2011; Kangas & Kangas, 2004). According to Kangas and Kangas (2004), however, the most important point for the decision-makes is not necessarily to make the right assumptions or use "the right" framework, approach, or tool, but rather to not ignore uncertainty when making decisions (Kangas & Kangas, 2004).

### 2.2.2. A conceptual model for the process of making decisions

Technically, a decision is simply a choice between two or several alternatives that may or may not lead to action(s) (Kaufmann & Kaufmann, 2009). Thus, the decision to implement climate change adaptive measures is in principle no different from any other forest management choice or any other decision. A conceptual model of the process leading up to the choice between alternatives may be useful when seeking to analyse and understand how decision makers make decisions. One such conceptual model is that of Simon (1960), who shows how decisions may be regarded as a process composed of three sequential stages. The first stage is searching the environment for conditions that calls for a decision, which Simon (1960), borrowing from the military, named “intelligence”. Secondly, there is a “design” stage, which is inventing, developing and analysing possible courses of action. Finally comes a “choice” stage, where the decision maker selects a particular course. Although intelligence always precede design and design always precedes choice so that the process may be visualized as linear process such as that shown in Figure 1, the author emphasise that the full process of taking a decision may be rather complicated. The design phase may for example call for additional intelligence activities, or intelligence activities associated with solving a problem may generate sub-problems that requires both intelligence, design and choice phases. As Simon (1960) states it: there may be *“wheels within wheels within wheels”*.


*Figure 1 A conceptual choice model*

### 2.2.3. Classical decision theory and rational choice – a normative model

The classical decision model is the cornerstone of many micro-economic models (Vatn, 2007). The assumptions of the model, i.e. rational choice and full information[1] stems from a long Western tradition and has, according to Hoogstra (2008) (p. 23)“… a paradigmatic status in for example (neo-classical) economic theory.” The model is normative, meaning that it shows an ideal approach to decision-making rather than describing how actors in reality make decisions (Kaufmann & Kaufmann, 2009). The core of the model is the assumption that decision-makers are rational in the sense that they with all their decisions seek to maximize their expected utility dependent on budget constraints and their individual preferences, which are context independent. This means that the ranking of preferences for good one and good two are independent of whether or not a third good is available. In addition, context independency implies that preferences are independent of social settings (Vatn, 2007).

For maximisation to be definable, preferences must also be rational in the sense that they need to be complete, transitive and continuous. Preferences is complete if individuals are able to rank all good or bundles of goods (for all x and y, one of the following holds: $x > y$, $x < y$, or $x = y$). Preferences are transitive if the ranking is so that if good one is preferred over good two and good two is preferred

[1] Full information here means that the actor has complete knowledge of the means to end a relationship (Beckert 1996).

over good three, good one must also be preferred over good three (for x, y, and z, where x > y and y > z, then x > z, if x = y and y = z, then x = z). Preferences are continuous if good one is preferred to good two and all other goods that gives utility close to good one must also be preferred to good two: there cannot be any "jumps" in preferences (Hausman, 1992).

It is assumed that decision-makers knows how to reach his objectives, which follows from the standard neoclassical "full information" theorem. It is also assumed that the decision-maker have a stable and known attitude towards risk (Vatn, 2007). The full information theorem means that the decision-maker know of, or may without costs, access all relevant information about the situation, possible action alternatives and outcomes of these alternatives. Risk attitudes guide how decision-makers (with the same preferences regarding outcome) may prioritize between alternative solutions with different associated risks. If the decision-maker chooses actions that may lead to high profit but have a low probability of being realized, he is risk-seeking. If he settles for lower profits with a high probability of realization, he is risk-averse. Then, there is risk-neutral decision-makers, decide between alternatives based expected outcome (determined by expected gain times the probability of the outcome being realized) alone (Kangas et al., 2015).

In summary, a decision-maker that wishes to maximize utility subject to individual preferences, must (as listed in Beyth-Marom et al., 1991):

1. List all possible decision-alternatives.
2. List all possible outcomes off all possible decision-alternatives.
3. Establish the relative utility of each possible outcome.
4. Identify/approximate/assess the probability of each possible outcome of each possible decision alternative.
5. Establish the expected utility of each possible outcome by multiplying relative utility with the probability of this outcome.
6. Identify and choose the best decision-alternative, that is, the decision that maximizes expected utility, subject to their risk attitude.

### 2.2.4. Decision making with risk and uncertainty – methods and examples

Models based on the classical normative decision-making theory, allows the researcher to isolate and study the effect of one or a limited set of stochastic variables, which may offer valuable insights. Thus, for analytical purposes, the models can be very useful. According to Yousefpour et al. (2012), most numerical models applied to forestry-decision problems with risk assumes decision-maker is assumed to be rational and knowledgeable within the scope of the model, i.e. they are rooted in classical decision theory. Thus, the models implicitly assumes that the decision-maker have clear objectives and know all possible outcomes and the probability distributions of the variables that affect the outcome of a management decision, like growth-rates, timber price development and expected climate change impacts.

There are a number of methods to model stochastic process(es), but those most frequently applied in the forest literature are geometric Brownian motion (stochastic process(es) over time) and simply specifying a probability distribution for key variables. The stochastic element is often assumed to be an exogenous factor, i.e. independent of forest management (Yousefpour et al., 2012). However, there are exceptions to this rule. One example is Thorsen and Helles (1998), who modelled risk of windthrow dependent on treatment and showed how the optimal solution differed significantly depending on whether risk was considered endogenously or exogenously.

The following are a small handful of selected decision-making studies in forestry integrating the risk of disturbances. Staupendahl and Möhring (2011), for example, applied the Weibull-distribution when calculating the optimal rotation age for a spruce stand for different levels of risk, early and in the end of the rotation. Zhou (1999) used stochastic optimization to study the effect of risk of mortality on the choice between two regeneration methods (quantified as the variation of the mortality rate assumed to follow a beta-distribution for one choice of regeneration method and the prediction-error for another; stumpage prices and investment costs were assumed to be fixed). Heinonen et al. (2009) used a regression model to predict the critical wind speed for windthrow of different species, using surrounding stands as predictors. Next, they used information on wind conditions and converted the critical wind speeds into wind-damage probabilities, and then calculated mean risk indexes; these were used as a variable in an objective function comparing the effect of minimizing or maximizing it to that of minimizing or maximizing alternative measures for wind risk, with or without cutting targets using heuristic optimization.

Also the decision-making rules applied when there is uncertainty, i.e. probability of outcomes is not known, share elements with classical decision theory. Hildebrandt and Knoke (2011) lists the Maximin-rule, Maximax-rule, Hurwicz-rule, Laplace-rile, Savage-Niehans-rule and Krelle-rule, which differ in their assumptions about the decision-makers preferences, as well-known models for making decisions under uncertainty. The Maxmin-rule, for example, assumes a decision-maker that would choose the alternative that gives him the best possible outcome from the worst possible scenario. If the worst possible climate change scenario were severely increased wind speed and frequency (i.e. more windthrow), he would choose a selection of tree species and combination of age classes would give the best possible outcome in this situation. A decision-maker following the Maximax-rule on the other hand, would choose the age and species-mix that would give the best outcome in the best possible future scenario.

### 2.2.5. Limitations

Models based on classical decision theory are, as mentioned above, very useful for analytical purposes. When seeking to understand actual behaviour, however, their ability to offer insights are limited. There are several reasons for this, out of which only some are included here. One reason is the full information assumption, which it is almost impossible to come even close to satisfy as the future has not yet happened and therefore in principle is unknown and unknowable. Decision-makers are never the less often, at least to some extent, able to project future developments using knowledge, experience, statistical tools, imagination and logic but such "projections" become more uncertain as the time horizon increases, since more variables may interact in ways the decision-maker might not anticipate (Hoogstra, 2008). The length of time-horizons in forestry is unmatched in the business world: rotations may span across centuries rather than years or decades. The relatively fast-growing species Norway spruce (*Picea abies (L). Karst.*)will for example when planted on the bests sites in Norway require more than 50 years to mature[2] (Tveite, 1977). Within 50 years, considerable shifts in the demand for forest-based products, social demands on forests, tax regimes, interest rates, and technology are possible. Considering this, knowing what means to apply to meet a preferred end in 50 years would thus be very impressive.

Even if it were so that this information could be obtained, gathering and interoperating information has a cost in terms of time and effort (at the very least). Information can furthermore be ambiguous, conflicting, unavailable, or challenging to obtain. According to Vatn (2007) the consequence of this is that decision-makers always will be left with the choice between gathering more information and thus come closer to "full overview", or outlining decision alternatives based on limited information they currently have access to, because at every point gathering that additional piece of information may result in better choices. If objective information is available and accessible, this does furthermore not automatically translate into decision-makers interoperating and perceiving the information correctly.

[2] Maturity here means technical maturity.

Evidence for example suggests that even when objective descriptions of it exist, risk may still be subjectively perceived (Hansson, 2010). The classical decision theories assumptions about preferences are also somewhat "problematic". According to Vatn (2007), for example, it is highly doubtful that anyone can know their preferences before having experienced the outcome of them. It is also unlikely that preferences should be independent of context, which is implicit when preferences are assumed stable, as this would mean that what society considers the right or proper decision in a given situation should not affect the choices made.

### 2.2.6. Bounded rationality and satisficing

Unlike the classical decision theory, which is an ideal process rather than a description of how decision-makers actually make decisions, bounded rationality and satisficing is a descriptive decision-model rooted in cognitive psychology (Kaufmann & Kaufmann, 2009). Simon (1979); (1977) and March (1994) shows how humans tend to make simplified cognitive models of problems when interpreting them, making complex problems tractable.

Because humans possess limited information and have limited capacity and time for interoperating it, they will instead of searching for an assessing all information focus on what they consider the most vital bits and mentally exclude what they consider less important (Kaufmann & Kaufmann, 2009). Instead of searching for a decision that maximizes utility, they will furthermore settle for a level of utility that is good enough, and then look for a decision that satisfice (i.e. the word is a combination of satisfy or will suffice) (Kaufmann & Kaufmann, 2009). Defining how targets are set thus becomes an important challenge. Rules of thumb, or behavioural habits, may be regarded as "regularized procedures" that will produce satisfactory levels of utility in a complex world. However, when repeating such acts, the acts may be established as the right way of solving problems and attribute value to the act independent of the initial target. Thus, as people learn from each other and repeats these actions, how to act or decide when specific problem emerges, problem solving may be institutionalized (Vatn, 2007).

Learning from others and developing rules of thumbs may also be a way of increasing the probability of obtaining more certain results when the possible strategies and decisions are many and the outcomes of these decisions hard to assess. Such rules may be seen as expressions for so-called socially tested tacit knowledge. Thus, the decision-makers reduces the time and effort needed in the intelligence phase.

According to Vatn (2007), some have interpreted this model as a way of maximizing utility when information is costly, but this is wrong; what the model is showing is a *"pragmatic, tractable, solution to intractable problems"*. According to March (1994) the concern with success and failure relative to a targeted value rather than optimisation, implies that there is a difference between the perceived risk of loosing something that one already possesses, and something that he or she not yet have "in his pocket". Vatn (2007) points out how this can explain observed deviations between "willingness to pay" and "willingness to accept compensation" throughout the literature.

### 2.2.7. Framing

Mental models of problem situations are always simplifications, which means that decision makers interpret problems and "solve" them in the context of the frames they have assumed. These simplifications are necessary, because even very simple problems may become rather complex if the decision maker take all information related to the problem into account and it does make the decision maker vulnerable for systematic errors of judgement (Kaufmann & Kaufmann, 2009). Bazerman (2002) for example described how participants in a typical experiment chose differently dependent on how the researchers had described the alternatives. When the researchers had described the outcome of a decision with emphasis on what the decision maker would gain, a much larger proportion of the test sample chose this alternative compared to when the same outcome was described emphasizing what the decision makers would lose. Kaufmann and Kaufmann (2009) writes that this shows how there is a tendency among humans to be risk-averse and conservative when the problem is positively formulated and the outcome is described as a gain, but when the problem is a possible loss, humans become risk-loving and bold in their decisions.

### 2.2.8. Prospect theory

Prospect theory (e.g. Tversky & Kahneman, 1992; Kahneman & Tversky, 1979), explains how people assess and choose between alternatives when outcomes are uncertain. Figure 2 shows how the values of potential losses and potential gains is perceived as relative to a reference point, and that this, rather than the probable outcome of the decision *per se*, determines the choices to be made. The theory assumes that the relationship between subjective and objective values takes the form of an s-shape rather than a straight one-to-one line. Thus, the exchange ratio between objective and subjective loss and between subjective and objective gain may be quite different from one to one. Moreover, the theory and the figure shows how decision makers perceive gains and losses for small values as larger than gain and loss for large values. A relevant example could be that few would consider having to pay 1000 NOK more than expected for an apartment advertised with a price of several million NOK a large loss, while the same increase (i.e. 1000 NOK) from for example 4000 to 5000 would according to this theory be considered a very large gain. Finally, it is important to note that the gain part of the curve is concave, while the loss part of the function is convex which indicates that small objective losses subjectively will be perceived as relatively large compared to the same objective gains that subjectively will be perceived as relatively small. losses or gains subjectively will be perceived as larger than the an equally large objective loss.  One particularly interesting consequence of this is the *"escalation of commitment"* (Staw, 1981; 1976) , which is a general mental model of reality as a balanced process where a series of losses is assumed to be followed by a series of wins. This leads people to increase their investment when having experienced loss motivated by wanting to "win it all back (with interests)" and still believing that gaining on the investment is possible. Instead of considering losses as sunk costs, humans have a tendency to consider it investments that they do not want to loose. This pattern or logic is perhaps most easy to envisage in a casino or in the stock exchange market, but Kaufmann and Kaufmann (2009) point out that people invest in all arenas of life and the mechanism of escalating commitment can thus be assumed to apply also for other arenas, both personal and professional.

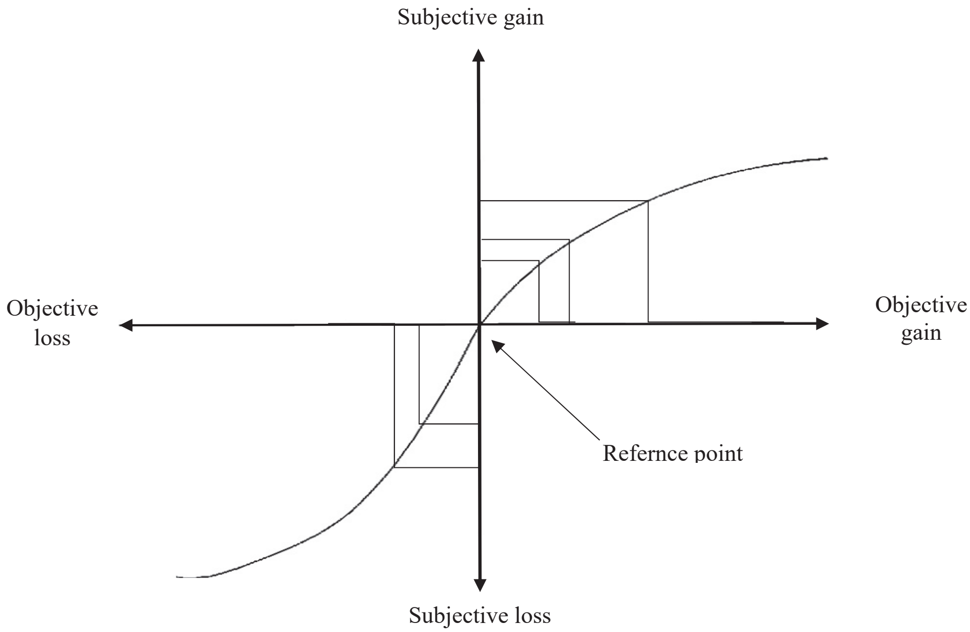


*Figure 2 Prospect theory*

### 2.2.9. General strategies for problem framing - cognitive biases

Many general mental models, or cognitive biases, for assessing probabilities and uncertainties have been identified (e.g. Kahneman & Tversky, 2000; Gigerenzer & Todd, 1999; Tversky & Kahneman, 1974). On one side, cognitive biases allows people to cope with complex situations. However, cognitive biases may also lead to serious misjudgements. Only cognitive biases particularly relevant for decision-making (Kaufmann & Kaufmann, 2009) is mentioned here. One example of such biases are availability heuristics, i.e. estimates of risks based on memory of examples of similar situations. One example of a situations where representative heuristics may be applied is when a decision maker seeks to identify the underlying causes of some event, or the probability that some event or measure will cause some effect. Another is the "base rate fallacy". Base rate fallacy means that people tend to neglect generic general information, and instead base their opinions on specific examples in their environment. How deep impression these examples have made on the decision maker, is influenced by how recent the event happened. A final example of a generic cognitive bias is "anchoring". Anchoring means that a decision maker relates and relies on some piece of initial information that may or that may not be relevant for the situation. The decision maker will have a tendency to interpret new information relative to the anchor (Kaufmann & Kaufmann, 2009).

### 2.2.10. Individual cognition within social frames

Risk perceptions, or perceiving concern and even panic is a well-known motivator of behavioural change. This is because feelings of danger and concern evoke humans affective system, one of two information systems humans are equipped with, which trigger actions and removal from the situation that is perceived dangerous. However, these triggers are triggered by experiences and remembrances of similar previous experiences, not by statistical descriptions of issues. Since climate change is described statistically: as on paper small changes in averages, it has been argued that climate change does not have the ability to evoke the human system that triggers change (Etkin & Ho, 2007). The state of these two variables, i.e. risk-perceptions and having experienced climate change are thus of particular interest when seeking to understand adaptive behaviour. Both risk perceptions and experiences, or appraisal of experiences perceived as risky in the past, plays important parts in the private practice adaptation to climate change model (MPPACC) of Grothmann and Patt (2005) shown in Figure 3.

The outcome of this model is either intention to adapt or avoidant reactions/maladaptation—that is, fatalism, denial of threat or wishful thinking. The model focuses on, and separates out, the psychological steps that individuals undertake when they make the decision to act. According to the model, three external factors influence the cognition process. First is the social discourse on climate change risks and adaptation, which shapes perceptions that influence risk appraisal and adaptation appraisal. Next come eventual external adaptation incentives, which shape perceptions that directly, influence adaptive intention. Third is the individuals' objective adaptive capacity (i.e. available resources like time, money and knowledge), which influences perceptions that in turn influence adaptation appraisal, and also enable or impede adaptation if the outcome is "intention to adapt".

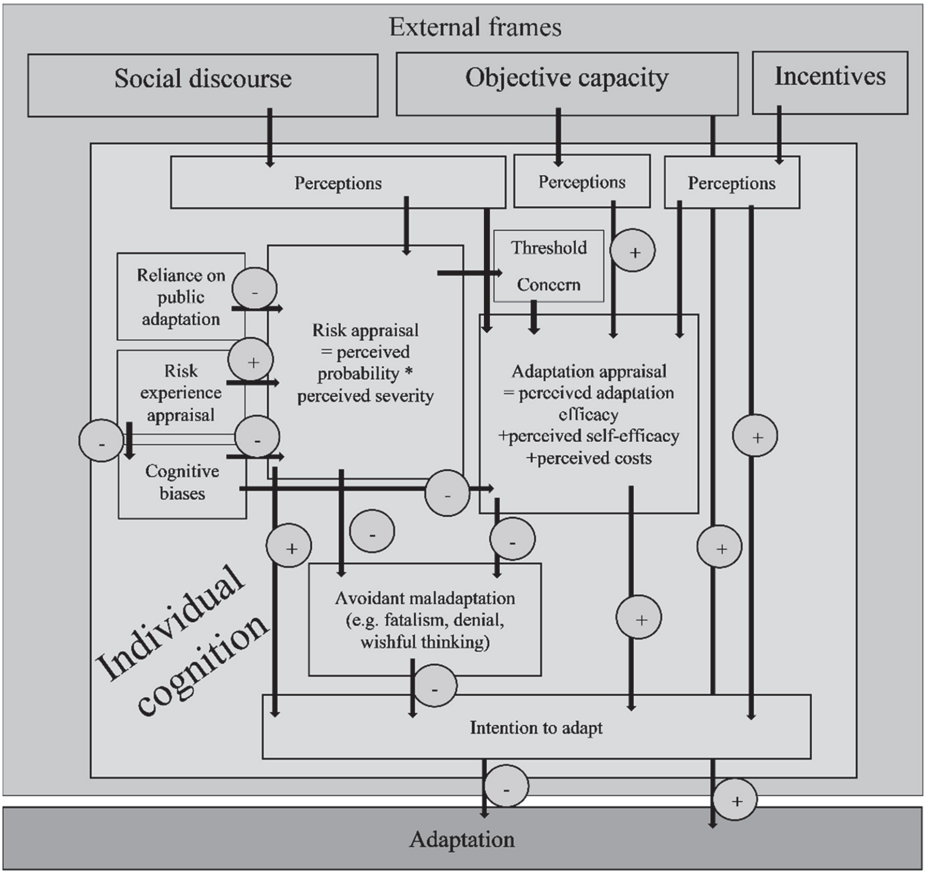


*Figure 3 Process model of private proactive adaptation to climate change (MPPACC)*

There are two main perceptual processes within this model. The first is a risk appraisal process that consists of a stage where individuals assess the probability of negative events occurring, and the probable severity of the consequent impact on objects that he or she values. In addition to being influenced by the individuals' perceptions of the social discourse on climate change risks and adaptation, risk appraisal is influenced by the individuals' reliance on public adaptation and appraisal of experiences, this latter influences the risk appraisal process both directly and through its impact on cognitive biases. Cognitive biases, in turn, are also important for the second main process, adaptation appraisal, which is contingent on the outcome of the risk appraisal process exceeding a certain threshold of concern. Adaptation appraisal has three components: perceived adaptation efficacy (one's assessment of the effectiveness of responses); perceived self-efficacy (one's assessment of one's ability to implement adaptive responses); and perceived adaptive cost (one's assessment of the cost, i.e. money, time, effort or similar, associated with implementing adaptive responses).

Also Moser and Ekstrom (2010), focus on individual cognitive processes within the frames of a society that affects the individual. They provided a framework for identifying barriers (i.e. obstacles the decision-maker can overcome) in the adaptation process that may stop, dilute or delay adaptive processes. The framework is structured according to Simon (1960), and for each sub-stage (see Figure 4) the authors provide a list of common barriers towards adaptation which they identified through a literature review.

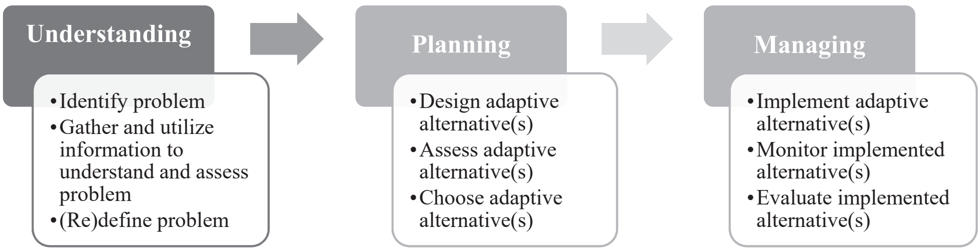


*Figure 4 Conceptual choice model with sub stages*

Taking the first sub-stage of the "understanding phase", i.e. the problem identification phase, potential barriers include the lack of a problem signal (or a weak or ambiguous one) from the forest or society, the decision-maker's failure to detect, perceive or be alarmed by the signal, and the decision-makers cognitive threshold for need and feasibility of response. For the second sub-stage, the gather and use of information phase, potential barriers includes interest and focus of information search, and (objective and subjectively perceived) availability, accessibility, salience/relevance, credibility, trust, legitimacy and respectability to/of information. There are additional potential common barriers throughout all the phases and sup-stages of the model. The common barriers need not arise, but if they do, they must be overcome for the process to continue.

To overcome barriers, it must be understood why the barrier have raised, and its origin. The authors built on the institutional analytical approach of Anderies et al. (2004), and provides a set of questions to identify which part of the interlinked system of the system of concern (e.g. the forest), the decision-makers (e.g. the forest owner, the forest manager) or the government system or society with all its formal and informal structures, the barrier origins. Because the three are linked, barriers that at first sight might appear to be associated with for example the decision-maker (i.e. he or she do not perceive that climate change is threat to the forest), might be dependent on the government system or society (clear communication from officials, discourse in society) to be overcome.

## *2.3. Studies of climate change adaptation in forestry*

A growing body of research-articles within the forestry field explores the role of such cognitive and subjective elements in relation to climate change adaptation. Some of these studies influenced the preparations for data-collection in this thesis. These articles are mentioned explicitly in the methodology chapter. Other articles made a more implicit impact, reading them contributed to the knowledge basis and perception of this field of research. Several of the mentioned articles were published (and others were identified), after the data-collection for this thesis. Such articles were not excluded for literature reviews or discussions and reading them have unavoidably also influenced perceptions while working with the material.

### 2.3.1. Quantitative studies

The qualitative articles in climate change adaptation in forestry presented in this section are based on questionnaires. Concepts being survived varies between articles, so the results from the different article are not necessarily directly comparable. Some articles for example report on propensity to adapt (e.g. Vulturius et al., 2018) and others on proportion already having taken measures to adapt (e.g. Blennow & Persson, 2009), while some focus on aspects related to adaptation, for example variables that impact climate change beliefs (e.g. Blennow et al., 2016). Questions measuring the same, or related variables (e.g. risk perceptions, climate change beliefs), and answer alternatives, are formulated differently in different studies. Reporting of results differ as well, some authors for example provide standardized effect sizes (e.g. André et al., 2017), while others do not. Sampling approaches differ both between studies, and within. While some have chosen their gross sample among the members of forest owners associations (e.g. German and Portuguese samples in Blennow et al., 2012), some have sampled randomly from public owner-databases (e.g. most studies conducted in Sweden), and some have used a snow-ball sampling like approach (Sousa-Silva et al., 2016). Finally, different authors do to varying extent provide for example non-response analysis, analysis of the extent their respondents is representative for the population they are sampled from in terms of for example gender, age, holding-sizes, income from forestry, which make comparisons of results challenging.

Only one such questionnaire-based study has (to the best of my knowledge) been conducted in Norway, prior to the studies conducted for this PhD project. This study, i.e. Størdal et al. (2007), did not focus on climate change adaptation per se, but on risk perceptions and risk-cooping strategies, including risk associated with environmental factors. The data underlying the study was 366 questionnaire-responses from forest owners of the "Mjøs-area" (Inland Norway) collected in 2004, combined with 9 years of logging data. The respondents ranked timber price variability as the main source of risk potentially affecting the economic performance of their property, followed by changes in forest taxes and consumer demand, while environmental forestry aspects received low ranking. The owners preferred to manage risk by seeking advice and services from their forest owners association and by buying insurance. Relationships between variables were explored using factor analysis and multivariate regression. There was a positive relationship between increased size of forest holding and perceived risk and risk management through harvest strategies.

*Variables influencing adaptation*

While research-based knowledge about cognitive variables and adaptation from Norway is scarce, a considerable proportion of the studies underlying the articles in this thesis have been conducted in Norway's nearest neighbouring country, Sweden. One of the first articles that empirically explores the influence of cognitive variables on adaptation was based on Swedish mail-survey data. In this study by Blennow and Persson (2009), NIPFs representing holdings with taxation value of more than 11000 EURO in 2004 sampled by The National Statistical Office of Sweden in two Southern and one Northern areas, answered questions about their climate change beliefs and changed management practices. The questionnaire was sent to 1950 NIPFs, out of which 75% answered. The objective of the article was testing influential theory at the time of the study, namely that climate change adaptation could be seen as "local adjustments to deal with changing conditions within the constraints of the broader economic–social–political arrangements" (definition by Smit & Wandel, 2006). According to the authors, this left no explicit role for cognitive variables like strength of belief in climate change. Using chi-square tests, the authors tested for differences between respondents who reported to have adapted to climate change, and other respondents in strength of belief in climate change and adaptive capacity (i.e. «acknowledged lack of understanding of how they could adapt, or a lack of belief in ways of how to adapt."). There was a significant and positive relationship between strength of belief and having adapted. Forest owners that believed in climate change, but who had not adapted, lacked adaptive capacity. Based on the results, the authors argued that the process of adaptation could not be understood only by analysing economic-social-political variables, but that strength of belief had to be taken into account.

Blennow et al. (2012) confirmed the positive relationship between strength of belief in climate change and adaptation. In addition, they found similar positive relationship between having experienced climate change and adaptation, and identified differences in risk-perceptions between adaptors and non-adaptors. The authors issued a mail-based questionnaire to non-industrial private forest owners in Sweden (Kronoberg), Germany (Schwarzwald) and Portugal (Chamusca) in 2010. The Swedish respondents were randomly sampled among NIPFs registered as owners of holdings larger than 5 ha in the Swedish Real Property Register, while it was sent to all members of regional forest owner organisations in Germany and Portugal. The questionnaire received 379 responses in Sweden, equalling a response-rate of 55.5%, 421 responses in Germany equalling a response-rate of 64.5%, and 71 responses in Portugal equalling a response-rate of 28%. To handle missing values, the authors used a maximum likelihood methodology to impute five full datasets where imputations varied based on uncertainty associated with predictions of the missing values. Then, the authors explored casual relationships between variables using Logistic regression. The fits of the models was evaluated by means of Likelihood Ratio tests and plots of receiver operating characteristics, the best model was chosen based on Akaike's Information Criterion (AIC). Results showed that 19.8% (n=349) of the Swedes, 47.1% (n=410) of the Germans and 53.6% (n=69) of the Portuguese respondents reported have adapted to climate change. Strength of belief in climate change and having experienced climate change had a significant impact on the probability of a respondent having adapted, and this model fitted the data better than a model with only socio-demographic independent variables. Adding variables that reflected household dependency on forest income, education, and nationality improved the fit additionally. Forest owners who had adapted were finally more likely to have selected answers indicating that the risk of damage due to wind, drought, fungi, and insects would be much higher due to climate change.

One of the most recent confirmation of the importance of cognitive variables came in Vulturius et al. (2018). The gross sample for this study consisted of 3000 NIPFs from a database of landowners in Sweden. Out of the 3000 owners, 836 responded. The data for this study was collected through a questionnaire distributed by regular mail, but was also available online. The purpose of this study was testing and comparing the different groups of factors in the model of Grothmann and Patt (2005), to establish the relative influence of subjective factors (i.e. cognitive and experiential), objective adaptive capacity, and socio-demographic variables on the respondents' intention to adapt, and their urgency to do so. Methods applied were simple ordinal and binary logistic regression. The results showed that only the cognitive variables, i.e. the respondents' assessments of climate change-related risks, belief in the salience of climate change in relation to extreme events and trust in climate change science had significant explanatory power on perceived urgency of adaptation. The individuals' risk assessments, experience with risk mitigation, belief in self-efficacy related to knowledge and (perceived) salience of climate change science had a significant impact on the forest owners' intentions to adapt within five years. Age, gender, level of education, income, size of forest holding, dependency on forest income, having experienced recent extreme events, past extreme events, self-efficacy ability, self-efficacy knowledge, having taken measures to mitigate risk, global concern for climate change, and local concern for climate change had no significant impact on the independent variable.

Sousa-Silva et al. (2016) studied impacts of climate change on forests and forest management in Belgium as perceived by Belgian forests owners and professionals. They developed an online questionnaire and distributed it through email, newsletters, and online media, aiming to create a snowball-effect. In total, 391 respondents completed the questionnaire. Out of these, 56% were owners, while the remaining 44% were forest managers. Only 5% rejected that the climate is changing, half the respondents stated that they had experienced climate change or climate change-related events, and 71% believed that climate change would affect their forests through for example extreme events, pests and diseases, or changes in tree species. Most were worried about climate change, and approximately half the sample was even very or extremely worried. However, only 32 % had taken measures to adapt. The respondents' reasons (in descending order) for not adapting were lack of information and technical assistance, lack of knowledge, lack of conviction that adaptive actions are important, and lack of finances. Those who had adapted had most frequently promoted mixed stands, planted better-adapted species or turned to natural regeneration. Drawing on the logistic regression model presented in Blennow et al. (2012), the authors predicted the probability of respondents having taken measures to adapt using belief and experience as independent variables, but concluded that the explanatory power of the model was poor. Adding a variable for "perceived need to be proactive" and another for "perceived positive effect of climate change on forest growth" and variables indicating the presence of constraints, i.e. "lack of knowledge", "lack of finances", "lack of interest in adaptation", "lack of information" and "lack of capacity", significantly improved the fit.

*The effect of scientific numeracy and literacy on concern*

Blennow et al. (2016) tested the effect of high scientific numeracy and literacy and cultural cognition (Kahan et al., 2012; Kahan et al., 2011) on climate change concern. The cultural cognition theory holds that highly educated individuals will be polarized in their concern about climate change, as they possess the means to seek information in accordance with value-based, pre-existing beliefs. The authors used data from a questionnaire distributed to forest owners in Sweden and Germany in 2010, where the Swedish NIPFs were sampled among owners registered with more than 5 ha in the Swedish real Property Register while the Germans were member of a regional forest owner association. The gross sample consisted of 1335 NIPFs, while 766 responded. Questions were designed to ascertain the respondents' educational level, climate change concern and beliefs, and to provide information that would enable the authors to compile value profiles. The authors used 'comprehensive statistical procedures to prepare and analyze the data. The results, show that the "knowledge deficit", namely, that individuals who do not possess scientific literacy and numeracy, i.e. higher education, are less concerned about climate change than those who do, better explains differences among the forest owners, as climate change risk perceptions can be explained without reference to values. Assuming that values will prevail over the influence of higher education under certain circumstances, risk perceptions and higher education should have been negatively correlated; instead, the authors found that risk perceptions were either uncorrelated or sometimes positively correlated with higher education.

*The role of knowledge-sharing networks*

André et al. (2017) studied contextual factors that impact whether forest owners receive and act on knowledge and information about climate change. Based on Moser and Dilling (2007) and Weichselgartner and Kasperson (2010), they argued that lack of information about climate change is not a limitation to decisions-making about climate change adaptation in forestry. Instead, the important questions is "… what knowledge is available, how is it produced and communicated, and to whom?". They furthermore write that researchers need to focus on the context in which decisions are made, identifying who the decision-maker perceive as credible sources of information and the channels they receive information through, and pre-existing mental models. To address this, the authors studied Swedish forest owners' characteristics, the size and heterogeneity of information- and knowledge-sharing networks, perception of climate change-related risks, forest resilience and need for adaptation. They used data from 932 (response rate of 31%) randomly sampled NIPFs, which had been collected through a questionnaire distributed by mail and e-mail in 2014. For comparing frequency and importance of communication with the different members of the NIPFs networks and significance and correlation between network size and heterogeneity, the authors used Spearman's rank order correlation. For exploring relationships between the presence of certain groups in the networks and he NIPFs perceptions, the authors used the (Wilcoxon-) Mann-Witney-U-test. The authors also provide effect sizes. The results from the study showed that respondents most frequently discussed and acquired information about forest management from peers (e.g. family, neighbours, other forest owners), forest owners associations, forest companies and the Swedish Forest Agency. There was a weak but positive correlation between owners' climate change perceptions and the size and heterogeneity of their network. The authors conclude that networks, at present, play only a minor role in knowledge-sharing about climate change adaptation, and emphasize the need to assess the timing of any advice or knowledge offered, due to the infrequent contact between owners and alter groups.

*Proportions having adapted and preferred practices*

Aiming to expand the knowledge on climate adaptation among NIPFs in Sweden, Blennow (2012) analysed data from two questionnaires, one issued in 1999 and the other in 2004. The Regional Forestry Boards sampled 402 NIPFs from two southern municipalities who received the 1999 questionnaire, out of which 40% responded. The 2004 questionnaire was the same as that underlying Blennow and Persson (2009). Thus, the sampling approach has already been described. To test for differences in proportions having adapted and in frequencies of the response “much higher risk than today” in 1999 and 2004, the authors used Chi-square tests. When testing for differences between areas, the authors used Log-linear analysis. Results showed that the proportion of forest owners reporting that they had taken measures to adapt had increased significantly between the two questionnaires, and a larger proportion had taken measures to adapt in the southern part of the country compared to the north. The most frequently implemented action was promotion of mixed forests. Yousefpour and Hanewinkel (2015) used data from a questionnaire to study German forest professionals’ perceptions of risk and uncertainty. They found that 83% of the foresters (n=262) perceived climate change as human-made, but that the majority (70%) did not perceive climate change a very high risk to forestry. Moreover, 97% thought risk to be a part of forestry in general, and most (81%) did not perceive climate change a limitation to management planning. The respondents’ preferred strategy for dealing with climate change risks was promoting resistant e tree species. Storms, frequency of dry years and insect calamities were considered the most disturbing impacts. The majority (72 %) regarded themselves as under-informed about climate change. The respondents’ knowledge about climate change most often came from forestry training, the media, and scientific literature. The respondents regarded support tools like spatially explicit maps with species recommendations and indices of risks as helpful, but believed the potential for forestry to mitigate climate change was low.

In Austria, Mostegl et al. (2017) distributed a questionnaire containing a choice experiment to small-scale forest owners (<20 hectares) to study how this segment of owners perceived the influence of climate change and whether they would “approach required activities”. They found that 57 % of the respondents believed in climate change, and that half the respondents believed climate change would affect their forests and that adaptive measures should be implemented as soon as possible. However, a considerable minority (20%) rejected the idea of climate change as a whole. The authors identified three typologies among their 919 respondents: utility-oriented owners, recreational-oriented owners, and tradition-conscious owners. These three types reacted differently to management options and management incentives, but most, regardless of scenario, favoured some management over no management. Economic incentives did not influence the respondents’ choices to a large extent, and they trusted local forest service providers but rejected national forest services. Many, too, were sceptical towards the use of harvesters, and believed that forest operations should leave as few visible signs in the field as possible. According to the authors, information campaigns aiming to motivate adaptation should focus on soft management, leading to attractive, stable, diverse and resilient stands rather than efficiency and economical gain.

The results from Austria detailed above are somewhat in contrast to the results from the cross-European study of Sousa-Silva et al. (2018). This study was based on questionnaires distributed in Belgium, Estonia, France, Netherlands, Portugal, Romania and Slovakia in 2013 and 2014 (in Romania) and 2015 and 2016 (in the other countries) to compare climate change adaptation in forest management across Europe. The online version of the questionnaire was distributed through social media and email lists targeting forest organizations, while paper versions were distributed at meetings. In total, 1131 owners and other stakeholders answered the questionnaires. The number of responses ranged from 20 in the Netherlands to 391 in Belgium. Most respondents (91 %) considered climate change to be a fact, and the majority (74 %) believed it to be partially or entirely human-made. In addition, 56 % had experienced events in their forests that they believed had been caused by climate change, while most (73 %) expected climate change to cause changes in the future. More than half of the respondents also perceived a need to adapt their management in response to climate change, but despite this, 60 % had not yet made any such changes. There was a significant relationship between perceived need to adapt and adaptation. Those who had adapted their management had most commonly adapted their regeneration strategies. For example, when selecting tree species and varieties, or increased the diversity of species. Economic support, more information and technical assistance were the most-cited requirements for assistance that would increase the respondents' likelihood of implementing adaptive measures. The authors suggest that differences between countries may be linked to the political and socio-economic context, that extreme events may present relevant opportunities to promote changes in management and that the relationship between scientific research and practice needs to be strengthened to foster adaptation.

### 2.3.2. Qualitative studies

Qualitative research, including interview-based studies, offers in-depth knowledge about participants' perceptions, petitions, motivations, thoughts, values, and underlying reasons for thinking and acting the way they do. Thus, interview-based studies offers important nuance and complementation to impressions formed by quantitative research articles. Qualitative studies tend to have smaller sample sizes, and are based on intensive analysis with qualitative aspects (i.e. interpretations and assessments). These are the reason for the nuanced results that facilitates understanding – but also the reason that generalization of results from qualitative research are more challenging than generalization of results from quantitative studies. The qualitative approach are furthermore less structured, and the informants or interview-participant(s) contribute and shape the data-collection state to a much larger extent than what is the case in quantitative research. There is also differences in analyses-strategies and reporting of this. Some authors of qualitative studies include detailed descriptions of approaches to coding and analyses, while others include only brief notes. All this does comparing approaches and results challenging. Considering the long distance between for example Sweden and Oregon, USA the results from the studies presented here, which have been conducted across several countries in the western world over a span of approximately 10 years, are remarkably similar.

*Adaptor profiles and variables influencing adaptive capacity*

van Gameren and Zaccai (2015) studied the adaptive capacity and adaptive practices of private forest owners in Belgium by means of semi-structured interviews with 32 NIPFs, 42 semi-structured interviews with other stakeholders (e.g. forest-based industries, organizations) assumed to influence the owners, a review of sectorial literature and observations on sectorial events. Using a grounded-theory approach in their analysis, they divided the interviewed forest owners into five adaptation profiles. The "innovative adapters" (5 owners) had implemented adaptive strategies and considered climate change in their management. The "no-regret adaptors" (10 owners) had implemented adaptive strategies to mitigate climate change risk but believed these actions would be beneficial either way. "Accidental adaptors" (10 owners) implemented climate-adaptive actions without explicitly considering climate change, instead following another management objective. The fourth profile, the "potential adaptor" (5 owners), had not yet implemented any actions but considered doing so in the future. The final profile, the "non-adaptor" (2 owners), did not plan to implement any adaptive actions. The "innovative" and "no regret" adaptors were knowledgeable about and interested in forest management, had acquired their knowledge through training and reading, were often members of (formal or informal) forestry networks, and more often owners of large holdings. The authors argue that these traits, together with family ties to the holding, being engaged in voluntary certification schemes, having attributed past experiences and changes to climate change, and being concerned about climate change, increased their adaptive capacity.

*Belief in climate change does not (necessarily) motivate perceived need for adaptation*

Bissonnette et al. (2017) interviewed 27 NIPFs in the Canadian province of Quebec to study their perceptions of vulnerability and climate adaptive capacity and understand how these two elements could constitute a barrier towards planned adaptation. The participants named a broad range of risks, but the majority of participants did not consider their forests vulnerable to climate change. Although most participants acknowledged human-made climate change, they perceived it as rather abstract in the forestry context and had no experience-based reference point. The participants framed their capacity to adapt in relation to past experiences, preferring to change management approaches when they identified areas that needed attention rather than pro-actively changing behaviour in anticipation of change.

*Traditional choices prevail in spite of experience and knowledge*

Lidskog and Sjödin (2014) explored forest owners' regeneration choices after the storm Gudrun in 2005, which damaged approximately 2700 km$^2$ hectares of forest, of which 11-1300 km$^2$ had to be regenerated. As spruce is vulnerable to high wind speed (an expected effect of climate change), the Swedish Forest Agency recommended increased planting of deciduous trees and pine to substitute spruce, and issued subsidies making the shifts cost-neutral. Despite recommendations and incentives, and despite having experienced extreme wind and being more aware of wind risk after Gudrun (Ingemarson et al., 2006), the majority chose to replant spruce. By analysing material from four studies (Linné, 2011; Sellerberg, 2011; Guldåker, 2009; Ingemarson et al., 2006), the authors found three main lines of reasoning that had guided owners' choices. Firs, the perception that calamities such as Gudrun are impossible to mitigate. Second, uncertainty related to for example alternative regeneration choices and subsequent management including growth, soil and climate requirements, vulnerability, the roundwood market, the need for change and the effect of climate change. In contrast, the owners considered the planting and management of spruce to be reliable and well understood. Finally, the forest owners considered the short-term economic burden (workload, etc.) associated with changing the dominating species to be higher than the benefits. The authors concluded that owners' decisions were primarily based on "experience, practical and embodied knowledge", that risks, such as the risk of windthrow, were perceived as relatively abstract, and that theoretical knowledge about the future was not considered relevant or reliable enough to impact decisions made in the present

Some of the results from Lidskog and Sjödin (2014), i.e. the position of traditional forestry and the lack of climate-change consideration when making forestry decisions, is echoed in Uggla and Lidskog (2016). They studied climate change, risk management and forest governance from the perspective of support and barriers towards change embedded in traditions and previous management schemes among non-industrial private forest owners. The data for the study were collected through semi-structured, open-ended interviews with 16 NIPFs. The participants were diverse in their knowledge about forestry, all were aware of climate change, and all named risks they associated with climate change. Most had not taken any measures to adapt, however, and one-third had not thought about adapting at all. Many considered increased diversity (i.e. species mixture) beneficial, but only a few had implemented this approach. The respondents had firm ideas about what kind of management they needed to apply to achieve a well-managed, profitable forest (i.e. "best practice"). Climate change was not considered when deciding about pre-commercial thinnings, thinnings, harvest and replanting, as these were understood as necessary forest activities. The authors concluded that awareness of risk and knowledge about how to adapt do not ensure adaptation. Further challenges include the long time horizon, together with uncertainty related to forestry and climate change impacts; previous management strategies (in particular, clearcutting, as it limits management options for present and future rotations); and the respondents' perceptions of alternative strategies as risky and costly barriers towards adaptation. Finally, the authors note that "the dissimilation of knowledge and advice seems to be a rather diffuse process involving various actors, information sources and contexts".

The studies by Boag et al. (2018), Lawrence and Marzano (2014), and Milad et al. (2013) shows that climate change have low salience in decision-making also in other geographical areas than Sweden. Boag et al. (2018) drew on interviews with 50 NIPFs in Oregon, recruited through a non-random self-selection approach making it likely that participants were more interested in forest management than the average owner in the area. The interview-guide contained questions on management goals, management planning, management activities, risk perceptions, belief and attitudes towards climate change, and engagement and resource needs to identify barriers to both planned and incidental adaptation[3]. Although participants had carried out a widespread range of incidental adaptive actions (motivated by other goals than climate change adaptation), climate change adaptation *per se* had low salience among the participants. This was despite the fact that most participants believed that human-made climate change was occurring and had observed local changes that they perceived to be consequences of climate change. The authors concluded that for example place-based education about climate change and adaptation and economic incentives may increase adaptive capacity and promote the resilience of privately-owned forests. Neither Milad et al. (2013) found that climate change had impacted state-of-the-art-management more than marginally. Their study was based on their series of 11 semi-structured in-depth interviews with German forestry professionals, using an interview-guide based on literature reviews on climate change impact on ecosystems and on adaptation and conservation. While participants claimed they considered climate change adaptation when making management choices, adaptive strategies were only implemented to a limited extent. The authors concluded that adaptation still was at an early stage, i.e. merely a supplement to established management for risk-diversification and nature-oriented forestry. Lawrence and Marzano (2014) collected their data through semi-structured interviews with 12 forest managers and advisors in the private forest sector in North Wales. The participants were recruited through a snowball sampling approach. The authors found that respondents perceived the future to be uncertain, but that this uncertainty related to tree diseases rather than to climate change. The managers, in particular, were

[3] Incidental adaptation is, according to the authors results of "synergies between climate-adaptive forest management and actions motivated by goals such as wildfire mitigation, which landowners may prioritize regardless of concerns about climate change".

not convinced of the need to adapt. Respondents believed that forest owners associated climate change adaptation with energy use rather than with forestry and the growing of trees. Further, the forest owners' perceptions of market demand and differing interpretations regarding which species were considered 'native' represented a barrier toward shift of species.

*Uncertainty about observations, cause and effect*

Laakkonen et al. (2018) interviewed 20 Finnish non-industrial forest owners about changes in their forests while walking through them. The interviews included a section of cognitive mapping, where respondents were asked to state all changes they had experienced in forests and forest management throughout the period of their ownership, and identify the cause of the three most important changes. After the walk, the researchers introduced the topic of climate change, and asked the respondents about the effects of climate change on forests and adaptation in the future. In addition, they collected data about the owners' values and climate change perceptions using two questionnaires. Results showed that some of those interviewed rejected climate change as a whole, while the majority were uncertain about how climate change would affect their forests. They also expressed considerable uncertainty about cause and effect, with regards to the changes the forest owners had seen in their forests, and many thought that climate change could be beneficial, as it would lead to increased growth, longer growing seasons and shorter rotations. The researchers found little urgency to modify behaviour: indeed, none of the respondents had implemented changes explicitly to mitigate risks, and their sense of having control over climate change-related impacts on their forests was limited.

*Information, knowledge, and (lack of) trust in information.*

Grotta et al. (2013) conducted 24 focus-group interviews with altogether 165 NIPFs and public managers in the Pacific Northwest region of the U.S. (i.e. Oregon, Washington, Idaho and Alaska). Analysis were organised according to concepts using an inductive approach, and by identifying reoccurring topics, themes and patterns in the data was identified. The authors found climate change to be well known among the participants, who reported having acquired their climate change knowledge from a wide range of sources. Some had actively sought out information, while most had remained passive, acquiring their knowledge through the usual media channels. The participants expressed doubts about the trustworthiness of the information they were exposed to, often perceiving it as biased and based on ambiguous evidence. Although they considered the scientific community to be more trustworthy than the media, many also suspected scientists of being biased. Participants were uncertain about the effects climate change would have on their forests, and did not envisage changing their forest management in response. However, many expressed a need for more knowledge about climate change and about possible effects on forests.

Lack of trust in climate change science or scientists were also one of the findings in the Swedish study by Vulturius and Swartling (2015). In this study, the authors tested the effect of transformative learning (Diduck, 2010; Mezirow, 2008) on foresters' learning and perceptions of climate change. The authors facilitated such learning for groups of forest owners through group discussions and meetings with climate scientists. The study is based on data from group interviews with 27 foresters in four groups who had taken part in the experiment. Results showed that none of the foresters reported feeling an increased sense of urgency, nor did they perceive that what they had learned had direct implications for forestry. The extent to which taking part in the discussion had affected participants' climate change perceptions varied. For some respondent, the impact was considerable, for others it was marginal, and for a minority there was no effect. The authors identified the following possible barriers towards adaptation: relating science to one's own experiences when forming opinions, handling uncertainty with a 'wait and see' approach, and having a long time horizon between implementing adaptive actions and seeing their effectiveness. The authors found that participants perceived scientists to be biased towards environmentalism, and to often exaggerate environmental problems. One participant for example explained that he was sceptical about climate change reports because the acid rain projections from past decades never actually manifested. Thus, the authors points towards trust in climate change science as a key to facilitate adaptation.

Instead of focusing on those owners behaviour, Lidskog and Löfmarck (2016) choose to interview those responsible for advising owners about their perception of challenges associated with facilitating publicly recommended management practices. The authors interviewed 19 forest consultants employed by the Swedish Forest Agency, who are responsible for disseminating knowledge about public forest policies, some of which are enforced by law and regulations and others are not (e.g. climate change adaptation). The interviews were semi-structured. The authors were interested in the challenges agency employees face and the strategies they apply to operationalize non-mandatory public forest policy objectives. Participants regarded their main challenges to be the uncertainties around the consequences, rate and magnitude of climate change; which adaptive measures would be effective and should be implemented; and the conflict between the long-term time perspective of climate change and short-term operational forest management plans.[4] Additional challenges included social change, lack of formal tools and resources to reinforce objectives and provide advice, increasing heterogeneity of forest owners and decreasing embedded trust in (and social status of) agency employees. Competing advice from both outside (e.g. the forest industry and online) and within the agency (i.e. between employees) were also considered challenging. To cope with uncertainty when consulting forest owners, the agents chose to articulate the uncertainty, as they reasoned that suppressing it would make them seem untrustworthy. They also used uncertainty as an

[4] According to the authors, a standard Swedish forest management plan has a time perspective of 10 years.

argument for risk diversification and for management practices that would fulfil national objectives. When giving specific advice, the forest consultants used historical references, aiming to communicate the reasons for the current condition of the stand and how the stand; in this way, they contextualized and adapted their advice to suit both the stand and the specific forest owner.

# 3. Ontological, epistemological and methodological approach

The contextual background of this thesis, climate change and climate change impacts, and forests' responses to these impacts, are entities belonging in the natural sciences. However, the objective of this thesis is to gain a better understanding of the perceptions and motivations of the people who manage the forests. Thus, while the contextual background of the thesis is typically the arena of the natural sciences, the aims of this thesis places it within the area of social sciences. Thus, research methods associated with the social sciences were applied.

## *3.1. Ontology and epistemology*

Research methods are linked to an underlying understanding or position regarding what reality is, what knowledge can be, and how a researcher may "legitimately" produce knowledge or discover facts (Bryman, 2001). The underlying understanding of reality in this thesis is what Bryman (2001) refers to as constructivism, Moon and Blackman (2014) as relativism, and (Chalmers, 2013) as anti-realistic ontology [5]. Moon and Blackman (2014) differentiate between relativism and bounded relativism. The first assumes that realities are purely internal mental constructions and thus reality is fundamentally subjective; the second, that people who share culture, moral and cognitive circumstances will construct similar realities (and meanings) through interaction with each other and their surroundings. This thesis follows statement that "social phenomena and their meanings are continually being accomplished by social actors" (Bryman, 2012 p. 33), or in other words, actors construct their own reality, truth or meaning when they engage with the world. It also assume, however, that reality is fully subjective but that human interaction influences perceptions, i.e. that an individual's cultural, historical, and social references and perspectives forms the basis for how this individual such understands the world (Bryman 2001). This is perhaps best understood when contrasted with its antithesis, objectivism (Bryman 2001) (called realism in Moon and Blackman 2014), which holds that the social reality is external to the actors, and indeed that "social phenomena and their meanings have an existence that is independent of social actors" (Bryman 2001).

With exception of the different degrees of scepticism which holds that knowledge is impossible or that nothing can be known with certainty (Chalmers 2013), the ontological positions imply (but do not dictate) a set of possible epistemological[6] positions (Bryman 2001, Moon and Blackman 2014).

[5] Ontology is the study of being, or the study of existence, i.e. what constitutes facts (Moon and Blackman 2014). The basic question of ontology is 'what exists?' (Chalmers 2009).

[6] Epistemology is the study of knowledge. It is concerned with validity, scope and limits, methods and the difference between justifiable beliefs and just beliefs. A central epistemological question is (if and) how knowledge can be created, for example whether knowledge can be objectively measured (Moon & Blackman, 2014).

A realistic (Moon and Blackman 2014) or objectivistic (Bryman 2001) ontological position would for example imply a positivistic epistemology (Bryman 2001), with the underlying assumptions that, since a generalizable meaning of social entities exists independently of the actors, the researcher should apply the same principles and procedures as in the natural sciences to derive information about social phenomena. Positivism is tied to sensing, and holds that only knowledge confirmed by the senses can be regarded as knowledge and connected to theory through the construction of hypotheses that may be tested using sensible data. Thus, according to this direction, the creation of science, or the scientific process, should and can be value-free, and to ensure this, the researchers should keep his or her distance from the social world they aim to study. Epistemologies related to positivism are realism and critical realism (Bryman 2001, Moon and Blackman 2014).[7]

A relativistic (Moon and Blackman 2014) or constructivist ontological position, on the other hand, often leads to the epistemology called interpretivism (Bryman 2001), which holds that people and their institutions (i.e. the focus of the social sciences) are fundamentally different from trees and the ecosystems they are a part of (i.e. the focus of the natural sciences). Because people and trees are so different—people, unlike trees, can interpret their environment, attribute meaning to phenomena in it and to their own actions, and communicate their perceptions, each requires a different research approach. The underlying objective of interpretivism is not only to explain human behaviour (i.e. the positivist approach to social sciences), but also to gain access to peoples' thinking and understanding. To gain such access, (face-to-face) interaction between the researcher and the study object, and other approaches that allow the researcher to take part in the actors' world (i.e. qualitative research methods), are useful (Bryman 2001). Thus, for answering the why/why not and partly also the how elements of this thesis,[8] I applied a qualitative methodology, involving face-to-face interactions through group interviews; to further explore the how, I used a quantitative approach.

[7] Moon and Blackman (2014) uses different names for the epistemologies, and introduces a third 'theoretical perspective' level. Some of the epistemologies from (Bryman, 2001) are "theoretical" perspectives in (Moon & Blackman, 2014).

[8] That is, to analyse whether, how and why risk and uncertainty related to climate change might influence the forest management strategies of forestry decision-makers who own or manage non-industrial private forest holdings in Norway.

## *3.2. Qualitative methodology*

Papers I and IV are based on data gathered using qualitative methods. The data for these papers were collected in semi-structured focus group interviews (with respondents who were recruited using purposeful non-random criteria), and then analysed using an inductive and interpretative technique. The epistemological positioning of the two qualitative articles is thus along the interpretive spectrum, as I sought to understand through participation and interaction, rather than measuring and making deductions from the measurements.

### 3.2.1. Interview-guide

We reviewed the literature on climate change adaptation in forestry, and developed the interview guide based on this review. We also developed a number of go-to questions that could be used to guide the group discussion if necessary, and notes and keywords for the same purpose.

The interview guide had four main topics (inspired by the sources enclosed in parentheses):

i. Climate change-related experiences and beliefs (Blennow & Persson, 2009; Blennow, 2012)
ii. Knowledge about climate change (Yousefpour & Hanewinkel, 2015; Blennow, 2012)
iii. Adaptation to climate change (Lawrence & Marzano, 2014; Blennow, 2012)
iv. Climate change-related risk and uncertainty in forestry

### 3.2.2. Case: forestry decision-makers in Southeastern Norway

The respondents in this study were forestry decision-makers—non-industrial private forest owners, forest managers employed to manage large holdings, and forest advisors working in forest owners associations—from the counties of Oslo, Akershus, Østfold, Vestfold, Telemark, Buskerud, Hedmark and Oppland, in Southeastern Norway. The forests in this region (mostly) consist of even-aged stands dominated by Norway spruce (*Picea abies (L.) Karst.*) or Scots pine (*Pinus sylvestris L.*). Clear-cuts followed by planting (spruce on medium and good sites) or natural regeneration (pine, spruce on poor sites or birch), pre-commercial, and in some cases commercial thinnings are common (Statistics Norway, 2018). The forest owners associations Glommen, Viken, Mjøsen and Norskog[9] are the dominant providers of forest services in the region. The first three are cooperatives, buying roundwood from members and non-members and selling to the pulp and paper industry and sawmills in Norway and internationally. Norskog is a non-regional forest owners association whose members are typically the owners of the largest private holdings in Norway; it offers training, advice and political representation. Traditionally, Norskog organise the owners of the largest private holdings in Norway, while membership is open to all. The association does not trade roundwood, but its daughter

[9] Glommen, Viken and Mjøsen are regional forest owners associations within the Norwegian Forest Owner Federation network, while Norskog is independent.

company Nortømmer does do so (Norskog.no, 2018). Climate change forest policy in Norway has thus far been focused on promoting mitigation. To increase carbon sequestration, the Norwegian Parliament has issued two subsidies that must be applied for: one supports higher planting densities, the other fertilization (Stortinget, 2015).

### 3.2.3. Recruitment of respondents

We sought to recruit active forestry decision-makers who were interested in forestry and forest management. We chose to include forest advisors among our participants because of the important role of the forest owners associations as roundwood traders and service providers in Southeastern Norway. Administrative staff in the forest owners associations assisted us in identifying and approaching groups of interview candidates among their staff and members. Selection criteria targeted forest owners and managers who were actively managing a forest holding, and staff members holding positions that involved contact with forest owners and forest managers. Table 1 shows the group composition.

*Table 1 Group composition and background variables.*

| ID | Number of group members | Stakeholder characteristic | Group composition and additional information |
|---|---|---|---|
| **1** | 3 | Advisors | The members of these groups were colleagues. Five advisors owned forest holdings. |
| **2** | 5 | | |
| **3** | 4 | | |
| **4** | 3 | Non-industrial private forest owners (NIPFs) | The members of Group 4 and Group 5 owned holdings in the same county, while the members of Group 6 owned holdings in the same community. |
| **5** | 4 | | |
| **6** | 4 | One future and three current NIPFs | |
| **7** | 4 | One future and three current NIPFs | The members of Group 7 were recruited through a local chapter of the Norwegian farmers association, and owned holdings in the same community. We intended this interview to be a pilot, but did not change the interview guide following this interview. We therefore chose to include the data from this interview in the analysis. |
| **8** | 12 | Mixed groups consisting of NIPFs, forest managers and forest advisors | All members of Group 8 either worked or owned forest holdings in the same community. The members of Groups 9 and 10 had no common geographical affiliation. |
| **9** | 8 | | |
| **10** | 7 | | |

### 3.2.4. Data collection

We conducted interviews between May 30th and September 27th 2016. The groups decided the locations. The moderator began the sessions by introducing herself and the project, informing participants about anonymity and data storage, and collecting socio-demographic and forest property information from participants. In the interviews, the moderator introduced topics using open-ended questions, and encouraged involvement from all participants or asked for clarifications and elaborations whenever necessary. The moderator transcribed the audio-files of each session, and entered these into NVivo for further analysis (QSR International Pty Ltd, 2015).

### 3.2.5. Data analysis

According to Nilssen (2012), qualitative data analysis begins during data collection, as the researcher must interpret and respond to what the participants say, thus forming initial impressions about the data. This process continues when the data are transcribed, coded, systemized and summarized. The researcher moves back and forth in the process of analysis, interpreting and reinterpreting the data, and forming and adjusting impressions while interviewing, transcribing, reading and coding.

The coding and organisation of the data was conducted as follows. First, we wrote brief summaries of each interview to document how discussions had emerged, keeping a holistic perspective in addition to the more fragmented coded data. Then, all statements were given an identity code representing a participant. The transcripts were coded "bottom up"(Berg, 2001) in NVivo, meaning that we marked statements with short codes or words representing the expressed meaning(s) without using any predetermined coding system. Often, words and phrases were close to those used by the participants, i.e. the coding process thus emerged from the data (Berg, 2001). This open approach resulted in many categories, which we grouped and re-grouped into broader themes. The process was influenced and guided by the research questions defined for Paper I, namely "… to research whether the forestry decision-makers in Norway i) believe climate is changing, and if so how climate change will affect forest ecosystems and forestry, ii) Have experienced events in or effects on forest ecosystems or forest infrastructure they attribute to climate change, and iii.) Have adjusted their forest management due to climate change, and if so what adaptive measures they have implemented." There were two sections in the interview-guide that did not have any direct equivalent in the research questions (i.e. "Knowledge about climate change" and "climate change-related risk and uncertainty in forestry"). Identifying the main perceptions connected with these topics naturally became additional focuses in the coding and analysis process. The statement "…. I have observed after logging – even if it was not that big an area", from the interview with Group 4 would for example first be marked with the identity code of the participant that uttered the statement. Then, it would be marked with "run-off", which eventually became a- sub-category of “water-related” which again sorted under “observations”. After the transcripts had been coded and systemized, we assessed, summarized and interpreted the material, focusing on determining the main direction in meanings and perceptions, and similarities and differences between interviews.

The results presented in Paper I were based on qualitative assessments of the statements related to the research questions. When exploring, coding and analysing the data we found that the data discourses on climate change in society and their descriptions and reasoning on how this affected their climate change perceptions and assessments was extensive and rich. Thus, it was decided that this theme deserved a separate presentation. Thus, after Paper I was completed and published, we revisited the raw data by listening through the audio-files and reading the full transcripts concentrating on the sections and parts connected with this theme. We then extracted all these sections, identified themes and meanings, interpreted and summarized and structured the results using the model described by Grothmann and Patt (2005). This gave the foundation for Paper IV.

## *3.3. Quantitative methodology*

Papers II and III are based on quantitative methodology. The data for these papers were collected using a questionnaire, respondents were sampled from a defined population, and we analysed the data using statistical tools. The underlying epistemological position of these two articles is towards positivism: the questions were based on pre-determined, although not explicitly stated, hypotheses about the relationship between variables, for example, between strength of belief in various aspects of climate change and behaviour. These hypotheses were developed based on results of similar studies (Sousa-Silva et al., 2016; Blennow et al., 2012; Blennow & Persson, 2009), our own qualitative study, and relevant papers and reports on climate change and adaptive forestry (Søgaard et al., 2017; Skogstyrelsen, [Swedish Forets Agency], 2017).

### 3.3.1. Questionnaire

We designed a questionnaire consisting of 32 questions, some were multi-category and 10 were follow-ups. Most questions were statements requesting that the respondents express their agreement/disagreement on a seven-point Likert-scale with a neutral mid-point. The questionnaire began with a section of questions designed to measure beliefs and observations, and then continued with a section regarding risk perceptions (i.e. whether the respondents expected climate change to increase damage due to storms, wind, drought, forest fires, pests and diseases, root rot, top breakage to forests, forest roads and other infrastructure). We also asked the respondents how they expected climate change to impact volume-growth, quality-growth (saw-log proportion), roundwood demand, and overall income potential and holding value.

We then asked the respondents to assess adaptive options. We wanted to avoid potential "yea-saying biases" (i.e. when respondents feel compelled to answer 'yes' because they know it is the "right" answer (Ferrando & Lorenzo-Seva, 2010)). Therefore, we avoided the generic "do you want to adapt to climate change". Instead, we suggested alternative adaptive practices recommended by Søgaard et al. (2017), Skogstyrelsen, [Swedish Forets Agency] (2017), and (Skogbrand, 2014), and asked the respondents whether they would considered implementing them. We suggested actions in three categories. The first were options for adjusting species mixture: changing dominating species in some areas, increasing the share of spruce, increasing the share of pine, or increasing the share of deciduous trees. The second were regeneration options: choosing plant material from lower provenances[10] or choosing better-adapted seedlings,[11] turning from even-aged stands to continuous forest cover forestry, or turning from planting to natural regeneration. The third were risk-reducing measures:

[10] Norwegian questionnaire
[11] Swedish questionnaire

conducting pre-commercial thinnings instead of thinnings, thin earlier in the rotation when conducting thinnings, avoiding thinnings, and conducting earlier final harvest. To account for adaptive alternatives unknown to us, we also included an "others" option. Next came a section comprised of questions about insurance, knowledge, and advice, followed by some questions about participants' backgrounds.

For questions involving assessments in the future, we asked the respondents to consider a time horizon in the range of a typical rotation (60–120 years). Throughout the process, we followed the advice of Dillman et al. (2009) whenever possible. We pre-tested the questionnaire in three steps. First, 12 forestry practitioners responded to an initial version of the questionnaire. Five scholars from the Norwegian University of Life Sciences reviewed a second version, before administrative staff from the forest owners associations gave their input. We developed the questionnaire in Norwegian, and a native Swedish speaker translated it into Swedish. An English translation of the questionnaire and the information letter that accompanied it is included in Appendices II and III.

### 3.3.2. Case: forest owner association members in Norway and Sweden

There is approximately 86629 $km^2$ of productive forested land in Norway (NIBIO, 2018), of which non-industrial private forest owners (NIPFs) own approximately 79%. There are 121000 NIPFs in Norway (Statistics Norway, 2015b), approximately 34500 of which are members of forest owner associations and own a combined total of 47000 $km^2$ of productive forested land. Sweden has three times as much forested land as Norway (Riksskogstaxeringen, 2017), and approximately 330000 NIPFs. NIPFs own approximately 50% of the Swedish forested land (Statistics Sweden, 2014), and close to 106000 of the Swedish NIPFs are members of forest owners associations.

Within Norway, six regional forest owner associations, organized as cooperatives and members of the Norwegian Forest Owners Federation, handle 84% of the national roundwood trade, buying roundwood from members and non-members (often organizing harvesting and transportation) and then reselling to national and international buyers (Norges Skogeierforbund, 2017). The members of Norskog, an independent forest owners association with 300 members, supply an additional 15% of the yearly harvested national volume (Norskog.no, 2018). Both the regional associations and Norskog offer advice, professional training and political representation to their members. Within Sweden, there are four regional forest owner associations. Similarly to Norway, these are organized as cooperatives, but they also offer various services and training to their members (Royal Swedish Academy of Agriculture and Forestry, 2015).

Norway and Sweden share a 1630 km-long border, and are similar in terms of language, socio-economic characteristics, culture, climate and forest composition (Statistics Norway, 2018; Statistics Sweden, 2014). Forestry decision-makers in both Norway and Sweden are free to manage their forests within the limitations of national law, regulations and voluntary certification schemes (PEFC Norway, 2015; PEFC Sweden, 2018; FSC, 2018). The sector is of considerably larger economic importance in Sweden than in Norway, contributing to approximately 10% of national employment, exports and sales (Royal Swedish Academy of Agriculture and Forestry, 2015). I n Norway, the economic contribution from the forest sector comprises less than 1% of the nation's gross domestic product (Espelien & Jakobsen, 2013). In addition, while Sweden's annual harvest (top and bark included) varies between 80 and 100 million $m^3$ (Skogstyrelsen, [Swedish Forest Agency], 2017), the annual harvest in Norway varies between 12 and 13 million $m^3$ (Statistics Norway, 2016). The majority of NIPFs in both countries own small holdings: in Norway, 20 % of the forest owners own approximately 80 % of the forested land, and the statistics are similar in Sweden (Statistics Norway, 2019) (Statistics Sweden, 2014). Because of climate change, both Norway and Sweden will experience a rise in temperatures, especially during the winter and particularly in the north, and increased precipitation (SMHI 2018, Skogstyrelsen [Swedish Forest Agency] 2017, Tveito 2014, Hanssen-Bauer et al. 2009). Forest productivity is already increasing due to longer growing seasons (Boisvenue and Running 2006), and results from model-based studies suggest that this trend might continue (Bergh et al. 2010, Bergh et al. 2003b, Pussinen et al. 2009). Water deficiency (Briceno-Elizondo et al. 2006) and increased frequency and intensity of disturbances, however, may cancel out the positive growth effect (Reyer et al. 2017, Subramanian et al. 2015).

### 3.3.3. Sampling and data collection

We wanted a sample of i) decision-makers who were interested in forestry and forest management and thus likely to have opinions about adaptive management, and ii) decision-makers representing a considerable proportion of the forest rather than a considerable proportion of forest owners (cf. Statistics Norway 2017, Statistics Sweden 2014). We therefore contacted the forest owner associations, with the assumption that owners who are interested in forestry and forest management, and who are actively managing their forests, are likely to be members of such associations. We asked the administrative staff to assist us in distributing the questionnaire to a random sample of members, using a simple Excel tool to ensure a random sample. Sample sizes were proportionate to the number of members in the associations, except for Norskog, from whom we requested 100 participants. Our motivation for this disproportionately large sample from Norskog was to increase the probability that owners representing the largest holdings in Norway would respond to the questionnaire. The administrative staff e-mailed invitations to participate in the survey, which contained links to the Questback web page (Questback 2017-2018) hosting the questionnaire. The Norwegian version was open from March 19th to April 9th 2019, and all the Norwegian associations sent a reminder to encourage participation. The Swedish questionnaire was open from April 10th to April 27th 2019, and two of the Swedish associations (Norra Skogsägarna and Norrskog) sent reminders to encourage participation. Table 2 provides an overview of the forest owners associations, affiliated forestland, number of members and gross sample.

### 3.3.4. Data preparation and analysis

We exported pre-coded data sets from Questback. The categorical seven-point scales were converted to numerical Likert-scale variables (1–7). The data was merged, prepared and analysed using R (R Core Team, 2018 ), Stata (Statacorp, 2015) and JMP (SAS Institute INC 2014, 2014). We used the non-parametric Whitney–Mann–U test (Mann & Whitney, 1947) called the two-sample Wilcoxon test (W) in R when testing for differences between two groups that had answered the same question. In the six cases where we had paired observations, we specified the one-sample Wilcoxon test. When comparing more than two groups, we used the Kruskal–Wallis tests (Kruskal & Wallis, 1952) and a post-hoc Dunn test (Dunn, 1964) with Benjamini–Hochberg adjustments (Benjamini & Hochberg, 1995). These non-parametrical tests were necessary, because the distributions were non-normal. To compare group differences in proportions of binary variables, we used a proportion test (prop.) (Crawley, 2012), while we used the Pearson chi-squared test (chi.) (Crawley 2012) for other categorical variables.

*Table 2 Population and gross and net sample, questionnaire*

| | Association | Region | Coverage in 1000 hectares | Members (N) | Gross sample | Responses, net sample (n) | Response rate (%) |
|---|---|---|---|---|---|---|---|
| Norway | Glommen Skog SA | East | 690 | 3650 | 518 | 117 | ≈ 22.5 % |
| | Mjøsen Skog SA | East | 550 | 3700 | 526 | 99 | ≈ 19 % |
| | Viken Skog SA | East | 950 | 9400 | 1420 | 211 | ≈ 15 % |
| | AT Skog SA | South | 740 | 7300 | 1037 | 250 | ≈ 24 % |
| | Vestskog SA | West | 120 | 2750 | 391 | 112 | ≈ 28.5 % |
| | ALLSKOG SA | Middle and North | 350 | 7500 | 1065 | 178 | ≈ 17 % |
| | Norskog | - | 1300 | 300 | 100 | 45 | 45 % |
| | **Total, Norway** | | **4700** | **34600** | **5057** | **1012** | **≈ 20 %** |
| Sweden | Södra Skogsägarna | South | 2517 | 51000 | 2406 | 332 | ≈ 13.5 % |
| | Skogsägarna Mellanskog | Middle | 1530 | 26000 | 1226 | 156 | ≈ 13 % |
| | Norrskog | North | 965 | 12000 | 566 | 96 | ≈ 16.5 % |
| | Norra Skogsägarna | Northernmost | 1000 | 17000 | 799 | 149 | ≈ 18.5 % |
| | **Total, Sweden** | | **6012** | **106000** | **4997** | **733** | **≈ 14.5 %** |
| | **Combined sample** | | **10712** | **140600** | **10054** | **1745** | **≈ 17.5 %** |

For Paper III, those who at had “completely agreed” that they would consider implementing at least one of the 12 adaptive options were placed into a “prone to adapt” group, and the rest were placed into an “others” group, thus creating a binary variable. Differences between groups in variables previously linked to adaptation were then identified using the simple tests listed above. Next, the data were randomly distributed into a training and test set. The group divided into “prone” (y = 1) and “others” (y = 0) was entered as the dependent variable in logit models, which were developed using similar, previously published models as a guide (Vulturius et al., 2018; Sousa-Silva et al., 2016; Blennow et al., 2012). For variables that lacked direct equivalents in our data set, e.g. “level of trust in climate change science” (Vulturius et al., 2018) and “forestry share of household income” (Blennow et al., 2012), candidates for proxies were identified. For example, “strength of belief in climate change being human-made” was assumed to cover the same underlying factor as “salience of climate change science”, and income from forestry was assumed to be closely linked to holding size. The models’ goodness of fit was evaluated by assessing the pseudo R square, Hosmer–Lemeshow $\chi^2$, likelihood ratio, Akaike information criterion (AIC) and sensitivity (ability to correctly identify the respondents, where y = 1, with a cut-off of 0.5). When possible, or necessary due to multicollinearity, the models and variables were simplified by excluding variables or merging factor levels. Finally, the models were used for prediction and their ability to predict group belonging was assessed using Tjur’s histograms, Tjur’s coefficient of discrimination (Tjur, 2009) and sensitivity.

# 4. Results

## *4.1. Results from Paper I*

*Do forest decision-makers in Southeastern Norway adapt forest management to climate change?*

Paper I was published in Scandinavian Journal of Forest Research, Volume 33, Issue 3, pages 278–290.

The aims of Paper I was to study whether forestry decision makers in Norway:

i. Believe climate is changing, and if so, how climate change will affect forest ecosystems and forestry.
ii. Have experienced events in or effects on forest ecosystems or forest infrastructure they attribute to climate change.
iii. Have adjusted their forest management due to climate change, and if so what adaptive measures they have implemented.

To accomplish this, we conducted 10 semi-structured group interviews with 54 forestry decision-makers (i.e. non-industrial private forest owners, managers of large forest holdings and forest advisors employed in forest owners associations) from Southeastern Norway.

With one exception, all participants believed that the climate was changing, but there was much uncertainty and dissent regarding the causes of climate change. The participants' perceptions of how climate change would influence forests and forestry varied. The phrase "warmer, wetter, wilder" was frequently used to describe the future climate. Few had specific knowledge of how the climate would change beyond this, but they were aware that climate change probably would influence their forests. No one expressed deep personal worries or concern, for how climate change would influence forests and forestry. One participant, had difficulty picturing how an increase in temperature of a few degrees could make a significant impact. Another said that if there had been any real reason to worry, governmental policies would have changed. Instead of deep-seated concern, we found a widespread belief (or hope)—that the forest sector will benefit from climate change. Respondents expected that both growth and demand for roundwood will increase, and hoped that climate change would increase political support and understand.

All groups discussed observations and experiences that they attributed or wondered whether to attribute to climate change, many expressed considerable uncertainty and discussion as to whether there had actually been any changes and whether the climate was the actual, sole or partial cause of the changes. Participants compared their observations of current weather patterns with past weather patterns and events, and discussed how the harvesting equipment, plant material, and the sector in general (e.g. pressure for cost efficiency) had changed and how this may have contributed to what they had observed.

Many respondents, the managers in particular, had adjusted their management in response to changes and problems they had experienced or observed. Most adjustments were related to the planning of harvesting operations and maintenance and upgrading of forest-infrastructure. The decision-makers had however implemented these changes without explicitly considering climate change. There were NIPFs who perceived that adjustments in the planning and execution of harvest operations would be beneficial, but who expressed that the structure of the sector and the size of their holding gave them limited autonomy: to execute forest management operations, they had to rely on external parties that were under considerable pressure to be efficient. Few had considered changing their forest management strategy explicitly because of climate change and, when asked, the respondents expressed reluctance towards actions like adjusting the species mix or changing the forests structure. They often substantiated this with economic considerations: the lack of demand for species other than spruce and pine, harvest equipment used that they considered suitable for today’s forestry only, and the need to produce and harvest large volumes. For the respondents, implementing such changes appeared risky.

## 4.2. Results from Paper II

*Forest management and climate change – forest owner perceptions in Norway and Sweden.*

Paper I is submitted for peer-review to Forest Policy and Economics.

The aims of Paper II was:

i. To conduct a quantitative survey of climate change beliefs, observations, related risk perceptions, and intentions to adapt among Swedish and Norwegian forestry decision-makers
ii. To present, for the first time, quantitative measures of Norwegian forestry decision-makers' climate change beliefs, risk perceptions and propensity to adapt.
iii. Compare and validate the Norwegian results with Swedish results, and test whether there is evidence to support the hypothesis[12] that Swedish decision-makers have stronger beliefs, perceive higher risks and that they would be more prone to adapt than the Norwegians would.

Analysing the data from the Norwegian survey, which received 1012 unique responses (≈ 20%), we found that a large proportion of the Norwegians believed the climate is changing globally and at their holding. Of those who believed the climate was changing at their holding, 46% (29% of the net sample), had seen or experienced climate change-related changes. Nearly 90% agreed (somewhat, mainly or completely) that climate change would increase forest damage caused by one or more of the following: wind (single trees/small areas), storms (continuous areas), drought, forest fires, pests and diseases, root rot, top breakage (due to heavy snow), or damage to infrastructure (n = 1006)[13]. However, in spite of the majority believing that damage would increase, only 29 % (n = 1000) thought this would decrease the overall income potential and value of their holding, and out of this minority, only 9 believed the decrease would be significant. The most frequent response when we asked the Norwegians to assess 12 adaptive options was "no opinion", while those who had expressed an opinion most frequently chose the "somewhat agree" or "somewhat disagree" alternatives (i.e. the low confidence alternatives). The most popular adaptive option was "when conducting thinnings, thin earlier in the rotation". This was the only suggested option more than50 % of the respondents (somewhat, mainly or completely) agreed that they would consider implementing (mean score of 4.55). The differences we found between geographical regions, seem to correlate with today's climate patterns or present forest-activity. For example, respondents from the Westcoast, where storms and

[12] The hypothesis were constructed on the basis of the differences between the two countries regarding the focus of the societal importance of the forest-based sector

[13] A total of 1006 respondents replied to one or more of the eight questions in the matrix measuring expected climate change-induced increase in damage(s) to forests.

strong winds are relatively common and it rains quite a lot, were more confident than respondents from other regions in that damages due to storm and wind would increase, while they together with respondents form the North were least confident that damages due to drought and forest fires would increase. Respondents from the Inland and East, the regions with most forestland and forest activity were similarly the most confident that demand would increase. The Westcoast respondents, coming from an area where thinnings are less common than for example in Inland Norway, were least confident than they would not avoid thinnings. The Inland respondents, on the other hand, were most confident that they would consider early thinnings.

Respondents with the combination "representing a large holding" and "having higher education" stood out as more confident concerning strong belief in climate change and increased damage to forests, and more likely to have experienced climate change-related changes in their forest and to have received or sought advice. The profound effect of the combination of higher education and holding size, did only partly extend to the planning and management phase, where this group was among the most confident in that they would consider suggested options that would require active interventions like replacing thinnings, and move thinnings and final harvests earlier in the rotation. In replacing thinnings or conduct thinnings earlier, they were followed by those with large holding and low education, and in earlier final harvest, they were followed by those with small holdings and high education.

Analysing the Swedish questionnaire, which received 736 responses, we found that the Swedish respondents were more confident than the Norwegians about climate change happening and being human-made, and that a larger proportion of the Swedes (49%, n=548 ≈36% of the net sample) had experienced climate change at their holdings. The Swedes were significantly more confident in that climate change would increase damage due to most risk elements[14] and slightly more convinced that forest growth, income potential and holding value would increase. The Swedes were furthermore significantly less uncertain than the Norwegians regarding having sufficient knowledge about adaptive management, and a much larger proportion of the Swedes had both sought (37%, n = 727) and received (28%, n=728)[15] information. Finally, in their assessments of adaptive options, the Swedes were far more confident that they would consider using adapted plant material: while more than 50% of the Norwegians answered "no opinion", more than 50% of the Swedes chose one of the agreeing alternatives (mean score differing by 0.9 Likert-scale points). Many Swedes disagreed as to consider "replacing commercial thinnings with pre-commercial thinnings", "turn to continuous cover forestry", and "avoid thinnings".

[14] i.e. storms, wind drought, fires, pests and diseases and root rot.
[15] The corresponding number in Norway was 12% (had sought advice, n = 1002) and 18% (had received advice, n = 1004).

## *4.3. Results from Paper III*

*Quantifying the effect of beliefs, observations, risk perceptions and information on climate change adaptation*

The aims of Paper III was using the data from the Swedish-Norwegian questionnaire to:

i. Test for statistical differences between respondents who are prone to adapt and other respondents regarding variables previously shown to impact adaptation.
ii. Model the probability of respondents' propensity to adapt, drawing on previously-published logistic regression models (i.e. Blennow et al., 2012; Sousa-Silva et al., 2016; Vulturius et al., 2018).
iii. Evaluate the models' ability to predict adaptive behaviour using independent data and to assess this using model sensitivity, Tjur's histograms and Tjur's coefficient of discrimination (Tjur, 2009).

There were statistically significant differences between the prone group and the other group for all the variables we tested, except for in three cases. These exceptions were for strength of belief in climate change being human made (i.e. or proxy for strength of belief in climate change science), expected overall economic impact of climate change on forestry (i.e. candidate for proxy for risk perception) and for the binary variable indicating higher education. For the orther variables, differences were quite consistent: those "prone to adapt" were more confident in that the climate was changing at their forest holding, and that damage due to wind, storms, drought, forest fires, pests and diseases, root rot, and top breakage would increase. Those prone to adapt were also more confident that damage to forest roads and forest growth would increase because of climate change, in having sufficient knowledge about climate change adaptation, and in needing advice on adaptive management.

Visually comparing the answer distribution for each variable between the two groups, we found that the primary difference was located in the uppermost parts of the distribution for strength of belief in climate change at the forest holding level: those prone to adapt more frequently chose the "completely agree" alternative. There were similar but less-clear differences in the upper parts of the answer distributions for wind, storms, insects and disease, top breakage, infrastructure, and volume-growth.

Finally, a significantly larger proportion of those prone to adapt had observed or experienced climate change-related changes at their holding (44% vs. 28%), received (26.5% vs. 19.5%), and/or sought (27% vs. 19.5%) advice about adaptive forest management, represented a holding larger than 99 hectares (43% vs. 36%) and had forestry education (20% vs. 11.5%).

Generalized linear regression models with logit-links were formulated and fitted using a randomly drawn subset of the material. The best model in terms of AIC, log-likelihood, and pseudo $R^2$ contained eight binary independent variables indicating whether the respondent:

- Had experienced climate change at his or her holding.
- Disagreed to having sufficient knowledge about adaptive management.
- Completely agreed that volume growth would increase because of climate change.
- Completely agreed that damage due to storms would increase because of climate change.
- Completely agreed that damage to infrastructure would increase because of climate change.
- Represented a holding larger than 99 hectares.
- Had insured his or her holding.
- Had forestry education.

The best model in terms of sensitivity contained four binary independent variables indicating whether the respondent:

- Completely agree that climate is changing at his or her holding.
- Had experienced climate change at his or her holding.
- Disagreed to having sufficient knowledge about adaptive management.
- Completely agreed that volume growth would increase because of climate change.

The best models were tested as predictors using a sub-set of the data that had not been used when fitting the models. However, all of the models had very limited ability to identify those prone to adapt. Thus, although there were many significant differences between the groups in the variables we tested, models based on these variables were largely unable to differentiate between the groups.

## *4.4. Results from Paper IV*

*Who and what to trust: Norwegian forestry decision-makers' interpretations of climate change information*

The aim of this study was using the model of private proactive adaptation to climate change as a backdrop and as a mean to structure results for analysing how Norwegian forestry decision makers that partook in focus-group interviews spring and summer 2015 interprets the social discourse on climate change, including a.) What sources of information they trust and distrust, and why it is so b.) Which common strategies they use for contextualising and making sense of the information.

For the most part, the respondents read, heard or watched what was presented by the media, but did not actively seek out information about climate change themselves. The mainstream media and the forest media were the two main sources of information. Most placed low trust in the reporting of the main-stream media, perceiving them as tabloid sensational hunters not to concerned with facts. They perceived that the media often contradicted themselves, which made them reason that risk of severe effects of climate change could not be as high as some claimed. The participants placed more trust in the forest media but joked that this might be due to their biases. Many intuitively associated climate change with carbon sequestrating, and the debate on this in Norway, and it seem that this had overshadowed other aspect of the social discourse on climate change. To be able to enter into debates with people with others views than themselves on carbon sequestration or differing opinions regarding best management practices in light of climate change, several participants had sought out information to support their stance.

Participants had reservations also when it come to trusting researchers and research results. They for example reasoned that since scientists were in disagreement about the scope and severity of climate change, that founding would decide the results of all research, or that researchers tended to be to remote and theoretical, information originating from them could not be trusted. Another common line of reasoning when it come to not trusting media, politicians and researchers message about the severity of climate change was references to experiences or memories. The acid rain debate, for example, was one such memory and argument: if scientists had been so wrong about projections in the past, there was reason to not get to concerned and wait and see.

# 5. Discussion

## *5.1. Implications and relation to previous research*

### 5.1.1. Paper I

The results from Paper I show how believing in and experiencing climate change does not necessarily motivate behavioural change or inspire concern. In fact, most of the decision-makers in this study believed (or hoped) that when taking both the socio-economic and physical impacts of climate change into account, climate change would be positive: i.e. an opportunity rather than a threat for the forest-based sector. Similar findings, although often related to increased tree-growth, has been reported in several other studies, conducted both before and after ours (e.g. Laakkonen et al., 2018; Bissonnette et al., 2017; Lawrence & Marzano, 2014). Several studies of forestry decision-makers and climate adaptation (e.g. Vulturius et al. 2018, Blennow 2012), and also more theoretical papers (Etkin & Ho, 2007; Weber, 2006), further show how individuals' perception of risk and vulnerability motivates action. As such, having positive expectations about the impact of climate change, quite the opposite of feeling vulnerable and concerned, is thus not a likely trigger for change.

The participants did not consider climate change in isolation (if they considered it at all) when making management decisions. Instead, a number of factors, e.g. the roundwood market, historical demand, harvest technology and the organization of forest operations, influenced how the decision-makers assessed the extent to which management options was considered possible, feasible or beneficial. This is similar to what forest owners from other countries have reported in other studies: for example, considerations and expectations related to market demand were among the reasons why Swedish forest owners chose to replant spruce after Gudrun (Lidskog & Sjödin, 2014). Participants furthermore considered possible actions within today's technological frames and in relation to prior management choices that had made them (feel) path-dependent (e.g. clear-cuts and planting or larger areas). This is in keeping with findings by (Uggla & Lidskog, 2016). Thus, and unsurprisingly, the contexts in which decisions are made, including forestry traditions within countries (Keskitalo et al., 2013), appear to be important frames for adaptation.

### 5.1.2. Paper II

Paper II suggests that some of the findings of Paper I apply outside Paper I's limited sample. First, although most Norwegian respondents believed that the climate was changing at their holding, and although a large majority (≈90%) believed that climate change would increase damage in their forests, relatively few believed that this would negatively affect the value of their holding or their income potential. Indeed, a relatively large portion believed that growth and demand would increase. Moreover, this also applied to the Swedes, who were statistically more convinced than the Norwegians that growth and income potential would increase. It may be that although the respondents were relatively confident that damage would increase, they believed that this increase would be too small to have any financial impact; alternatively, it may be that they expected the positive effects of increased growth and demand to cancel out and even exceed the negative effects of increased damage.

As discussed in the previous section, "positive expectations" are not without parallels in the literature (e.g. Laakkonen et al., 2018; Bissonnette et al., 2017; Lawrence & Marzano, 2014) , nor are they without cause. Forest productivity has already increased due to a longer growing season (Boisvenue & Running, 2006) and current climate predictions suggest that growth may continue to increase (SMHI, 2018; Skogstyrelsen, [Swedish Forets Agency], 2017; Tveito, 2014; Hanssen-Bauer et al., 2009). Results from model-based studies also project increased growth in the region (Bergh et al., 2010; Pussinen et al., 2009), as long as it is not limited by water deficiency (Briceno-Elizondo et al., 2006) or calamities (Reyer et al., 2017; Subramanian et al., 2015).

Comparing these particular results with those from previous studies in Sweden is challenging, as these studies did not include questions about expected changes in demand, forest growth and overall economic impact (Blennow, 2012; Vulturius et al., 2018). Several Swedish studies due however contain measures of risk perceptions. For example, in the most recent Swedish study (e.g. Vulturius et al., 2018), nearly 30% reported that they were concerned about climate change in relation to their forests. Also in Blennow and Persson (2009), Blennow (2012), and (Blennow et al., 2012) it appears that a relatively large proportion of Swedish NIPFs are concerned and worried about climate change. In contrast, approximately 5 % of the Swedes who responded to our questionnaire thought climate change would lead to a moderate or major decrease in their forest income potential or holding value. Compared to the findings in, for example, Sousa-Silva et al. (2018) or Sousa-Silva et al. (2016), both the Norwegian and Swedish respondents in our sample seemed moderate in their concern.

Comparing the Norwegian and Swedish responses, the Swedes were systematically more confident on the majority of questions, including beliefs and risk perceptions. An important note on this, which provides some context for this finding, is that the overall Swedish population is among the most convinced about climate change in Europe (TNS political & social, 2017), Norwegians, in comparison, are more moderate (Buckley et al., 2017).

Next, focusing on the patterns of the responses and the size of the differences, the answer distributions from the Norwegian and the Swedish sample were often quite similar. For example, the confidence that climate change is happening decreased with geographical scope in both countries, a finding that has been documented previously in Sweden (Vulturius et al. 2018). For the eight potential causes of increased climate change-related damage, the graphs followed each other closely, and although the Swedes had somewhat more pronounced opinions (not necessarily affirmative), the pattern was generally quite similar for the suggested adaptive practices.

The shift from high confidence with regards to beliefs and expectations to low confidence with regards to considering adaptive practices is evident in both sub-samples. It is possible that considering changing management proactively in response to climate change may have been new and unfamiliar to the respondents, and this might explain their high frequency of answering “no opinion”. Another possible explanation is that many of the respondents had taken out insurance, which has been shown to be the preferred risk-management strategy among forest owners in some parts of Norway (Størdal et al., 2007).

In comparison to non-Scandinavian countries, Scandinavian forestry decision-makers are more confident about climate change happening than small-scale forest owners from, for example, Austria, (Mostegl et al., 2017), but share a similar level of confidence as forest owners and professionals from other European countries (Sousa-Silva et al., 2018; Yousefpour & Hanewinkel, 2015). However, compared to the rest of Europe (Sousa-Silva et al., 2018), where a majority (>50%) of the respondents reported having experienced climate-related changes in their forests, relatively few of our respondents reported that they had experienced climate change at their holding.

### 5.1.3. Paper III

Drawing on prior studies, Paper III explores the differences between those who completely agreed that they would consider one or more proposed adaptive actions (those "prone to adapt") and those who did not. The two groups were statistically different in their responses to the majority of the tested variables, and the direction of these differences is consistent with the literature. Those prone to adapt were significantly more confident about climate change happening at their holding (Blennow et al., 2012; Blennow & Persson, 2009), had more frequently experienced climate change (Blennow et al., 2012), and were consistently more confident that forest damage will increase (i.e. had higher risk perception) (Vulturius et al., 2018; Blennow, 2012). However, those most prone to adapt were also more confident that growth would increase, a somewhat surprising finding in light of Sousa-Silva et al. (2016) study, in which this was identified as a constraint towards adaptation. With regards to holding size, which could also be assumed to be a proxy for income from and importance of forestry (and thus vulnerability), there was a significant difference between the two groups (cf. van Gameren & Zaccai, 2015; Blennow et al., 2012).

Finally, there were between-group differences for each of the variables related to knowledge: having sufficient knowledge, needing knowledge and advice, having sought advice and having received advice. These variables were assumed to relate to or cover some of the same underlying factors as adaptive capacity, having or lacking knowledge on how to adapt, and having or lacking information (Laakkonen et al., 2018; Sousa-Silva et al., 2018; Sousa-Silva et al., 2016; van Gameren & Zaccai, 2015).

It was challenging to compare the performance of previously published models (Vulturius et al., 2018; Sousa-Silva et al., 2016; Blennow et al., 2012) with those we fitted and adjusted, but most of the variables included in these models were significant predictors of the propensity adapt. Prediction was not attempted in any of the previously published papers.

### 5.1.4. Paper IV

Results from Paper IV correspond with findings from previous qualitative studies on climate change perceptions, particularly with regards to the lack of trust in mainstream information and the belief that scientists are biased towards environmentalism or are motivated by external funding (Bissonnette et al., 2017; Vulturius & Swartling, 2015; Grotta et al., 2013).

The perceived sensationalism of the media, for example “monster weather”- headlines in combination with perceived lack of action from politicians made participants doubt that climate change will be as serious as is currently depicted. A study of the Norwegian publics perceptions on these issues shows that the forestry decision-makers were in line with other segments in this, and an analysis of media reporting shows that some parts of the Norwegian media do have a tendency to create, rather than report, news and use “balanced reporting” to dramatize (Ryghaug et al., 2011; Ryghaug, 2006). When considering that the mainstream media is a continuous and untrusted source of information and that news on climate change research is often disseminated through the media, the perceived lack of scientific consensus on climate change is understandable. Moreover, the participants’ weather- and climate-related observations and experiences were not consistent with the public discourse on the climate change ‘crisis’. These kinds of personal experiences have been shown to play an important role in how forestry decision-makers in Sweden interpret information (Vulturius & Swartling, 2015). Indeed, their reasons and rationales seem quite similar to those of our study participants, and even draw on the same specific references like the acid rain debate.

What appears new is the finding that participants associated knowledge about climate change and forestry primarily with knowledge about carbon sequestration, and that the debate about forestry’s role in the carbon cycle seemed to almost overshadow other aspects of climate change for many. However, Lawrence and Marzano (2014) report some of the same. They found that forest advisors in Wales perceived that many owners associated climate change adaptation primarily with use of energy, and that stakeholders had yet to make the connection between climate change and the growing of trees. This suggests that stakeholders’ interests, areas of focus, and frames of thought may prevent them from assessing, or even thinking about, climate change-related adaptation.

## *5.2. Answering the thesis objectives: whether, how, and why?*

*Is climate change-related risk and uncertainty affecting forest management (in Norway)- and if so, how?*

Findings from the focus group interviews suggest that forestry decision-makers, and managers in particular were adapting to climate change, but that the implemented practices largely were reactive (Bernier & Schoene, 2009). Climate change had not necessarily been considered when the adjustments had been made. Focus group participants who had adjusted their management in response to (climate change-related) changes, were largely focused on infrastructure (e.g. increasing maintenance, upgrading culverts), harvest planning (flexible harvest planning), and surveillance of roads and the forest, the latter because of rapid growth and development. Some practices related to infrastructure can be considered proactive, especially increased focus on robust road building for mitigating damages from water and heavy rains. Whether to consider e.g. adjustments in harvest planning strategies and road maintenance, or increased focus on robustness in road planning adaptation to climate change-related risk and uncertainty is a matter of discussion as the phenomenon climate change was not the explicit motivation for these adjustments. The statement below from focus groups exemplifies the many considerations and factors that are implicitly or explicitly considered when making management decisions, out of which climate change cannot be isolated from other factors. The statement echoes findings in for example Uggla and Lidskog (2016):

*"Actually, when we make investments or plant a stand, it does happen that I ponder over these things: is it sensible to place these plants here? There will be 50, maybe 100 years before we will harvest them, so will they be in demand in 50–100 years? I do not know, but I do hope so, and I think that there will be need for long-fibres*[16] *in the future. When making investments, there is really not so much else that you can do except using today as your basis for assessment, because the future, we don't really know that much about it, do we? We have to hope and we have to believe that we are making the right assessments and that that little spruce plant can adjust as we go along and not dry out or die and that it has the inhabited robustness to cope with one or two extra degrees on average".*

Nothing suggested, however, that adapting forests and forestry to climate change was a matter given much attention by most of those we interviewed.

The questionnaire did not contain questions asking the respondents if they had already adapted to climate change, but rather if they would consider implementing such adaptations. The most frequent response to the questions about adaptive practices was no opinion, and the second most frequent was somewhat disagree or somewhat agree. One practice suggested in the questionnaire stood out as most

[16] i.e. Spruce fibers

favoured among the Norwegians: “when conducting thinnings, thin earlier in the rotation”. This was the only suggested practice to which more than half the sample had answered in the affirmative. Apart from this, “earlier final harvest” and “replacing commercial thinnings with pre-commercial thinnings” were more favoured than the other suggested practices, while “increasing the share of deciduous trees”, “shifting to natural regeneration” and “avoiding thinnings” received the largest proportion of negating answers. This could suggest that management practices requiring active intervention will preferred over practices that may be characterized as more passive approaches (Bolte et al., 2009). Results from the focus group interviews supports this. The participants signalled that practices involving changing the structure or the species distribution in the forests rarely were considered, while practices that increase resilience or robustness of the forests were considered helpful.

In summary, the results from the two studies does not indicate that any large-scale adaptation process is happening in Norway at present, nor that adaptation is a matter given much attention among forestry decision-makers (yet). The question of how forest management may be affected by climate change remains relatively open, considering the relatively low proportion who actually rejected considering any adaptive management approach. At present, strategies promoting resilience or robustness through interventions seems to be preferred over passive strategies or strategies that would change the structure of the forest (cf. e.g. Bolte et al., 2009; Millar et al., 2007).

*Why climate change-related risk and uncertainty is (not) affecting forest management in Norway?*

The model of private proactive adaptation to climate change gives the means to structure the different elements and explain how they together affect adaptation. Focusing first on risk appraisal, the results from the focus-group interviews shows how participants already had implemented actions they experienced and perceived to be necessary. It does thus seem that measures that was considered relevant and needed had already been implemented, and that the participants appraisal of risk, and by association need, would need to change for them going to consider additional actions. The results from the questionnaire offers measures of respondents confidence that climate change will cause damages in their forests (cf. perceived probability), and of impact on volume, demand, and income potential and holding value. Although most respondents believed that they would be affected through forest-damages, relatively few though this would negatively affect the volume growth, or the income potential and holding value which taken together could be interpreted as expressing low risk appraisal. A final possible underlying reason for appraising risk to be low, could be that the majority of respondents (75% of the Norwegians) having insured their forest, which could be seen as adaptation to or mitigation of financial risk. Taking out insurance has previously been identified among the strategies Norwegian forest owners use to handle risk (Størdal et al., 2007).

As for the second process of the model, adaptation appraisal, the focus group participants pointed towards a number of reasons for not adapting including marked consideration, and considerations of technology (harvesters, carriers), the system (dependency on associations and entrepreneurs), the and traditions and objectives (roundwood production). Many considered the economic uncertainty associated with adapting the forest structure or changing species mixture as to high, i.e. they considered adaptation costs potentially high. Technology was mentioned both in the economic context i.e. that the effective harvest equipment was important for creating monetary values and that abolishing these approaches would be costly, and together with dependency on entrepreneurs and their equipment in a (lack of) self-efficacy context. Then, it was quite common that some participants would point out that as yet, there was to much uncertainty regarding the effect of climate change on forests to know if adaptation were necessary or would be effective (i.e. perceived adaptation efficacy).

The objective capacity of the Nordic countries is assumed quite high (Lindner et al., 2010). Thus, it is no reason to believe that this had been a particularly influential underlying factor. However, the social discourse on climate change, including the focus on mitigation rather than risks, the perceived ambiguousness of the media and the lack of trust in researchers and research results may have influenced the participants more. The way the participants referred to memories with researchers (e.g. the acid rain debate) and the media (i.e. tabloid reporting in general), could furthermore resemble availability or representatively heuristics. Respondents also frequently contextualized information with own experiences or the experiences of people they trusted. The results from the questionnaire showed that a relatively modest proportion of respondents (perceived) they had observed or experienced climate change at their holding. Those who had made observations and experiences, often reported increased growth and/or changed conditions for harvesting, rather than increased damage to forests which might have been a larger motivator for risk appraisal and concern.

## *5.3. Methodology and material*

### 5.3.1. Qualitative methodology and material

The data providing the basis for Papers I and IV were collected through 10 focus group interviews with forest owners, forest managers and forest advisors in Southeastern Norway. The participants were recruited according to specific criteria to facilitate a sample with participants with interested in forestry and likely to have opinions about forestry and climate change. As such, we did not assume that participants were representative of the average forestry decision-maker in Norway, but rather that they represented the segment of forestry decision-makers most likely to be ‘first movers’ in the adaptation process in Norwegian forestry.

The data consisted of audio-files, transcripts and notes from the interviews, in addition to background information about the participants (i.e. their age, experience, size of forest holdings and whether or not they had forestry education). To ensure that all views and perceptions were voiced and discussed, we tried to engage all participants in the discussions. However, some participants had more thoughts and opinions than others, or were more extroverted and easier to engage. Although the opportunity to observe how group members exchange views, build on each other's statements, and jointly construct meaning about phenomena is one of the advantages to the focus group setting (Bryman, 2001), there are risks to using this method. Some group members may for example dominate the interview, overshadowing the other participants or affecting the discussion to such an extent that others do not voice their opinions at all. Because each of the focus groups except for one were pre-existing, the established social order within the group may have had a similar effect. On the other hand, using pre-existing groups may also increase the possibility that participants will feel safe enough to engage in discussion, as the setting and the other respondents are familiar to them. This can increase the chance of genuine and spontaneous replies, resulting in nuanced and representative data (Bryman, 2001).

Examples of other factors that may affect the data collections, includes the moderator's language, formulations and style, framing and order of questions, and the participants' perceptions about the 'best' or 'right' responses.  Such risks were mitigated in several ways. For example, a large number of interviews and participants reduces the possibility of results being disproportionately affected by methodological choices or a single focus group (Carlsen & Glenton, 2011). Ten focus group is a relatively large number. We strived to facilitate an easy, informal, casual atmosphere so that the participants should feel safe to speak their mind, and formulated balanced and open example-questions and included in the interview-guide. Finally, we tried to avoid guiding the discussion more than necessary, as letting participants discuss freely may increase the probability genuine responses (Bryman, 2001). However, active moderation through e.g. chairing (using word, glance, or hand), interpretation of body language (e.g. "you look sceptical, do you want to add something?") or asking follow-ups was often necessary.

The same moderator conducted all the interviews, transcribed the audio-files, and conducted the coding and interpretation of the data. There are both advantages and risks associated with this. Since the moderator's perceptions of the interviews influence the data-interpretation and thus the results. The qualitative research process involves a series of choices and interpretations: not only those of the researchers, but also those of the participants. Interpretations are interpretations, and when interpreting and choosing what to emphasize, there is an obvious risk of misjudging the meaning of the participants or failing to represent the full spread of opinions and elements represented in the data. To mitigate the risk of such biases influencing the process to much, the authors had regular discussions throughout the interviewing and analysis process. As for advantages, working through the whole process with interviews, repeated listing when transcribing and coding, does offer unique overview and insight in the data. In qualitative methodology there is no clear division between analysis and interpretation, data collection (interviewing) and data preparation (transcribing) (Nilssen, 2012). Instead, the identification of the meaning in the data is a continuous process, one that begins during the interviews. Thus, if the moderator leading the interviews also performs the transcription and analysis, this can be a strength since the moderator is familiar with the context and has overview and may thus be less at risk for e.g. emphasising details and fragments of the interviews, which is a risk when data is coded and restructured using digital tools. In addition, the moderator, who was presents when the data were collected, and may for example be better suited to judge whether the participants are using under- or overstatements, or (subtle) irony, sarcasm or humour, elements that may be lost when only reading the text.

Finally, it is important to note that qualitative data, although nuanced and rich, contains only the information that the participants chose to give

### 5.3.2. Quantitative methodology and material

Papers II and IIII are based the responses to a questionnaire issued to 10,054 randomly selected forest owner association members in Norway and Sweden. The invitation to participate and a link to an online questionnaire-form in Questback (Questback, 2017-2018) was distributed by the associations' administrative staff. In the invitation, we specified that if an owner employed a forest manager who held the strategic and operational responsibility for the management of their holding, we preferred that the manager respond.

The overall response rate to the survey was 17.5 %. This is a lower response rate than those of similar studies conducted in Sweden (Vulturius et al., 2018; Blennow et al., 2016; Blennow, 2012). However, while we conducted our study using only email and online tools (using post was not an option in our case), the other studies used post to send all or some of the following: information, invitations, the questionnaire and reminders. Nulty (2008) writes that online surveys often have approximately 10% lower response rates than surveys sent through the post. Interestingly, our response rate was approximately 10 % lower than that of a recent Swedish study, in which questionnaires were distributed via the post (i.e. Vulturius et al., 2018).

According to Dillman et al. (2009), a number of elements influence recipients' propensity to respond, such as the visual design of the questionnaire, the formulation and ordering of questions, and the length: shorter questionnaires are encouraged. When this was possible, we made sure to follow the authors' advice (i.e. the advices in Dillman et al. 2009) on how to increase the likelihood of recipients finishing the questionnaire. Our questionnaire cannot, however, be characterized as short as it contained 32 (some were however follow-ups) questions, of which many were matrices). However, since respondents had to press send at the end of the form to be registered, we have no indicators of the proportion of participants who started but aborted the questionnaire. Thus, we cannot say assess whether the length of the questionnaire affected the response rate.

The majority of responses were submitted within a few days after the invitations or the reminders were sent. All the Norwegian associations sent reminders, as did Norrskog and Norra in Sweden. Interestingly, the response rates for Norrskog and Norra were higher than the response rates for the other two Swedish associations. This could indicate that our response rate might have been higher if the two other Swedish associations had sent reminders. Finally, although the response rate was relatively low compared to e.g. Blennow and Persson (2009) or Vulturius et al. (2018), the overall size of our material was relatively large when compared to the material underlying recent similar studies (Vulturius et al., 2018; Sousa-Silva et al., 2018; Mostegl et al., 2017; Sousa-Silva et al., 2016).

Although higher response rates are beneficial, Dillman et al. (2009) argue that considering non-responses and sampling errors may be as important as a high response rate for avoiding biases and for assessing whether results can be generalized. However, we could not obtain population parameters[17] on variables such as level of education and holding size, which would have given us a basis for assessing the extent to which the nearly 20% who chose to answer the questionnaire were representative of members of forest owners associations. Thus, our only means to assess whether the net sample had special features was to compare them to parameters for the overall population of forest owners and use common sense. Compared to the overall population, our respondents were highly educated: 46% of the Norwegians and 48% of the Swedes had higher education, while approximately 27% of the population in both Norway (Statistics Norway, 2015a) and Sweden (Sweden, 2018) had higher education. Many respondents represented relatively large holdings. Out of both the Norwegian and the Swedish samples, 40% of both represented holdings of over 100 hectares. The proportion of holdings larger than 100 hectares is 11% in Norway and 14 % in Sweden, respectively. Likewise, relatively few respondents represented holdings smaller than 25 hectares, i.e. 18% of the Norwegians and 16% of the Swedes (the number of holdings of this size in each country totals 60 % and 47 %, respectively) (Statistics Norway, 2015b; Statistics Sweden, 2014).[18] Further, a large proportion of the Norwegian sample (75 %) had insured their forests in comparison with the overall proportion of insured holdings in Norway (i.e. 31 % Skogbrand, 2014). In the Swedish sample, 86% had taken out insurance, while the proportion in the population is approximately 90% (Munthe-Kaas, 2012). The proportion of professional managers employed to handle the strategic and operative management of holdings were comparable across both samples (2% in Norway and 1% in Sweden), while the proportion of respondents with forestry education was 26% and 19%, in Norway and Sweden respectively. There were relatively few women in the samples. All this suggests that our sample represented a segment of forest owners and managers with relatively high knowledge about forest and

[17] Population here is members of forest owner associations.

[18] The Swedish and Norwegian statistics differ with regards to population parameters for holdings smaller than 25 hectares. Thus, the Norwegian population parameter represents holdings between 2.5 and 25 hectares. The Swedish population parameter represents holdings between 1 and 21 hectares.

forestry, relatively frequent forest-income, and relatively high awareness of risks (i.e. because of insurance) compared to the population of forest owners.

Questionnaire's topic typically influences the likelihood of a respondent replying (Martin, 1994), we think it likely that our samples contained the typical 'first movers' of the adaptation process (Moser & Ekstrom, 2010). Consequently, we do not think it likely that this process is more advanced in other segments of the population of non-industrial private forest owners and managers; on the contrary, our assumption would be that the process might be less advanced in other segments. While comparing our net sample to those of previous studies proved challenging, our net sample is similar to that of recent studies: for example, the relatively large mean holding size and large share of respondents with higher education in Vulturius et al. (2018) and the relatively large share of respondents with higher education in Blennow et al. (2016).

When using a questionnaire-based approach, researchers should strive to formulate questions that will provide objective measures of variables (Dillman et al., 2009). As such, the approach is related to the odontology and epistemology underlying the natural sciences (Bryman, 2001). However, there are elements of interpretation associated also with questionnaires which may lead to measurement errors. For example, respondents do not necessarily understand the questions in the way the researcher intended, leading to measurement errors. To avoid such errors, we followed the advices of Dillman et al. (2009) on formulation of questions. In addition, we conducted three pilots, which we hope helped mitigate the risk of measurement errors.

## *5.4. Practical relevance*

### 5.4.1. Knowledge transfer

Assuming that there is a lack of (perceived) salience, relevance, credibility, trustworthiness and legitimacy of information, and that this constitutes a barrier towards forestry decision-makers worrying about climate change impacts and adapting to climate change, adjusting the way knowledge is transferred from experts (scientists) to decision-makers (foresters) appears to be the key to overcoming this barrier. Several researchers have already discussed how best to communicate science and promote climate change adaptation to forestry decision-makers (Boag et al., 2018; Sousa-Silva et al., 2018; Lindner et al., 2014). Boag et al. (2018) has suggested that scientists should contribute with clearly written, simple articles outlining likely local scenarios in for example resource management newsletters. Lindner et al. (2014) also recommend simplicity, and suggest emphasizing that change will happen rather than focusing on time perspectives. However, results from recent studies show that decision-makers are already aware of the uncertainty associated with scenarios, adaptive practices and time horizons, and that this sometimes constitutes an argument for not adapting (Bissonnette et al., 2017; Uggla & Lidskog, 2016; Vulturius & Swartling, 2015; Grotta et al., 2013). Participants in the focus groups referenced how, in the past, scientists confidently made what turned out to be inaccurate projections; they expressed having greater trust in scientists who admitted and articulated the limits to their knowledge. It follows from this that simplifying complex matters must be undertaken with caution. Boag et al. (2018) have proposed that scientists be present at local training events to explain climate change science and promote adaptation. However, as Vulturius and Swartling (2015) have shown, even participating in focus groups in which scientists presented climate change science did not change the participants' engagement with adaptation, although it did increase their knowledge and understanding. Thus, even meeting with scientists in-person and being provided with in-depth explanations of climate change science does not automatically lead to action.

However, reports from the Swedish forestry consultants show that one-to-one in-field communication, like using site-specific historical references to argue for changed management and contextualizing advice to suit the owners' management style and objectives and articulate uncertainties and link uncertainties with management (i.e. risk diversification), seems more likely to succeed if the objective is affecting behaviour. has been successful in impacting management behaviour (Lidskog & Löfmarck, 2016). An additional lesson learned from our study is the importance of choosing an appropriate platform for communication: in the Norwegian case, the specialized forest magazines were regarded as more trustworthy than other media.

### 5.4.2. Relevance for policy

If adaptation of Norwegian forests to climate change should become a policy objective, this thesis may offer some useful insights.

With regards to the results of Paper IV in particular, it is apparent that simply stating a policy objective and expecting forestry decision-makers to change accordingly will only be effective if this objective aligns with the decision-makers' own objectives. Forestry decision-makers do not necessarily trust politicians' motives or competence when determining objectives, nor do they automatically trust forest scientists' judgements. If subsidies to promote specific actions are issued, the decision-makers might find ways to exploit the subsidy to reach their own objective, as they did with the plant density grant. In general, participants in our study reacted to experienced or perceived need, and not to information. To motivate decision-makers to change, therefore, the promoted actions must be aligned with the decision-makers objectives, be compensated or subsidized, or be mandatory and enforced by law or regulations.

The usefulness of these insights are not necessarily limited to climate change adaptation, but might also apply to other policy objectives that require behavioural change.

## 5.5. *Future research directions*

### 5.5.1. The role of advisors, and the relationship between advisors and forest owners

The focus group interviews revealed a particular relationship between the forest owners associations, the forest owners and the forest advisors. First, some owners suggested that the advisors' primarily motivations were on increasing harvested volumes, not helping them reach their objectives. Next, There were owners who felt that they were so dependent on the services organized by the advisors and associations that they could not object to things they did not agree with: for example, the time at which a harvest was carried out in their forest, even if the ground was too wet and the carrying capacity too low. The advisors, on the other hand, perceived many owners to be rather uninterested in forestry, and felt that they were sometimes the de facto decision-maker and not the advisor. Against this backdrop, therefore, it would be interesting to explore the advisors objectives, opinions and perceptions of their advisor roles. Another angle could be exploring power and autonomy of different stakeholders in the final-harvest and regeneration phase, i.e. the advisors planning the harvest operations; the entrepreneurs carrying out the harvests; and the owners of the forests.

### 5.5.2. Long periods of extreme weather and climate change perceptions

The summer of 2018 was very dry and warm in Norway and Sweden. There were numerous small and some larger forest fires, water use was restricted, and agricultural crops failed in several regions. When we conducted our study in the spring of 2018, a relatively large proportion of the Norwegian respondents replied that they did not expect damage due to forest fires and drought to increase. It would be interesting to distribute a questionnaire similar to that underlying this thesis, and explore whether perceived risk of future drought and forest-fires have changed. Exploring whether the last summer has made an impact on perceptions of climate change in general, e.g. did the hot summer impact beliefs? Did it impact only perceptions of risk related to drought and fires, or did it also impact risk-perceptions in general? A qualitative design, allowing for dialogue and in-depth understanding, could be purposeful for such a study.

### 5.5.3. The impact of values and objectives

At least two authors have explored the effect of forest owners' values on climate change perceptions or choice of management strategies (Mostegl et al., 2017; Blennow et al., 2016). While values surfaced during the focus groups, through the participants' statements, priorities and reasoning, the interview guide did not contain any questions measuring forest owners' objectives or values. Studying values and objectives in relation to adaptation among Norwegian forestry decision-makers would make an interesting contribution to the body of research on adaptation and climate change.

### 5.5.4. Information networks and learning

Learning more about where Norwegian forestry decision-makers get their information about forest management and climate change, and about which platforms and conveyers of information they consider trustworthy, could be beneficial not only for climate change policy, but for forest policy in general. The study of knowledge sharing networks by André et al. (2017), for example, address related aspects, surveying the extent to which the owners make decisions alone or jointly, how they discuss forestry with colleagues, and which actors might inspire or prevent change. A study such as that adapted to suit Norwegian conditions could be a potential further research-direction.

### 5.5.5. The effect of insurance

The effect of insurance on mitigating financial risk was presented as a possible explanation e.g. for respondents lack of belief that climate change would affect income potential and holding value negatively, and for them not having considered adaptation yet in Papers II and III. Insurance was also identified as a common risk-mitigation measure in the study by Størdal et al. (2007). Further exploring the effect of taking out insurance on risk mitigation and forest management choices is thus a fifth direction for potential future research.

## References

Adams, M. A. (2013). Mega-fires, tipping points and ecosystem services: Managing forests and woodlands in an uncertain future. *For Ecol Manage*, 294: 250-261. doi: http://dx.doi.org/10.1016/j.foreco.2012.11.039.

Alam, A., Kilpeläinen, A. & Kellomäki, S. (2008). Impacts of thinning on growth, timber production and carbon stocks in Finland under changing climate. *Scand J For Res*, 23 (6): 501-512. doi: 10.1080/02827580802545564.

Allen, C. D., Macalady, A. K., Chenchouni, H., Bachelet, D., Mcdowell, N., Vennetier, M., Kitzberger, T., Rigling, A., Breshears, D. D., Hogg, E. H., Gonzalez, P., Fensham, R., Zhang, Z., Castro, J., Demidova, N., Lim, J.-H., Allard, G., Running, S. W., Semerci, A. & Cobb, N. (2009). A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *For Ecol Manage*, 259 (4): 660-684. doi: 10.1016/j.foreco.2009.09.001.

Anderies, J. M., Janssen, M. A. & Ostrom, E. (2004). A Framework to Analyze the Robustness of Social-ecological Systems from an Institutional Perspective. *Ecol Soc*, 9 (1). doi: 10.5751/ES-00610-090118.

André, K., Baird, J., Swartling, Å. G., Vulturius, G. & Plummer, R. (2017). Analysis of Swedish forest owners' information and knowledge-sharing networks for decision-making: insights for climate change communication and adaptation. *Environ Manage*, 59 (6): 885-897.

Andretta, M. (2014). Some Considerations on the Definition of Risk Based on Concepts of Systems Theory and Probability. *Risk Anal*, 34 (7): 1184-1195. doi: 10.1111/risa.12092.

Babst, F., Poulter, B., Trouet, V., Tan, K., Neuwirth, B., Wilson, R., Carrer, M., Grabner, M., Tegel, W., Levanic, T., Panayotov, M., Urbinati, C., Bouriaud, O., Ciais, P. & Frank, D. (2013). Site- and species-specific responses of forest growth to climate across the European continent. *Global ecol bigeogr*, 22 (6).

Bazerman, M. H. (2002). *Judgment in managerial decision making*. 5 ed. New York: Wiley.

Begg, S. H., Welsh, M. & Bratvold, R. (2014, 19-20 May ). *Uncertainty vs. Variability: What's the Difference and Why is it Important?* . SPE Hydrocarbon Economics and Evaluation Symposium, Houston, Texas Society of Petroleum Engineers.

Benjamini, Y. & Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *J royal stat soc. Series B (Methodological)*: 289-300.

Berg, B. L. (2001). *Qualitative reserch methods for the social sciences* 4ed. Needham Heights, MA USA Allyn & Bacon.

Bergh, J., Freeman, M., Sigurdsson, B., Kellomäki, S., Laitinen, K., Niinistö, S., Peltola, H. & Linder, S. (2003). Modelling the short-term effects of climate change on the productivity of selected tree species in Nordic countries. *For Ecol Manage*, 183 (1-3): 327-340. doi: https://doi.org/10.1016/S0378-1127(03)00117-8.

Bergh, J., Nilsson, U., Kjartansson, B. & Karlsson, M. (2010). Impact of climate change on the productivity of silver birch, Norway spruce and Scots pine stands in Sweden and economic implications for timber production. *Ecol Bull*, 53: 185-196.

Bernier, P. & Schoene, D. (2009). Adapting Forests and Their Management to Climate Change: An Overiew. *Unasylva*, 60 (231/232): 5-11.

Beyth-Marom, R., Fischhoff, B., Quadrel, M. J. & Furby, L. (1991). Teaching Decision Making to Adolescents: A Critical reviw In Baron, J. & Brown, R. V. (eds) *Teaching Decision Making to Adolescents* New York, USA Routledge.

Bissonnette, J.-F., Dupras, J., Doyon, F., Chion, C. & Tardif, J. (2017). Perceptions of small private forest owner's vulnerability and adaptive capacity to environmental disturbances and climate change: Views from a heterogeneous population in Southern Quebec, Canada. *Small-scale for*, 16 (3): 367-393.

Blennow, K. & Persson, J. (2009). Climate change: Motivation for taking measure to adapt. *Glob Environ Chang*, 19 (1): 100-104. doi: 10.1016/j.gloenvcha.2008.10.003.

Blennow, K., Andersson, M., Sallnäs, O. & Olofsson, E. (2010). Climate change and the probability of wind damage in two Swedish forests. *For Ecol Manage*, 259 (4): 818-830.

Blennow, K. (2012). Adaptation of forest management to climate change among private individual forest owners in Sweden. *For Policy Econ*, 24: 41-47. doi: https://doi.org/10.1016/j.forpol.2011.04.005.
Blennow, K., Persson, J., Tomé, M. & Hanewinkel, M. (2012). Climate Change: Believing and Seeing Implies Adapting *PLoS ONE* 7 (11): 7. doi: doi.org/10.1371/journal.pone.0050182.
Blennow, K., Persson, J., Persson, E. & Hanewinkel, M. (2016). Forest Owners' Response to Climate Change: University Education Trumps Value Profile. *PloS one*, 11 (5): e0155137. doi: doi:10.1371/journal.pone.0155137.
Boag, A. E., Hartter, J., Hamilton, L. C., Christoffersen, N. D., Stevens, F. R., Palace, M. W. & Ducey, M. J. (2018). Climate change beliefs and forest management in eastern Oregon: implications for individual adaptive capacity. *Ecol Soc*, 23 (4): 1. doi: 10.5751/ES-10355-230401.
Boisvenue, C. & Running, S. W. (2006). Impacts of climate change on natural forest productivity–evidence since the middle of the 20th century. *Global Change Biol*, 12 (5): 862-882. doi: https://doi.org/10.1111/j.1365-2486.2006.01134.x.
Bolte, A., Ammer, C., Löf, M., Madsen, P., Nabuurs, G.-J., Schall, P., Spathelf, P. & Rock, J. (2009). Adaptive forest management in central Europe: climate change impacts, strategies and integrative concept. *Scand J For Res*, 24 (6): 473-482. doi: 10.1080/02827580903418224.
Bossel, H. (1994). *Modeling and simulation*. Wellsley, MA. : A. K. Peters, Ltd. .
Briceno-Elizondo, E., Garcia-Gonzalo, J., Peltola, H., Matala, J. & Kellomäki, S. (2006). Sensitivity of growth of Scots pine, Norway spruce and silver birch to climate change and forest management in boreal conditions. *For Ecol Manage*, 232 (1-3): 152-167. doi: https://doi.org/10.1016/j.foreco.2006.05.062.
Brumelle, S., Stanbury, W. T., Thompson, W. A., Vertinsky, I. & Wehrung, D. (1990). Framework for the analysis of risks in forest management and silvicultural investments. *For Ecol Manag*, 36 (2-4): 279-299. doi: https://doi.org/10.1016/0378-1127(90)90031-6.
Bryman, A. (2001). *Social Research Methods* 1 ed. Oxford, Greate Britain Oxford University press
Bryman, A. (2012). *Social reserch methods*. 4 ed. Oxford, UK: Oxford University Press.
Buckley, P. J., Pinnegar, J. K., Painting, S. J., Terry, G., Chilvers, J., Lorenzoni, I., Gelcich, S. & Duarte, C. M. (2017). Ten thousand voices on marine climate change in Europe: different perceptions among demographic groups and nationalities. *Front Mar Sci*, 4: 17.
Bugmann, H. (2001). A review of forest gap models. *Clim Chang*, 51 (3-4): 259-305.
Carlsen, B. & Glenton, C. (2011). What about N? A methodological study of sample-size reporting in focus group studies. *BMC Med Res Methodology*, 11 (26).
Chalmers, A. (2013). *What is this thing called science* 4ed. St Lucia, Australia: University of Queensland Press.
Crawley, M. J. (2012). *The R book*: John Wiley & Sons.
Creutzig, F., Ravindranath, N. H., Berndes, G., Bolwig, S., Bright, R., Cherubini, F., Chum, H., Corbera, E., Delucchi, M., Faaij, A., Fargione, J., Haberl, H., Heath, G., Lucon, O., Plevin, R., Popp, A., Robledo-Abad, C., Rose, S., Smith, P., Stromman, A., Suh, S. & Masera, O. (2015). Bioenergy and climate change mitigation: an assessment. *Gcb Bioenergy*, 7 (5): 916-944.
de Groot, W. J., Flannigan, M. D. & Cantin, S. (2013). Climate change impacts on future boreal fire regimes. *For Ecol Manage*, 249: 35-44. doi: 10.1016/j.foreco.2012.09.027.
Delzon, S., Urli, M., Samalens, J.-C., Lamy, J.-B., Lischke, H., Sin, F., Zimmermann, N. E. & Porté, A. J. (2013). Field evidence of colonisation by Holm Oak, at the northern margin of its distribution range, during the Anthropocene period. *PLoS ONE*, 11 (11).
Diduck, A. (2010). The Learning Dimension of Adaptive Capacity: Untangling the Multi-level Connections. *Adaptive Capacity and Environmental Governance*: 199-221.
Dillman, D. A., Smyth, J. D. & Christian, L. M. (2009). *Internet, mail, and mixed-mode surveys*. The tailored design method, vol. 3. Hoboken, New Jersey: John Wiley & sons
Dunn, O. J. (1964). Multiple comparisons using rank sums. *Technometrics*, 6 (3): 241-252.
Espelien, A. & Jakobsen, E. (2013). *Skog og trenæringen, status og utvikling 2005-2011 [Forestry and the forest sector, status and development 2005-2011]*. MENON-PUBLIKASJON, 18. Oslo: Menon Economics. p. 43.

Etkin, D. & Ho, E. (2007). Climate change: perceptions and discourses of risk. *J Risk Res*, 10 (5): 623-641. doi: https://doi.org/10.1080/13669870701281462.
European Forest Institute. (2012). *Reserch report no.5: Growth trends in European forests: studies from 12 countries*: European Forest Institute, Springer
Ferrando, P. J. & Lorenzo-Seva, U. (2010). Acquiescence as a source of bias and model and person misfit: A theoretical and empirical analysis. *Brit J of Math Stat Psy*, 63 (2): 427-448. doi: https://doi.org/10.1348/000711009X470740.
Ferson, S. & Ginzburg, L. R. (1996). Different methods are needed to propagate ignorance and variability. *Reliability Engineering & System Safety*, 54 (2-3): 133-144. doi: 10.1016/s0951-8320(96)00071-3.
FSC, F. S. C. (2018). *Om oss [About us]*. Forest Stewardship Council: Forest Stewardship Council. Available at: https://se.fsc.org/se-se (accessed: 16.03 2018).
Gigerenzer, G. & Todd, P. M. (1999). *Simple heuristics that make us smart*. New York Oxford University Press
Godfrey, K. (1983). *Compartmental models and their application*: Academic Press, Orlando USA.
Goodale, C. L., Apps, M. J., Birdsey, R. A., Field, C. B., Heath, L. S., Houghton, R. A., Jenkins, J. C., Kohlmaier, G. H., Kurz, W. & Liu, S. (2002). Forest carbon sinks in the Northern Hemisphere. *Ecol Applic*, 12 (3): 891-899.
Grothmann, T. & Patt, A. (2005). Adaptive capacity and human cognition: the process of individual adaptation to climate change. *Glo Environ Change*, 15 (3): 199-213. doi: https://doi.org/10.1016/j.gloenvcha.2005.01.002.
Grotta, A. T., Creighton, J. H., Schnepf, C. & Kantor, S. (2013). Family forest owners and climate change: Understanding, attitudes, and educational needs. *J of For*, 111 (2): 87-93. doi: https://doi.org/10.5849/jof.12-052.
Guldåker, N. (2009). *Krishantering, hushåll och stormen Gudrun. Att analysera hushålls krishanteringsförmåga och sårbarheter* Lund, Sweden Lund University
Gustavsson, L. & Madlener, R. (2003). CO2 mitigation costs of large-scale bioenergy technologies in competitive electricity markets. *Energy*, 28 (14): 1405-1425.
Gustavsson, L., Madlener, R., Hoen, H.-F., Jungmeier, G., Karjalainen, T., Klöhn, S., Mahapatra, K., Pohjola, J., Solberg, B. & Spelter, H. (2006). The role of wood material for greenhouse gas mitigation. *Mitig Adapt Strat Gl*, 11 (5-6): 1097-1127.
Hanssen-Bauer, I., Drange, H., Førland, E., Roald, L., Børsheim, K., Hisdal, H., Lawrence, D., Nesje, A., Sandven, S., Sorteberg, A., Sundby, S., Vasskog, K. & Ådlandsvik, B. (2009). *Klima i Norge 2100. Bakgrunnsmateriale til NOU Klimatilplassing [Climate in Norway 2100. Background material for the Official Norwegian report on climate adaptation]*. Oslo: Norsk klimasenter [Norwegian climate center].
Hansson, S. O. (2010). Risk: objective or subjective, facts or values. *J of Risk Res*, 13 (2): 231-238. doi: https://doi.org/10.1080/13669870903126226.
Hausman, D. M. (1992). *The inexact and separate science of economics*. 1 ed. University of Cambridge Cambridge University Press
Heinonen, T., Pukkala, T., Ikonen, V.-P., Peltola, H., Venäläinen, A. & Dupont, S. (2009). Integrating the risk of wind damage into forest planning. *For Ecol Manage*, 258 (7): 1567-1577. doi: 10.1016/j.foreco.2009.07.006.
Hildebrandt, P. & Knoke, T. (2011). Investment decisions under uncertainty—a methodological review on forest science studies. *For Policy Econ*, 13 (1): 1-15.
Hoen, H. F. & Solberg, B. (1997). CO2-taxing, timber rotations, and market implications. *Critical Reviews in Environmental Science and Technology*, 27 (S1): 151-162.
Hong, S.-Y. & Kanamitsu, M. (2014). Dynamical downscaling: Fundamental issues from an NWP point of view and recommendations. *Asia-Pac J of Atmo Sci*, 50 (1): 83-104.
Hoogstra, M. (2008). *Coping with the long term: an empirical analysis of time perspectives, time orientations, and temporal uncertainty in forestry*. Wageningen: Wageningen University.
Ingemarson, F., Jansson, V., Malmhäll, J., Merkell, B., Nasic, S. & Svensson, S. A. (2006). *Hur drabbades enskilda skogsägare av stormen Gudrun? Resultat av en enkätundersökning*. Jönköping, Sweden Skogsstyrelsen

IPCC, I. P. o. C. C. (2000). *Land use, land use change, and forestry - Special report of the IPCC*. In Noble, I., Bolin, B., Ravindranath, N., Verardo, D. & Dokken, D. (eds), 0521804957. Montreal, Canada: Cambridge University Press.
IPCC, I. P. o. C. C. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. In Core Writing Team, R. K. P. a. L. A. M. e. (ed.). Geneva, Switzerland: Intergovernmental Panel on Climate Change.
IPCC, I. P. o. C. C. (2018). *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* In Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P. R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., et al. (eds). Geneva, Switzerland: World Meteorological Organization,.
Jönsson, A. M., Harding, S., Bärring, L. & Ravn, H. P. (2007). Impact of climate change on the population dynamics of Ips typographus in southern Sweden. *Agr forest meteorol*, 146 (1). doi: 10.1016/j.agrformet.2007.05.006.
Kahan, D., Peters, E., Wittlin, M., Slovic, P., Ouellette, L., Braman, D. & Mandel, G. (2012). The polarizing impact of science literacy and numeracy on perceived climate change risks. *Nat Clim Change*, 2 (10): 732-735.
Kahan, D. M., Jenkins-Smith, H. & Braman, D. (2011). Cultural cognition of scientific consensus. *J Risk Res*, 14 (2): 147-174. doi: https://doi.org/10.1080/13669877.2010.511246.
Kahneman, D. & Tversky, A. (1979). "Prospect Theory: An Analysis of Decision under Risk". *Econometrica*, 47 (2): 263-291.
Kahneman, D. & Tversky, A. (2000). *Choices, values, and frames*. New York Cambridge university press
Kangas, A., Kurttila, M., Hujala, T., Eyvindson, K. & Kangas, J. (2015). *Decision Support for Forest Management* 2ed. Managing Forest Ecosystems, vol. 30. Cham Heidelberg New York Dordrecht London: Springer
Kangas, A. S. & Kangas, J. (2004). Probability, possibility and evidence: approaches to consider risk and uncertainty in forestry decision analysis. *For Policy Econ*, 6 (2): 169-188.
Kaufmann, G. & Kaufmann, A. (2009). *Psykologi i organisasjon og ledelse* 4ed. Bergen Fagbokforlaget Vigmostad og Bjørke AS
Kauppi, P. E., Posch, M. & Pirinen, P. (2014). Large impacts of climatic warming on growth of boreal forests since 1960. *PLoS ONE*, 9 (11).
Keane, R. E., Loehman, R. A. & Clark, J. A. (2011). Modeling Effects of Climate Change and Fire Management on Western White Pine (Pinus monticola) in the Northern Rocky Mountains, USA. *Forests*, 2 (4): 832-860. doi: 10.3390/f2040832.
Keenan, R. J. (2015). Climate change impacts and adaptation in forest management: a review. *Ann For Sci*, 72 (2): 145-167.
Kellomäki, S., Strandman, H., Nuutinen, T., Peltola, H., Korhonen, K. T. & Väisänen, H. (2005). *Adaptation of forest ecosystems, forests and forestry to climate change. FINADAPT Working Paper 4.* Helsinki, Finland Finnish Environment Institute.
Keskitalo, E. C. H., Nocentini, S. & Bottalico, F. (2013). Adaptation to climate change in forest management: what role does national context and forest management tradition play? In: Forest management of Mediterranean forest under the new context of climate change In Lucas-Borja, M. E. (ed.) *Forest management of Mediterranean forest under the new context of climate change*, pp. 149-161. New York: Nova Science Publishers, Inc.
Knight, F. H. (1964). *Risk, Uncertainty and Profit* Reprints of economic classics New York, USA
Knutti, R. & Sedláček, J. (2013). Robustness and uncertainties in the new CMIP5 climate model projections. *Nat Clim Change*, 3: 369-373.
Koca, D., Smith, B. & Sykes, M. T. (2006). Modelling regional climate change effects on potential natural ecosystems in Sweden. *Clim Chang*, 78 (2-4): 381-406.
Kolström, M., Lindner, M., Vilén, T., Maroschek, M., Seidl, R., Lexer, M. J., Netherer, S., Kremer, A., Delzon, S., Barbati, A., Marchetti, M. & Corona, P. (2011). Reviewing the science and

implementation of climate change adaptation measures in European forestry. *Forests*, 2 (4): 961-982.
Kruskal, W. H. & Wallis, W. A. (1952). Use of ranks in one-criterion variance analysis. *J Am Stat Ass*, 47 (260): 583-621.
Laakkonen, A., Zimmerer, R., Kähkönen, T., Hujala, T., Takala, T. & Tikkanen, J. (2018). Forest owners' attitudes toward pro-climate and climate-responsive forest management. *For Policy Econ*, 87: 1-10. doi: https://doi.org/10.1016/j.forpol.2017.11.001.
Landsberg, J. (2003). Modelling forest ecosystems: state of the art, challenges, and future directions. *Can J Forest Res*, 33 (3): 385-397. doi: 10.1139/x02-129.
Lawrence, A. & Marzano, M. (2014). Is the private forest sector adapting to climate change? A study of forest managers in north Wales. *Ann For Sci*, 71 (2): 291-300. doi: 10.1007/s13595-013-0326-4.
Lemprière, T., Kurz, W., Hogg, E., Schmoll, C., Rampley, G., Yemshanov, D., McKenney, D., Gilsenan, R., Beatch, A. & Blain, D. (2013). Canadian boreal forests and climate change mitigation. *Environ Reviews*, 21 (4): 293-321.
Lenoir, J., Gégout, J. C., Marquet, P. A., De Ruffray, P. & Brisse, H. (2008). A significant upward shift in plant species optimum elevation during the 20th century. *Science*, 320 (5884): 1768-71. doi: 10.1126/science.1156831.
Lidskog, R. & Sjödin, D. (2014). Why do forest owners fail to heed warnings? Conflicting risk evaluations made by the Swedish forest agency and forest owners. *Scand J For Res*, 29 (3): 275-282. doi: https://doi.org/10.1080/02827581.2014.910268.
Lidskog, R. & Löfmarck, E. (2016). Fostering a flexible forest: Challenges and strategies in the advisory practice of a deregulated forest management system. *Forest Policy and Economics*, 62: 177-183.
Lindner, M., Maroschek, M., Netherer, S., Kremer, A., Barbati, A., Garcia-Gonzalo, J., Seidl, R., Delzon, S., Corona, P., Kolström, M., Lexer, M. J. & Marchetti, M. (2010). Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. *For Ecol Manage*, 259 (4): 698-709. doi: https://doi.org/10.1016/j.foreco.2009.09.023.
Lindner, M., Fitzgerald, J., Zimmermann, N., Reyer, C., Delzon, S., van der Maaten, E., Schelhaas, M.-J., Lasch, P., Eggers, J., van der Maaten-Theunissen, M., Suckow, F., Psomas, A., Poulter, B. & Hanewinkel, M. (2014). Climate change and European forests: What do we know, what are the uncertainties, and what are the implications for forest management? *J Environ Manage*, 146: 69-83.
Linné, T. (2011). *Skogens framtid. En sociologisk undersökning av skogsägares uppfattningar.* Lund University Publications Lund, Sweden Media and Communication Studies Lund University
Liu, Y., Stanturf, J. & Goodrick, S. (2010). Trends in global wildfire potential in a changing climate. *For Ecol Manage*, 259 (4): 685-697. doi: 10.1016/j.foreco.2009.09.002.
LOV-2005-05-27-31. (2005). *Lov om skogbruk (skogbrukslova) [The forestry law]*. Oslo, Norway
Mann, H. B. & Whitney, D. R. (1947). On a test of whether one of two random variables is stochastically larger than the other. *Ann Math Stat*, 18 (1): 50-60.
March, J. G. (1994). *A primer on decition making - How decisions happen* New York, USA: The free press/ Simon and Schuster Inc. .
Martin, C. L. (1994). The impact of topic interest on mail survey response behaviour. *J Market Res Soc*, 36 (4): 1-11. doi: https://doi.org/10.1177/147078539403600404.
Menzel, A., Sparks, T. H., Estrella, N., Koch, E., Aasa, A., Ahas, R., Alm-Kübler, K., Bissolli, P., Braslavská, O. G., Briede, A., Chmielewski, F. M., Crepinsek, Z., Curnel, Y., Dahl, Å., Defila, C., Donnelly, A., Filella, Y., Jatczak, K., Måge, F., Mestre, A., Nordli, Ø., Peñuelas, J., Pirinen, P., Remišová, V., Scheifinger, H., Striz, M., Susnik, A., Van Vliet, A. J. H., Wielgolaski, F. E., Zach, S. & Zust, A. (2006). European phenological response to climate change matches the warming pattern. *Glo Change Biol*, 2006 (10): 1969-1976. doi: 10.1111/j.1365-2486.2006.01193.x.
Mezirow, J. (2008). *An overview on transformative learning." Lifelong learning*: Routledge.
Milad, M., Schaich, H. & Konold, W. (2013). How is adaptation to climate change reflected in current practice of forest management and conservation? A case study from Germany. *Biodivers Conserv*, 22 (5): 1181-1202.

Millar, C., Stephenson, N. & Stephens, S. (2007). Climate change and forests of the future: Managing in the face of uncertainty. *Ecol Appl*, 17 (8): 2145-2151.
Moon, K. & Blackman, D. (2014). A Guide to Understanding Social Science Research for Natural Scientists. *Conserv Biol* 28 (5): 1167-1177. doi: 10.1111/cobi.12326.
Moser, S. C. & Dilling, L. (2007). Toward the social tipping point: Creating a climate for change. In Moser S C & L, D. (eds) *Creating a climate for change: Communicating climate change and facilitating social change*, pp. 675-731. Cambridge: Cambridge University Press.
Moser, S. C. & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *P Natl Acad Sci USA* 107 (51): 22026-22031. doi: 10.1073/pnas.1007887107.
Mostegl, N. M., Pröbstl-Haider, U., Jandl, R. & Haider, W. (2017). Targeting climate change adaptation strategies to small-scale private forest owners *For Policy Econ*, 99: 83-99.
Munthe-Kaas, O. S. (2012). *Markedsanalyse av skogforsikring i Sverige og Finland. [Marked analysis for forest insurance in Sweden and Finalnd]*. Ås: Norwegian University of Life Sciences.
Mäkelä, A., Landsberg, J., Ek, A. R., Burk, T. E., Ter-Mikaelian, M., Ågren, G. I., Oliver, C. D. & Puttonen, P. (2000). Process-based models for forest ecosystem management: current state of the art and challenges for practical implementation. *Tree physiol*, 20 (5-6): 289-298.
Nabuurs, G.-J., Masera, O., Andrasko, K., Benitenz-Ponce P, Boer, R., Dutsche, M., Eldidig, E., Ford-Robertson, J., Frumhoff, P., Karjalainen, T., Kranikina, O., Kurz, W., Matsumoto, M., Oyhantcabal, W., Ravindranath, N. H., Sanchez, M. & Zhang, X. (2007). *Forestry in Climate change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Summary for Policymakers*. In Metz, B., Davidson, O., Bosch, P., Dave, R. & Meyer, L. (eds). Cambridge University Press, Cambridge, UK.: IPCC
Neuner, S., Albrecht, A., Cullmann, D., Engels, F., Griess, V. C., Hahn, W. A., Hanewinkel, M., Härtl, F., Kölling, C., Staupendahl, K. & Knoke, T. (2015). Survival of Norway spruce remains higher in mixed stands under a dryer and warmer climate. *Glo Change Biol*, 21: 935-946. doi: 10.1111/gcb.12751.
NIBIO, N. I. o. B. R. (2018). *Nøkkeltall om skog [Keynumbers forests]*. nibio.no Norwegian Institute of Bioeconomy Research. Available at: https://nibio.no/tema/skog/skog-og-miljoinformasjon-fra-landsskogtakseringen/nokkeltall (accessed: 16.03. 2018).
Nilssen, V. (2012). *Analyse i kvalitative studier, den skrivende forskeren [Analysing qualitative studies, the writing scientists]*. 1 ed.: Universitetsforlaget
Norges Skogeierforbund, N. F. O. F. (2017). *Om oss (about us)*. skogeier.no: Norges Skogeierforbund [Norwegian Forest Owners' Federation],. Available at: http://www.skogeier.no/om-oss/ (accessed: 18.09 2017).
Norskog.no. (2018). *Om oss [About us]*. norskog.no: Norskog Available at: http://norskog.no/om-oss/ (accessed: 16.03 2018).
Nulty, D. D. (2008). The adequacy of response rates to online and paper surveys: what can be done? *Assessment & evaluation in higher education*, 33 (3): 301-314. doi: https://doi.org/10.1080/02602930701293231.
Ogden, A. & Innes, J. (2007). Incorporating climate change adaptation considerations into forest management planning in the boreal forest. *Int For Rev*, 9 (3): 713-733.
Pan, Y., Birdsey, R. A., Fang, J., Houghton, R., Kauppi, P. E., Kurz, W. A., Phillips, O. L., Shvidenko, A., Lewis, S. L., Canadell, J. G., Ciais, P., Jackson, R. B., Pacala, S. W., McGuire, A. D., Piao, S., Rautiainen, A., Sitch, S. & Hayes, D. (2011). A large and persistent carbon sink in the world's forests. *Science*, 333 (6045): 988-993.
Pasalodos-Tato, M., Mäkinen, A., Garcia-Gonzalo, J., Borges, J., Lämås, T. & Eriksson, L. O. (2013). Assessing uncertainty and risk in forest planning and decision support systems. *For Syst*, 22 (2): 282-303. doi: 10.5424/fs/2013222-03063.
PEFC Norway. (2015). *Norwegian PEFC Forest Standard*. PEFC N 02. Oslo: PEFC Norway. p. 31.
PEFC Sweden. (2018). *Om svenska PEFC [About swidish PEFC]*. http://pefc.se/om-svenska-pefc/: Swedish PEFC,. Available at: http://pefc.se/om-svenska-pefc/ (accessed: 16.03 2018).

Peltola, H., Ikonen, V.-P., Gregow, H., Strandman, H., Kilpeläinen, A., Venäläinen, A. & Kellomäki, S. (2010). Impacts of climate change on timber production and regional risks of wind-induced damage to forests in Finland. *For Ecol Manag*, 260 (5): 833-845.
Piao, S., Wang, X., Ciais, P., Zhu, B., Wang, T. & Liu, J. (2011). Changes in satellite-derived vegetation growth trend in temperate and boreal Eurasia from 1982 to 2006. *Glo Change Biol*, 17 (10): 3228-3239. doi: 10.1111/j.1365-2486.2011.02419.x.
Pussinen, A., Nabuurs, G.-J., Wieggers, H. J. J., Reinds, G. J., Wamelink, G. W. W., Kros, J., Mol-Dijkstra, J. P. & de Vries, W. (2009). Modelling long-term impacts of environmental change on mid-and high-latitude European forests and options for adaptive forest management. *For Ecol Manage*, 258 (8): 1806-1813. doi: https://doi.org/10.1016/j.foreco.2009.04.007.
QSR International Pty Ltd. (2015). *NVivo qualitative data analysis Software for WINDOWS*. qsrinternational.com: QSR International Pty Ltd2015).
Questback. (2017-2018). *Questback* Available at: https://www.questback.com/2017-2018).
R Core Team. (2018 ). *R: A Language and Environment for Statistical Computing*. Vienna, Austria R Foundation for Statistical Computing. Available at: https://www.R-project.org2018 ).
Raymer, A. K. P. (2006). A comparison of avoided greenhouse gas emissions when using different kinds of wood energy. *Biomass and Bioenergy*, 30 (7): 605-617.
Reyer, C. (2013). *The cascade of uncertainty in modeling forest ecosystem responses to environmental change and the challenge of sustainable resource management*. Berlin: Humboldt-Universität.
Reyer, C., Lasch-Born, P., Suckow, F., Gutsch, M., Murawski, A. & Pilz, T. (2014). Projections of regional changes in forest net primary productivity for different tree species in Europe driven by climate change and carbon dioxide. *Ann For Sci*, 71 (2): 211-225. doi: 10.1007/s13595-013-0306-8.
Reyer, C. P. O., Bathgate, S., Blennow, K., Borges, J., Bugmann, H., Delzon, S., Faias, S., Garcia-Gonzalo, J., Gardiner, B., Gonzalez-Olabarria, J. R., Gracia, C., Hernández, J. G., Kellomäki, S., Kramer, K., Lexer, M. J., Lindner, M., van der Maaten, E., Maroschek, M., Muys, B., Nicoll, B., Palahi, M., Palma, J. H. N., Paulo, J. A., Peltola, H., Pukkala, T., Rammer, W., Ray, D., Sabaté, S., Mart-Jan Schelhaas, M.-J., Seidl, R., Temperli, C., Tomé, M., Yousefpour, R., Zimmermann, N. E. & Hanewinkel, M. (2017). Are forest disturbances amplifying or canceling out climate change-induced productivity changes in European forests? *Environ Res Let*, 12 (3): 034027.
Riksskogstaxeringen, S. F. I. (2017). *Forest statistics 2017*. In Fransson, J. (ed.). SKOGSDATA [Forest data]. Umeå: Statistiska centralbyrån/ Riksskogstaxeringen Sveriges Lantbruksuniversitet [Statistics Sweeden/Swedish Forest Inventory Swedish University of Agricultural Sciences].
Royal Swedish Academy of Agriculture and Forestry. (2015). *Forests and Forestry in Sweden*. Stockhold, Sweden The Royal Swedish Academy of Agriculture and Forestry (KSLA).
Ryghaug, M. (2006). «Some like it hot»–Konstruksjon av kunnskap om klimaendringer i norske aviser ["Some like it hot" - Construction of knowledge about climate change in Norwegian newspapers]. *Norsk medietidskrift* (13): 197-219.
Ryghaug, M., Holtan Sørensen, K. & Næss, R. (2011). Making sense of global warming: Norwegians appropriating knowledge of anthropogenic climate change. *Pub Underst Sci* (20 ): 778-795.
Sarmiento, J., Gloor, M., Gruber, N., Beaulieu, C., Jacobson, A., Mikaloff Fletcher, S., Pacala, S. & Rodgers, K. (2010). Trends and regional distributions of land and ocean carbon sinks. *Biogeosciences*, 7 (8): 2351-2367.
SAS Institute INC 2014. (2014). *JMP Pro 14.* . Cary, NC: SAS Institute Inc2014).
Schelhaas, M. J., Nabuurs, G. J. & Schuck, A. (2003). Natural disturbances in the European forests in the 19th and 20th centuries. *Glo Change Biol* 9(11): 1620-1633. doi: 10.1046/j.1365-2486.2003.00684.x.
Schoene, D. & Bernier, P. (2012). Adapting forestry and forests to climate change: A challenge to change the paradigm. *For Policy Econ*, 24 (SI): 12-19.
Seidl, R., Spies, T. A., Peterson, D. L., Stephens, S. L. & Hicke, J. A. (2016). Searching for resilience: addressing the impacts of changing disturbance regimes on forest ecosystem services. *Journal of Applied Ecology*, 53 (1): 120-129.

Seidl, R., Thom, D., Kautz, M., Martin-Benito, D., Peltoniemi, M., Vacchiano, G., Wild, J., Ascoli, D., Petr, M., Honkaniemi, J., Lexer, M. J., Trotsiuk, V., Mairota, P., Svoboda, M., Fabrika, M., Nagel, T. A. & Reyer, C. P. O. (2017). Forest disturbances under climate change. *Nat Clim Change*, 7: 395-402.
Sellerberg, A. M. (2011). *Efter stormen. En sociologisk undersökning av skogsägarfamiljer [After the storm. A sociological analysis of families owning forest properties.]*. Lund University Publications Lund, Sweden Sociology of Everyday Life-lup-obsolete (research group) Lund University
Simon, H. (1977). The logic of heuristic decision making.  In: Models of Discovery. In Boston Studies in the Philosophy of Science, vol. 54 *Models of discovery*, pp. 154-175. Dordrecht, Holland: Springer, Dordrecht.
Simon, H. A. (1960). *The new science of management decitions* The Ford Distinguished Lectures. New York Harper and Brothers
Simon, H. A. (1979). *Models of thought*, vol. 352. New Haven Yale University Press
Sjølie, H. K., Latta, G. & Solberg, B. (2013). Potentials and costs of climate change mitigation in the Norwegian forest sector—Does choice of policy matter? . *Can J Forest Res*, 43: 589-598.
Sjølie, H. K., Becker, D., Håbesland, D., Solberg, B., Lindstad, B. H., Snyder, S. & Kilgore, M. (2016). Willingness of nonindustrial private forest owners in Norway to supply logging residues for wood energy. *Small-scale forestry*, 15 (1): 29-43.
Skogbrand, S. f. G. S. i. c. (2014). *Skogbehandling før skogen kommer [forest management before the storm]*. Oslo Skogbrand forsikringselskap Gjensidige [Skogbrand insurance company].
Skogstyrelsen, S. F. A. (2017). *Bruttoavvirkning [Gross harvest]*. In Skogstyrelsen [Swedish Forest Agency] (ed.). https://www.skogsstyrelsen.se/statistik/statistik-efter-amne/bruttoavverkning/: Skogstyrelsen [Swedish Forest Agency]. Available at: https://www.skogsstyrelsen.se/statistik/statistik-efter-amne/bruttoavverkning/ (accessed: 19.06. 2018).
Skogstyrelsen, S. F. A. (2017). *Skogsstyrelsens arbete  för ökad klimatanpassning  inom skogssektorn, Handlingsplan [The Swedish forest Agencys strategy for promotion of increased climate adaptation in the forest sector, Actionplan]*. RAPPORT Jönköping: Skogstyrelsen [Swedish Forets Agency].
SMHI, S. m. o. h. i. S. M. a. H. I. (2018). *Klimaet [Climate]*. smhi.se: Sveriges meterologiske och hydrologiske institut [Swedish Meteorological and Hydrological Institute]. Available at: https://www.smhi.se/klimat (accessed: 10.04. 2018).
Smit, B. & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Glo Environ Change*, 16 (3): 282-292. doi: https://doi.org/10.1016/j.gloenvcha.2006.03.008.
Sousa-Silva, R., Ponette, Q., Verheyen, K., Van Herzele, A. & Muys, B. (2016). Adaptation of forest management to climate change as perceived by forest owners and managers in Belgium. *For Ecosyst*, 3 (22): 2-11.
Sousa-Silva, R., Verbist, B., Lomba, Â., Valent, P., Suškevičs, M., Picard, O., Hoogstra-Klein, M., Cosofret, V.-C., Bouriaud, L., Ponette, Q., Verheyen, K. & B, M. (2018). Adapting forest management to climate change in Europe: Linking perceptions to adaptive responses. *For Policy Econ*, 90: 22-30. doi: https://doi.org/10.1016/j.forpol.2018.01.004.
Spittlehouse, D. & Stewart, R. (2004). Adaptation to climate change in forest management. *BC J Ecosyst Manag*, 4 (1): 1-11.
Statacorp. (2015). *Stata Statistical Software: Release 13*. College Station, TX: StataCorp LP.2015).
Statistics Norway. (2015a). *Befolkningens utdanningsnivå, 1 oktober 2014 [Level of education in the population, Octorber 1st 2014],* . ssb.no: Central Bureau of Statistics Norway. Available at: http://www.ssb.no/en/jord-skog-jakt-og-fiskeri/statistikker/stskog/aar/2015-09-22?fane=om#content (accessed: 20.05 2018).
Statistics Norway. (2015b). *Forest properties, 2014*. Public Webpage In Norway, C. B. o. S. (ed.). Agriculture, forestry, hunting and fishing. Forestry, Structural statistics. ssb.no: Central Bureau of Statistics Norway. Available at: http://www.ssb.no/en/jord-skog-jakt-og-fiskeri/statistikker/stskog/aar/2015-09-22?fane=om#content (accessed: 01.06. 2018).
Statistics Norway. (2016). *Commercial roundwood removals, 2016, quarterly preliminary figures*. Internet. In Norway, C. B. o. S. (ed.). Agriculture, forestry, hunting and fishing, Commercial

roundwood removals. ssb.no: Central Bureau of Statistics Norway. Available at: https://www.ssb.no/en/jord-skog-jakt-og-fiskeri/statistikker/skogav/kvartal (accessed: 01.11. 2016).
Statistics Norway. (2018). *The National Forest Inventory*. Growing stock and annual increment. Volume inside bark. ssb.no: Statistics Norway Available at: https://www.ssb.no/en/lst (accessed: 14.05 2018).
Statistics Norway. (2019). *10613: Skogeiendommer og skogareal, etter eierkategori 2013 - 2017 [forest holdings and forested area, after ownership categories]*. In Norway, C. B. o. S. (ed.). ssb.no: Central Bureau of Statistics Norway,. Available at: https://www.ssb.no/statbank/table/10613/ (accessed: 26.07 2019).
Statistics Sweden. (2014). *Skogsstatistisk årsbok 2014 [Swedish Statistical Yearbook of Forestry],*. In Christiansen, L. & Skogsstyrelsen [Swedish Forest Agency] (eds). Skogsstatistisk årsbok [Swedish Statistical Yearbook of Forestry]. Jönköping: Skogstyrelsen [Swedish Forest Agency] Official Statistics of Sweden
Staupendahl, K. & Möhring, B. (2011). Integrating natural risks into silvicultural decision models: A survival function approach. *For Policy Econ*, 13 (6). doi: 10.1016/j.forpol.2011.05.007.
Staw, B. M. (1976). Knee-deep in the big muddy: A study of escalating commitment to a chosen course of action. *Organ behav hum perf*, 16 (1): 27-44.
Staw, B. M. (1981). The escalation of commitment to a course of action. *Acad of manage rev*, 6 (4): 577-587.
Stortinget, T. N. P. (2015). *Statsbudsjettet 2016 [State budget 2016]*. Stortingets administrasjon, K. a. P. a., Constitutional Department]. Oslo: Stortingets administrasjon, Konstitusjonell avdeling [Parliament administration, Constitutional Department].
Størdal, S., Lien, G. & Hardaker, J. B. (2007). Perceived risk sources and strategies to cope with risk among forest owners with and without off-property work in eastern Norway. *Scand J For Res*, 22 (5): 443-453. doi: https://doi.org/10.1080/02827580701553701.
Subramanian, N., Bergh, J., Johansson, U., Nilsson, U. & Sallnäs, O. (2015). Adaptation of forest management regimes in southern Sweden to increased risks associated with climate change. *Forests*, 7 (1): 18. doi: https://doi.org/10.3390/f7010008.
Sun, H.-g., Zhang, J.-g., Duan, A.-g. & He, C.-y. (2007). A review of stand basal area growth models. *Forestry Studies in China*, 9 (1): 85-94.
Sweden, S. (2018). *Var fjärde i Sverige är högutbildad [every forth Swede have higher education]*. scb.se: Statistics Sweeden. Available at: https://www.scb.se/hitta-statistik/sverige-i-siffror/utbildning-jobb-och-pengar/befolkningens-utbildning (accessed: 30.05 2018).
Søgaard, G., Astrup, R., Allen, M., Andreassen, K., Bergseng, E., Fløistad, I., Hanssen, K., Hietala, A., Kvaalen, H. & Solberg, S. (2017). *Skogbehandling for verdiproduksjon i et klima i endring [Forest management for value production in a changing climate]*. NIBIO Rapport, 2464-1162. ÅS: NIBIO.
Taylor, K. E. (2012). An Overview of CMIP5 and the Experiment Design. *Am Meteorol Soc*, 93: 485-498. doi: 10.1175/BAMS-D-11-00094.1.
Thorsen, B. J. & Helles, F. (1998). Optimal stand management with endogenous risk of sudden destruction. *For Ecol Manage*, 108 (3): 287-299. doi: 10.1016/S0378-1127(98)00233-3.
Tjur, T. (2009). Coefficients of determination in logistic regression models—A new proposal: The coefficient of discrimination. *The American Statistician*, 63 (4): 366-372.
TNS political & social. (2017). *Special Eurobarometer 459 Climate Change*. In TNS political & social (ed.): European Commission,Directorate-General for Climate Action and co-ordinated by the Directorate-General for Communication.
Tveite, B. (1977). *Bonitetskurver for gran (Picea abies (L.) Karst) [Site-index curves for Norway spruce (Picea abies (L.) Karst)]*: Norsk Inst. for Skogforskning.
Tveito, O. E. (2014). *Klimaendringer og betydning for skogbruket [Climate change impacts on forestry]*. MET reports Oslo Norwegian Meteorological Institute
Tversky, A. & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, 185 (4157): 1124-1131.
Tversky, A. & Kahneman, D. (1992). Advances in prospect theory: Cumulative representation of uncertainty. *J Risk Uncertainty*, 5 (4): 297-323.

Uggla, Y. & Lidskog, R. (2016). Climate risks and forest practices: forest owners' acceptance of advice concerning climate change. *Scand J For Res*, 31 (6): 618-625. doi: https://doi.org/10.1080/02827581.2015.1134648.
van Gameren, V. & Zaccai, E. (2015). Private forest owners facing climate change in Wallonia: Adaptive capacity and practices. *Environ Sci Policy*, 52: 51-60. doi: https://doi.org/10.1016/j.envsci.2015.05.004.
van Vuuren, D. P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., Hurtt, G. C., Kram, T., Krey, V. & Lamarque, J.-F. (2011). The representative concentration pathways: an overview. *Clim Chang*, 109 (1-2): 5.
Vatn, A. (2007). *Institutions and the Environment* Edward Elgar
Vulturius, G. & Swartling, Å. G. (2015). Overcoming social barriers to learning and engagement with climate change adaptation: experiences with Swedish forestry stakeholders. *Scand J For Res*, 30 (3): 217-225. doi: https://doi.org/10.1080/02827581.2014.1002218.
Vulturius, G., André, K., Swartling, Å. G., Brown, C., Rounsevell, M. D. A., Jönsson, A. M. & Blanco, V. (2018). The relative importance of subjective and structural factors for individual adaptation to climate change by forest owners in Sweden. *Reg Environ Chang*, 18 (5): 1517-1571. doi: https://doi.org/10.1007/s10113-017-1218-1
Walker, W. E., Harremoës, P., Rotmans, J., van der Sluijs , J. P., van Asselt, M. B. A., Janssen, P. & Krayer von Krauss, M. P. (2003). Defining Uncertainty: A Conceptual Basis for Uncertainty Management in Model-Based Decision Support. *Integrat ass*, 4 (1): 5-17. doi: 10.1076/iaij.4.1.5.16466.
Weber, E. U. (2006). Experience-based and description-based perceptions of long-term risk: Why global warming does not scare us (yet). *Clim Chang*, 77 (1-2): 103-120.
Weichselgartner, J. & Kasperson, R. (2010). Barriers in the science-policy-practice interface: Toward a knowledge-action-system in global environmental change research. *Glo Environ Change*, 20 (2): 266-277. doi: https://doi.org/10.1016/j.gloenvcha.2009.11.006.
Yousefpour, R., Jacobsen, J. B., Thorsen, B. J., Meilby, H., Hanewinkel, M. & Oehler, K. (2012). A review of decision-making approaches to handle uncertainty and risk in adaptive forest management under climate change. *Annals of forest science*, 69 (1): 1-15.
Yousefpour, R. & Hanewinkel, M. (2015). Forestry professionals' perceptions of climate change, impacts and adaptation strategies for forests in south-west Germany. *Clim Chang*, 130 (2): 273-286. doi: 10.1007/s10584-015-1330-5.
Yousefpour, R., Temperli, C., Jacobsen, J. B., Thorsen, B. J., Meilby, H., Lexer, M., Lindner, M., Bugmann, H., Borges, J. & Palma, J. (2017). A framework for modeling adaptive forest management and decision making under climate change. *Ecology and Society*, 22 (4).
Zhou, W. (1999). Risk-based selection of forest regeneration methods. *For Ecol Manage*, 115 (1): 85-92. doi: 10.1016/S0378-1127(98)00438-1.
Zimmermann, H.-J. (2000). An application-oriented view of modeling uncertainty. *Eur J Oper Res* 222 (2): 190-198. doi: https://doi.org/10.1016/S0377-2217(99)00228-3.

# Paper I

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# Do forest decision-makers in Southeastern Norway adapt forest management to climate change?

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**ABSTRACT**

To study whether, why, and how forestry decision-makers in Southeastern Norway adapt to climate change, we conducted a series of semi-structured interviews in focus groups consisting of non-industrial private forest owners, forest managers, and forest advisors. Our results show that a majority of the participants believed in climate change as a phenomenon, and had experienced events or observed changes that they attributed to climate change. However, we found little evidence of concern regarding climate change impacts on forest ecosystems and forestry among the participants. Instead, the majority regarded climate change more as an opportunity for the Norwegian forest-based sector than a threat. A minority had implemented proactive practices motivated by climate change but in all but one case, the adjustments were adaptation of forest infrastructure. In general, the participants agreed that the uncertainty associated with the effects of climate change and the (economical) uncertainty associated with adaptation of forest ecosystems were too large to change forest management practices at present. However, many participants, in particular the managers, are already adapting in response to experienced problems, such as increased frequency and duration of periods with low carrying capacity of the ground implying reduced or no accessibility within and to stands.

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## Introduction

The fifth assessment report from the Intergovernmental Panel on Climate Change (IPCC) leaves no doubt, the climate on earth is changing. It is extremely likely (>95%) that human emissions of greenhouse gases are the main driver of climate change. The global average temperature is rising, and precipitation and weather patterns are changing. These changes will have numerous effects on ecology and human structures. However, because our knowledge of the climate system and its response to greenhouse gases is limited, and as the amount of future emissions are unknown, there is considerable uncertainty regarding future climate development (Intergovernmental Panel on Climate Change 2014). The response of the forest ecosystems to climate change and impacts on forestry are likewise uncertain (Millar et al. 2007; Yousefpour et al. 2012). Knowledge on this subject is, however, expanding (Keenan 2015). Climate change may, for example, alter the distribution of tree species and forest dynamics (Sykes and Prentice 1996; Hanewinkel et al. 2013), the attributes of the species (Keenan 2015), and the disturbance regime (Schlyter et al. 2006). One of the underlying assumptions of forest management decisions has been that the climate will remain approximately the same throughout the lifetime of the forest (Cook 1996). Projected climate change breaks this paradigm (Schoene and Bernier 2012), and it is evident that climate change is an emerging source of risk and uncertainty in forest management planning (Millar et al. 2007). Forest decision-makers (FDMs) must therefore assess the climate-related risk and uncertainty and determine whether or how to adapt (Spittlehouse and Stewart 2004).

Several definitions of climate change adaptation in forestry have been proposed (see for example Schelhaas et al. (2015) or Millar et al. (2007)). In this study, we have used the broad definition introduced by IPCC stating that climate adaptation is "the process of adjustment to actual or expected climate change and its effects" (Intergovernmental Panel on Climate Change 2014). Bolte et al. (2009) and Millar et al. (2007) each define three main strategies for adaptation of forest ecosystems based on adaptation objectives. According to Bolte et al. (2009), the FDMs can choose to (i) actively adapt the forest structure, (ii) conserve the existing forest structure, or (iii) passively adapt by allowing spontaneous ecological possesses to develop. Only the two first strategies require silvicultural interventions, while passive adaptation essentially allows the ecosystem to develop without intervention. Millar et al. (2007) used the terms (a) resistance options, (b) resilience options, and (c) response options. The resistance options correspond to the conservation strategy. Response actions include all measures that mimic, accommodate, or facilitate change, but exclude all measures aiming to resist. This option therefore combines the active and the passive adaptation strategy. The resilience options are all measures that may improve the forest's ability to return to the desired

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conditions after being disturbed. Other authors focus on categorizing the adapting decision-makers rather than adaptive actions. Furness and Nelson (2012) divided forest organizations in British Colombia into “stage-two adapters”, “stage-one adaptors”, and “non-adapters”. “Stage-two adapters” were implementing adaptive actions, and “stage-one adapters” were reviewing adaptation, while “non-adapters” did neither. van Gameren and Zaccai (2015) introduced a framework with five adaptive profiles. When categorizing the forest owners into profiles, the authors considered adaptive strategy, motivations for adapting, and attitude toward future adaptation. “No-regret adapters” and the “innovative adapters” were both consciously planning and assessing climate change in their forest management. However, while the no-regret adapters had limited their actions to measures they considered beneficial also independent of climate change, the innovative adapters took actions beyond this. “Non-adapters” and “potential adapters” had not yet implemented any climate adaptive actions, and while the potential adapters envisaged doing so, the non-adapters did not. “Accidental adaptors” had implemented climate adaptive measures motivated by other objectives than adaptation to climate change. An example of accidental adaptation could be increasing forest diversity motivated by the guidelines of a sustainable forest management standard. Forest diversity in the literature repeatedly referred to as a climate adaptive measure (Millar et al. 2007; Ogden and Innes 2007; Bolte et al. 2009).

There are cognitive barriers to adaptive behavior: behavioral research points at effect, concern, and worry as the cognitive drivers of all adaptation. In addition, perceptions of risk are strongly influenced by personal experiences. Climate change is slow, hard to perceive, invisible from day to day, abstract, and has a statistical nature. Therefore, climate change does not stir the feeling of acute risk in most people. Changed behavior is often dependent of such a feeling of risk (Weber 2006). Etkin and Ho (2007) argue that adaptation may even seem irrational to some individuals because of the uncertainty associated with climate change, and because of the complex nature of the phenomena. Having witnessed or experienced climate change-related events does promote adaptation (Akerlof et al. 2013).

The productive forestland in Norway constitute 8.3 million hectares (Central Bureau of Statistics Norway 2015b) distributed on approximately 130,000 forest holdings. Non-industrial private forest owners (NIPFs) own 94% of the holdings, which constitutes 80% of the forestland. The majority of holdings are small. Fifty percent consists of less than 25 hectares forestland, while only 1200 hold more than 500 hectares (Central Bureau of Statistics Norway 2015a).The owners are free to manage their forests according to their own objectives within limitations of national law and regulations, and voluntary certification schemes, that is, the Norwegian PEFC standard (PEFC Norway 2015). The average income from forestry is low. In 2014, it constituted only 7% of the average gross income for the 20,000 owners with any registered forest income that year (Central Bureau of Statistics Norway 2016b). Given the modest average forest income, there is reason to believe that forest management is an avocation rather than an occupation for the majority of Norwegian NIPFs. Many small-scale NIPFs are therefore dependent on assistance from professional foresters. Providers of forestry services are therefore *de facto* important decision-makers alongside the NIPFs. The official forest policy related to climate change has so far been limited to mitigation. The Norwegian parliament issued two voluntary policy instruments in December 2015 to stimulate increased carbon sequestration in forests: a subsidy promoting higher planting densities, and a subsidy promoting fertilization (The Norwegian Parliament 2015). Planned climate change adaption of forest ecosystems and forestry in Norway is therefore at present dependent on NIPFs and their advisors. The overall objective of this article is therefore to study whether and how Norwegian FDMs have adjusted their forest management to climate change.

Climate predictions for Norway show a rise in mean annual temperature between 2.3°C and 4.6°C. Precipitation and the number of days with high precipitation intensity will increase, there will be fewer days with frozen ground, and the growing season will expand. Climate change projections at the local and regional scales are more uncertain than global projections (Hanssen-Bauer et al. 2009). Research addressing what impacts climate change might have on Norwegian forests are scarce. However, research from neighboring countries, that is, Sweden and Finland, may offer some indications. Several studies suggest that forest productivity may be positively affected (see, for example, Alam et al. 2008; Blennow et al. 2010; Koca et al. 2006; Peltola et al. 2010), a shift in species distribution is possible (Koca et al. 2006; Kellomäki et al. 2008), and that the risk of wind-throw may increase (Blennow et al. 2010; Peltola et al. 2010). Higher temperatures combined with wind-throw increase the risk of secondary damage through pathogens and pests (Schlyter et al. 2006; Jönsson et al. 2007). Forest resources may also become increasingly difficult to access due to the expected increase in soil moisture (Lindner et al. 2010). To which degree the results are applicable to Norway remain uncertain. The uncertainty makes advising FDMs how to adapt to climate change challenging (Lindner et al. 2014).

We are not aware of any research-based study of adaptation to climate change among FDMs in Norway prior to our work. Results from studies conducted in other countries offers valuable input. A growing number of articles study adaptive behavior, perceptions of climate change, and characteristics for adapting and non-adapting FDMs. Blennow and Persson (2009) argue that cognitive variables are vital for understanding climate adaptation in forestry. Results from several studies show that adaptive behavior is influenced by personal strength of belief in climate change (Blennow and Persson 2009; Blennow et al. 2012), and experiences or observations attributed to climate change (Blennow et al. 2012; Furness and Nelson 2012; van Gameren and Zaccai 2015). Concern related to climate change effects (Blennow 2012; Furness and Nelson 2012; van Gameren and Zaccai 2015), knowledge about how to adapt and trust in the effect (Blennow and Persson 2009) also affect the probability of adapting positively. However, the literature is not consistent. Sousa-Silva et al. (2016) found widespread concern and strong belief in climate change among forest stakeholders in Belgium. In addition, 50% of the stakeholders also reported having experienced events they attributed to climate change. One out of three had modified their forest management. Still, a logistic regression model with belief, experience, and concern as predictors for adaptive behavior had little explanatory value.

Being aware of risk does not necessarily promote worry or change in behavior. Using data from a questionnaire, Yousefpour and Hanewinkel (2015) found that professional foresters (private and public) in Southwest Germany viewed climate change as a significant, but not very high risk. The foresters did not agree on whether forestry proactively could adapt to manage risks associated with climate change, or whether they should reactively respond as climate change-related issues emerge. Another German study, based on interviews with forest officers, showed that even though the respondents claimed to consider climate change when taking management decisions, they had only occasionally implemented adaptive measures in practice (Milad et al. 2013). The authors suggest that the lack of specific climate adaptive strategies reflects the uncertainties related to climate development and the forest ecosystems ability to adjust to change. The storm Gudrun felled some 250 million trees in Sweden in 2005. After the storm, the Swedish Forest Agency encouraged planting of different tree species as this could reduce forest vulnerability. Lidskog and Sjödin (2014) combined data describing the consequences of Gudrun, data on regeneration, and analyzed a number of studies on forest owners in the affected areas. The forest owners had not followed the recommendations. The authors identified three main reasons for this. First, the forest owners felt that risk associated with natural catastrophes was impossible to control by forest management. Second, the owners regarded alternative management practices as uncertain. Finally, the forest owners had emphasized short-term economic priorities due to the stressful situation. Lidskog and Sjödin (2014) concluded that the forest owners perceive the risk of future events as theoretical and abstract, thus not influencing forest management planning processes. Therefore, it is evident that even if a FDM experience dramatic events with severe consequences related to climate, this do not necessarily facilitate adaptive behavior.

Some evidence suggests a South–North trend in adaptive behavior between FDMs within Europe. Based on the replies to a questionnaire distributed to forest owners in Sweden, Germany, and Portugal, Blennow et al. (2012) found that forest owners situated in Portugal were more likely to have adapted than the owners in Germany, while the Swedish owners were least likely to have adapted. The South–North trend in adaptive behavior has also been found among NIPFs within Sweden (Blennow 2012). Lawrence and Marzano (2014) found little worry or perceived need to adapt forest management to climate change among NIPFs in Wales. Still, some adaptive practices, mainly change of tree species, were reported. Risk diversifying measures, such as increased diversity in tree species, are a dominant adaptive practice reported in the literature (Blennow 2012; Milad et al. 2013; van Gameren and Zaccai 2015; Sousa-Silva et al. 2016).

The combined results and theory suggest that whether an FDM has implemented adaptive strategies is related to his or her strength of belief in climate change, whether he or she has an experience(s) attributed to climate change, and whether he or she possesses knowledge about how to adapt. We therefore aimed at studying whether FDMs in Norway: (i) believe climate is changing, and if so how climate change will affect forest ecosystems and forestry, (ii) have experienced events in or effects on forest ecosystems or forest infrastructure they attribute to climate change, and (iii) have adjusted their forest management due to climate change, and if so what adaptive measures they have implemented.

## Materials and methods

Perceptions, opinions, and motivations for actions are phenomena of the social world. Unlike the study objects of the natural world, the study objects of the social world attribute meaning to their surroundings (Bryman 2001). Climate change is a new, emerging, statistical, and abstract issue (Weber 2006). A qualitative approach allows the researcher to interact with the study objects, and through this interaction interpret the social phenomena through the eyes of the study objects (Bryman 2001). We therefore decided to conduct semi-structured interviews in focus groups. The interaction in a focus group may reflect the way people construct opinions and perceptions with others in everyday life. This allows the researcher to study how individuals as members of a group jointly construct understanding around a topic. In a focus group setting, the moderator introduces topics and asks questions. The participants discuss the topics, react to each other's statements and opinions, and challenge each other's views. In the process, the participants are forced to rethink their opinions and possibly revise or moderate their opinions, which may increase the probability of collecting more nuanced and accurate data on how and what the participants think (Bryman 2001).

We designed an interview guide containing main topics, suggestions for question formulations, and helpful keywords for formulating eventual follow-up questions. The interview guide had four main sections with defined main topics, and an open post. The four main sections were: (i) climate change, beliefs, and experiences, (ii) knowledge about climate change, (iii) adaptation to climate change, and (iv) risk and uncertainty in forestry and in relation to climate change. The topics and question formulations from previous similar studies reported in the scientific literature gave input to the design process (section I: Blennow and Persson 2009; Blennow et al. 2012; Weber 2006, 2010; section II and IV: Yousefpour and Hanewinkel 2015; section III: Lawrence and Marzano 2014; Blennow 2012). We started all interview session with questions from section I, after that the order varied from focus group to focus group. Based on the discussion in each group, we then decided which topics to introduce next and the need for follow-up questions. During the design process, we tested the guide on a group of NIPFs recruited through personal connections. We designed the interview guide in Norwegian. A version of the interview guide translated to English is presented in Appendix 1.

We conducted the study among FDMs in Southeastern Norway, which consists of the counties Oslo, Akershus, Østfold, Vestfold, Telemark, Buskerud, Hedmark, and Oppland. The total productive forest area of this region is approximately three million hectares. The forests mainly consist of even-aged mixed species stands. The main species in terms of growing stock are Norway spruce (*Picea abies* (L.) Karst., Scots pine ((*Pinus sylvestris* L.), and birch (*Betula pendula* Roth and *Betula pubescens* Ehrh.). Spruce and pine are the commercially important species. Clear cutting, followed by planting (of spruce) or natural regeneration are widely applied (Central Bureau of Statistics Norway 2015b). There are, however, variation in terms of site quality, property sizes, topography, and local climate both between and within the counties in the region.

The dominating provider of forestry services in Southeastern Norway is the forest owners associations Glommen, Viken, Mjøsen, and Norskog[1]. The associations handle the majority of the roundwood trade, organize most logging operations, conduct inventories, and offer planning and implementation of forest management. Mean yearly commercial roundwood removal between 2006 and 2016 was 8.6 million cubic meters. The harvested roundwood was either processed domestically or exported (Central Bureau of Statistics Norway 2016a).

We conducted 10 focus group interviews with FDMs in three categories. The categories were (i) NIPFs (mainly current owners, but also some future[2] and previous owners[3]), (ii) employees in forest owners associations, hereafter referred to as "forest advisors", and (iii) forest managers responsible for the management of a forest holding. In total, 54 people participated in the interviews. Nine of the groups were recruited through the Southeastern forest owners associations. We applied a purposive and criterion-based sampling approach, asking administrative staff in the owner associations to identify and contact groups of interview-candidates. For forest advisors, the criteria for selection were that their work should involve broad contact with members (NIPFs and/or forest managers) and with practical forestry. The criterion for NIPFs and managers was that the candidates actively were managing a forest holding. The tenth group was originally a pilot group recruited through a local chapter of the Norwegian farmer organization. We did not alter the interview guide after having carried out this interview, so we included the data from this session in the analysis. Table 1 shows the sociodemographic features and the composition of each group. All groups but number 4 were pre-existing groups (sensu Bryman 2001) meaning that the group members knew each other in advance to the group interviews.

We conducted all the interviews in-person, at various locations chosen by the participants, between the 30th of May and the 27th of September in 2016. All interview sessions began with a presentation of the moderator, information about the objectives of the study, methodology, treatment and storage of data, eventual questions and some informal conversation. The purpose of this was to facilitate an atmosphere of trust and foster an honest group discussion. Then, the participants filled out a form mapping forest property and sociodemographic data. After that, we conducted the interviews. Each interview lasted between one and two hours. We recorded the interviews with a Samsung UB1 microphone connected to a computer, and stored the records as audio files before transcribing them later. Time between the interviews and transcribing varied from one day up to three weeks. In addition to the audio files, we kept a research log with observations on body language and group dynamics. We emphasized to create an inclusive and informal tone, with room for digressions and jokes. Furthermore, we strived to facilitate for involvement of all group members in all the interviews. In some situations, the moderator acted as a more active chair instead of letting the discussion being open, or asked the participants to answer a question in turn. In other situations, the moderator directed questions by trying to interpret body language. The moderator could for example say: "you are leaning back and crossing your arms above your chest, does that mean that you disagree with what he is saying?"

The transcripts were coded and analyzed in NVivo (QSR International Pty Ltd. 2015). First, we read the transcripts holistically, noting our impressions and our assessment of the overall essence of each interview. Then, the statements of each participant were coded with an ID-key, which allowed us to analyze whether one or several group members acted as opinion leaders or were dominating the sessions. We emphasized identifying the statements and the patterns that could be linked to each research question, letting this guide the coding process. All statements describing a climate change-related observation or experience were first marked and labeled "observation/experience". We then analyzed these sections separately.

Even though we did not directly use theory or empirical advice to formulate the coding categories, the results from scientific literature affected the coding through the formulation of the research questions and the interview guide. Apart from that, we followed the guidelines described by Berg (1998) approaching the coding inductively, finding the codes as we worked through the data using reappearing words or words close to those used by the participants as category names. Throughout the process, we emphasized identifying common argumentation and perceptions. We also assessed whether the opinions were dynamic, that is, whether the participants adjusted their opinions during the interviews or uttered strong predefined perceptions and keeping to this throughout the discussion. For example, to assess whether the participants believed in climate change as phenomena and to assess the strength of their belief, we started with marking all statements that directly or indirectly expressed any opinion regarding the reality of climate change. We then coded the statements into "positive", "negative", and "doubt". These three categories also had several sub-categories. The positive statements were divided into "strong", "medium", and "light". The statement "I am absolutely sure" would be marked as "strong", while "there is something in it, yes" would be marked as "light". We then extracted the coded statements of the group, and assessed whether all statements were building on each other, constructing a consensus within the group. If there were no detectable dissents or clear deviations between group members, we treated the

**Table 1.** Sociodemographic features and group composition of the focus groups. The groups consisted mainly of members from the following categories of forestry decision makers: Non Industrial Private Forest Owners (NIPFs), forest managers responsible for the management of a larger privately or publicly owned forest holding, and forest advisors employed in a forest owners association.

| ID | Participants | Age span | Years of ownership/ experience | Group-members with forestry related education | Group features and additional information |
|---|---|---|---|---|---|
| 1 | 3 Forest advisors | 24-60 | 1-38 | 2 | 1 of the forest advisors were in addition a NIPF. The participants in the group were colleagues. |
| 2 | 5 Forest advisors | 33-55, one undisclosed | 3-33 | 5 | 1 of the forest advisors were in addition a NIPF. The participants in the group were colleagues. |
| 3 | 4 Forest advisors | 27-51 | 2-30 | 4 | 3 of the forest advisors were in addition themselves NIPFs. The participants in the group were colleagues. |
| 4 | 3 NIPFs | 65-71 | 23-46 | 2 | Constructed group. The NIPFs owned forest medium sized forest holdings between 150 and 240 hectares in the same county, and all group members held positions in the forest owners association. |
| 5 | 4 NIPFs | 36-62 | 16-30 | 1 | The NIPFs owned medium to lager sized holdings between 100 and 900 hectares in the same county. All group members held positions in the same forest owners association. |
| 6 | 3 NIPFs 1 coming NIPF | 47-62 | 12-27 | 0 | The coming NIPF was a forestry student (bachelor level). The NIPFs owned holdings small to medium sized holdings between 20 and 340 hectares in the same community. The NIPFs also held positions in the same forest owners association. |
| 7 | 3 NIPFs 1 coming NIPF | 34-36 | 1-4 | 2 | The NIPFs owned small to large sized holdings between 33 and 1350 hectares in the same community. This group was not recruited through a forest owner association. |
| 8 | 8 NIPFs 1 previous NIPF 2 forestry advisors 1 forest manager | 32-52 | 1-28 | 3 (NIPFs) 4 (others) | Two of the NIPFs had forestry-related occupation in addition to being NIPFs. The NIPFs owned small to medium sized holdings of between 35 and 250 hectares in the same community. The group members met with each other regularly through the forest owners association. |
| 9 | 7 forest managers 1 forest advisor | 34-63 | 3 participants less than 11 years, 5 more than 27 years. | 5 | The group was an organized forestry network group. The forest advisor was the group organizer. All the forest managers were responsible for the management of a larger forest holding sized between 2250 and 4300 hectares. The group had no common geographical affiliation. |
| 10 | 5 forest managers 1 previous forest manager/ current NIPF 1 NIPF | 58-81 | 28-52 | 6 | The group was an organized forestry network group. All the group members were responsible for the management of a large forest holding sized between 720 and 14500 hectares. The group had no geographical affiliation. Two of the manager were managing holdings owned by a family member. |

whole group as one. In other cases, we considered the coded statements of each participant separately, and grouped them together with other participants that had uttered similar perceptions. The coding and analysis process were conducted simultaneously.

One of the authors moderated, transcribed, coded, and analyzed the interviews. The other authors contributed through discussions and assessments throughout the process. We conducted the interviews in Norwegian.

## Results

All participants but one agreed that the climate on Earth is changing and that it will continue to change in the future. However, there was uncertainty and dissent among them regarding the causes of climate change. Few had a precise vision of how the climate would change apart from becoming "warmer, wetter, wilder" which is *a* frequently used phrase in the Norwegian climate debate. Common for those few who had a more detailed perception was a professional background that at some point had involved working with climate projections. None expressed deep concern about climate impacts on forest ecosystems and forestry in Southeastern Norway. Instead, the majority of the FDMs viewed climate change more as an opportunity than as a threat for the Norwegian forest-based sector:

> Isolated, I think this (climate change) might actually be positive for us (in Norwegian forestry) because of increased growth. (Forest manager, Group 9)

Many anticipated that the demand for roundwood would increase as result of climate mitigation in society:

> I believe that bio-based material will be utilized in new products, because it is renewable. That is the bottom line: our product, the

> resource that we manage, is renewable. That is why the market will demand it. (NIPF, Group 5)

Furthermore, most participants believed that climate change would lead to increased political support, and increased focus on forestry in society. The following statement from a forest advisor illustrates this view:

> (…) I sincerely believe that in the climate-context, there is no way of getting where we want to go in the future without forestry. (Forest advisor, Group 3)

Others were more careful in their statements, emphasizing that they hoped for such a change, but they were not yet convinced that this would take place. Figure 1 shows the main differences in expressed strength of belief and concern for climate change effects between participant categories.

The managers stood out as most concerned with climate-related risks, but also on risk and uncertainty in forestry in general. They discussed and assessed multiple climate risks more concretely than the other groups, and consented that emerging climate change-related risks would demand more knowledgeable and professionals FDMs. Two managers dissented from the dominating view in their group as they emphasized that they were uncertain about whether climate change might just be natural weather variability with statements like, "I, myself, am still not convinced about the whole thing (climate change)", and "there have been periods of high weather variability also in the past". Together with a forest advisor, they constitute the group referred as "climate change doubters". We found larger variability in perceptions among the NIPFs, than among the other groups. The NIPFs in Groups 4, 5, and 6 were just below the forest managers in both concern and belief. They stated to think that climate change would affect the forest and forestry, but were less concrete than the managers in describing how. They substantiated their views with reference to statistical trends, expert opinions, and personal observations. There were also NIPFs that believed the global climate is changing, but who did not think climate change would affect their forest or forestry significantly. Others emphasized that they saw no reason to worry about climate change. One NIPF denied the whole idea of climate change and was therefore classified as "climate change denier".

The majority of the forest advisors were in line with those who expressed that there was little reason to worry. One advisor for example questioned how an average rise in temperature of a few degrees could have any large effect on the forests in his region. Others emphasized that as long as the politicians (whom they perceived to have access to vast knowledge and expert advice) did not alter their behavior there would be no need to worry about climate change:

> If it were as bad as "they" say, the politicians would have done things differently. (Forest advisor, Group 3)

Another advisor thought that the media, the politicians, and the environmental lobby generally exaggerated the severity of most issues. Therefore, he refused to be alarmed:

> I do not believe in anyone who is telling me that the world go under. If "someone" say it (the world) will go under due to the

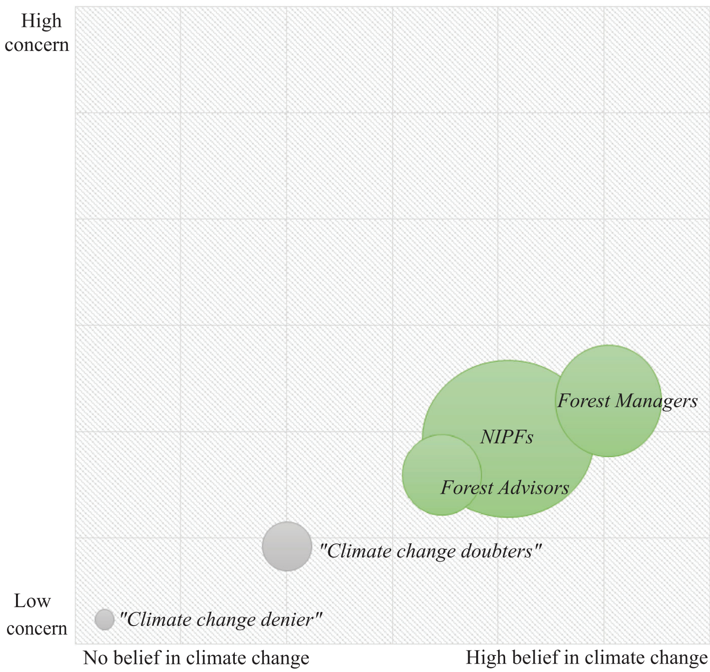


**Figure 1.** Main trend in differences between the participant categories regarding belief in climate change and concern for climate change impacts.

**Table 2.** Experiences attributed to climate change by the participants, and their impact on forest ecosystems and on forestry.

| Impact | Observation/ experience | Associated with climate change attribute | Consensus regarding novelty of observation/ experience | Confidence of relation to climate change | Suggested alternative explanations | Emphasis |
|---|---|---|---|---|---|---|
| Positive economic impact | Increased growth, faster development of stands and systematic positive site index shift | Longer growing season and temperature increase | Consensus in and between groups except for in Focus Group 7. | With some exceptions, the participants all believed that climate change were the main or a partial cause. However, all groups discussed alternative/ contributing explanations. | Improved plant material, and changed forestry practices. | High (except for in group 7) |
| Negative economic impact | Longer periods with low ground carrying capacity. Increase in severe machine induced ground-damages and periods with little or no accessibility to or on sites. Increase in water-induced damages to forest roads | Warmer winters: periods with frozen ground replaced with wet periods. More rainfall and periods with high rain intensity | Consensus, except for in group 8 and among a minority of the participants in group 2 and 3 | The opinions varied. The majority were convinced that climate change were a partial cause. Others considered it more likely than not to be a partial cause. The NIPFs in group 4,5, and 6 together with most managers were the most confident regarding causality. However, all groups discussed alternative/ contributing explanations. More uncertainty regarding causality with climate change, and more emphasis on alternative explanations among forest advisors, and in group 8, than in the other groups. | Reduced flexibility in when to harvest (due to year-round demand for roundwood), heavier forwarders and harvest-machinery. Reduced flexibility in when to harvest. Inadequate maintenance of culverts and drainage-systems. Increased ground pressure from forwarders. | High |
| | Rapid increase in the growth of pioneer species on newly felled and regenerated areas. | Warmer climate | Consensus in the six groups that discussed this issue | The majority of the groups considered it very likely that climate change were the cause, but there were no consensus. | Heavy machinery and increased machine induced damages to the forest ground | High |
| | Reappearing autumn shooting in spruce | Warmer climate | Consensus in the three groups where a participant had experienced autumn shooting. | Some variation, climate change was generally considered to be a likely cause or a likely triggering factor | A random genetic change | High by those who shared this experience |
| Both negative and positive | Increase or decrease in wind-felling | More/ less wind/changed wind pattern | The issue were discussed in most groups, change were reported in five. However, we could find no consistent perception of changes in the frequency of wind-felling neither between nor within groups. | We could find no consistent pattern. Some participants were convinced that there had been a change, while others were convinced of the opposite. | More forest in an mature (and therefore vulnerable) state | Low |
| | More or less snow-break dependent on where the FDM in question were situated | Either more heavy snow due to warmer temperatures in areas were the winters historically have been cold and snowy, or less snow in general | Consensus among those who had experienced this. | The participants were certain that there was a direct linkage between climate change and amount of precipitation falling as snow, there were however some discussion regarding whether the changes might just be natural variability. | Natural weather variability | Low |
| Neutral | Increased prevalence of thermophilic trees, and an (upward) shift in the tree-line | Warmer climate | Consensus in the five groups who mentioned this. | The participants were certain that there was a direct linkage between climate change and longer growing season/increased temperatures, there were however some discussion regarding whether the changes might just be natural variability. | Natural weather variability | Low |

> environment, the climate, or other things, I don't believe them. (Forest advisor, Group 2)

In all groups, the participants suggested a number of events and changes they had noticed that they either attributed, or wondered whether to attribute, to climate change. We have included the most frequently discussed issues in Table 2.

The most commonly suggested changes were increased forest growth and issues related to rain (rain intensity/ longer periods of rain) and increased ground wetness. In addition to the issues presented in Table 2, a few FDMs reported having experienced severe mudslide or ground slippages. Several had also observed increase in water run-off and/or erosion:

> (…) there is more water in less time, and the rain intensity is higher, this causes much more erosion. (NIPF, Group 5)

There was however much discussion regarding the causality between climate change and the observations, for example, illustrated by this excerpt:

> (…) of course, there have been natural variations and periods like this before. Still, it strikes me, how the frozen ground season even in the inland have diminished and how we annually seem to be tumbling around in mud to over Christmas, and then again, in February, That's a short winter-season! (Forest advisor, Group 1)

As a reaction to his colleague's statement, another participant replied:

> I think I disagree. Maybe I am a skeptic. I don't doubt that there is climate change, but still I don't think that climate change is the reason why the frozen ground season was short and that the ground was very wet this winter and spring. (Forest advisor, Group 1)

All the groups discussed whether the weather really had changed over the past decades or not. A forest advisor stated:

> That thing with roads flooding away, I am fairly sure that I remember that happening before as well. If they (the roads) were poorly maintained, if the draining was not open and such. I don't think that there is any novelty to this. (Forest advisor, Group 2)

A repeatedly suggested and discussed alternative explanation for the increase in damages to infrastructure and forest ground was pressure on cost-efficiency in forestry:

> The old way of forestry was better, we used to log when the conditions were appropriate, now there is a pressure that it (the logging) should run all year round. (NIPF, Group 6)

In the end, no definitive conclusion was reached, but the prevailing opinion was that climate change is a likely partial cause for the observed changes.

We found only one case of planned active adaptation of forest composition (Bolte et al. 2009) motivated by climate change (sensu Bolte et al. 2009). One NIPF was experimenting on a very minor scale with pure stands of black alder (*Alnus glutinosa* (L.) Gaertn), and stated that a warmer climate in the future was a partial cause for this action. Introducing new species (deciduous trees in particular) or increasing species diversity were the first thing the majority of the groups discussed when asked to name what a climate adaptive measure might be. In Group 2, there was a discussion about the possibility of advising NIPFs to change from conifers to birch in particular areas:

> (…) the thing with birch, we have to be careful and not recommend it without caution. There are some places, though, where I believe it would be rather wise to think about alternatives and not necessarily keep on forcing spruce at all costs. (Forest advisor, Group 2)

However, the group concluded that it was highly unlikely that NIPFs would want to implement this scheme. The other groups dismissed the idea of changing main species due to the current, and to the historic market situation. In addition, the FDMs believed that spruce are a robust species that could adapt to climate change if necessary. Thus, the FDMs expressed no need to search for alternatives. Regarding implementing silvicultural measures to promote stability, the FDMs expressed that uncritical implementation were in conflict with other objectives:

> It is the golden mean. If you want a forest that is robust against wind, you need low plant density. If you want it to be robust against snow breakages, you need the same and large foliage as well. But if you want to produce much timber, you need high plant density. (Forest advisor, Group 2)

In general, the FDMs agreed that before implementing management adjustments, they would need to be certain about how climate change would affect the forest ecosystems, and on the benefit of adaptation outweighing the associated cost. Therefore, the FDMs dismissed measures they perceived to be costly, like promotion of mixed or uneven-aged stands:

> (…) that train left the station ages ago, because the machinery is what it is. You cannot go around collecting one tree here and then one there, like before when they used horses. The machinery is made for clear cuttings. (NIPF, Group 7)

The FDMs also bluntly rejected the possibility of implementing a passive adaptation strategy (sensu Bolte et al. 2009). When the moderator presented this possibility, the FDMs appeared provoked and responded with phrases like "but, we do forestry because we want to produce", and implied that passive adaptation for them would be the same as giving up forestry. A minority, consisting of a few NIPFs in Group 8 and two forest advisors, did not see the relevance of climate change to forest management today at all:

> How can I, at present, relate my job as a forest advisor to climate change? This is a slowly emerging issue. If it is going to be warmer and wetter in the future – what am I to do about that? (Forest advisor, Group 1)

FDMs in all categories also emphasized that forestry is a long-term production, were fashions in management, and the market projections are ever changing. A widespread view was that hasty adaptation based on uncertain assumptions could be more risky than doing nothing:

> But do people want to put money into adaptation now, when they do not really know if it is going to work? Because that is the challenge, it is all just guesswork. (NIPF, Group 7)

Still, other NIPFs believed that forest management would change in the future:

> I think we are going to do forest management in another way in the future. I think that silviculture is going to change as a result of the changes that are happening. (NIPF, Group 5)

We found no dominating perception of how the FDMs in question believed that forest management would change. Most groups discussed whether future forest management would involve increased emphasis on sequestering and storing $CO_2$. However, the groups generally concluded that producing quality timber should remain the main objective in Norwegian forestry also in the future, a conclusion often drawn from demand in the past:

> There has been a demand for the same qualities throughout history; no one has ever wanted crooked timber. (Forest Advisor, Group 3)

There were several examples of proactive climate change adaptation measures related to infrastructure. The managers and NIPFs that were building forest roads, or planning on doing so, had taken precipitation projections and shorter frozen ground periods into account by increasing the dimensions of the drainage-system. Some managers mentioned considering building new roads to ensure that forest resources in areas with high soil moisture could be accessed also in the future. There were also FDMs that reported that they were systematically upgrading old drainage systems and roads to increase the robustness of existing infrastructure. Finally, the advisors in groups 2 and 3 mentioned that they recommended NIPFs to "assess everything related to infrastructure more thoroughly".

The most common climate adaptive actions were responses to experienced issues, particularly adjustments of management in response to low ground carrying capacity and increased frequency of road slippages due to heavy/longer rain periods or short frozen ground season. Table 3 shows the most common reactive measures.

Some FDMs being uncertain of the causality between low ground carrying capacity or road slippages and climate change had adjusted their behavior in the same way as those who were convinced about this causality. In addition, those who believed there was a causality emphasized that they mainly had adapted to the situation, and that they did not think about climate change explicitly when doing so. The FDMs agreed that their perceptions regarding causality were of little importance to their behavior, as they – no matter the underlying cause – had to tackle the present situation to prevent economical loss. The management adjustments were always limited to tackling issues that directly or indirectly were related to an experience. Having experienced an issue and perceiving this issue to be a climate change effect had not motivated the FDMs to implement adaptive measures in other management areas. For example, FDMs whom had experienced road slippages due to increased precipitation had not implemented strategies for increasing forest resilience or stability.

Reading Table 3, it is apparent that the managers had carried out more adaptive measures in response to experiences than the other FDMs. The managers were, however, responsible for large management units, and the size of the management unit seemed to influence whether the FDMs perceived that they possessed the autonomy and possibility needed for carrying out such adjustments. An example is implementation of flexible harvest planning. A prerequisite for implementing this scheme is to perceive to have autonomy over all operational and operative decisions. While the managers were responsible for operative planning on their holdings, most NIPFs left the planning, organization, and administration of the harvest to a forest owner association. Many NIPFs stated that after signing the logging contract, they felt they had no autonomy regarding operational decisions. They also feared that terminating or delaying planned logging operations would be too costly. However, several NIPFs, especially the members of groups 4 and 6, argued strongly that the forest owners associations should focus on flexible harvest practices:

**Table 3** Most commonly implemented measures as a response to or in extent to experiences among the participants.

| Measure | Implemented by | Motivation | Type of adaptation |
|---|---|---|---|
| Flexible logging-planning (alternative sites cleared for logging, prioritize stands according to season, accessibility, and ground carrying ability) | Systematically by managers. Forest advisors (group 2 and 3) stated to *"consider everything more thoroughly".* | Prevent stop in logging, prevent machine-induced damages to forest ground (and roads), prevent water run-off etc. | Operational and operative |
| Targeted dimension-upgrading of drainage and culverts | Systematically by managers, recommended by advisors (group 2 and 3) | Prevent damages on roads due to under dimensioned drainage and culverts | Infrastructural |
| Focus on at site consideration (vulnerability, state, development, ground-conditions) in short-term management planning | Systematically by managers, sporadically by NIPFs, recommended by advisors (group 2 and 3) | Secure forest health, stability and robustness. Ensure right measure at right time. Based on observations of development an experiences from previously treated stands | Monitoring to improve basis for decisions |
| Old growth management: Shorter rotations in response to faster growth | Systematically by forest managers (mixed objectives), and by one NIPF (objective: increase profit) | Decrease risk (over-mature stands perceived to be more exposed to various risks). Prevent stands from decreasing in value as they reach mature state (faster than expected according to yield and development tables). Meet demand for smaller dimensions. | Forest structural |
| Planting of specially treated plants imported from Sweden | One NIPF | Preventing autumn shooting | Forest structural |
| Increased maintenance (and monitoring) of roads, culverts and drainage-systems | Systematically by managers, sporadically by other NIPFs. Recommended by advisors in (group 2 and 3) | Avoid escalating damages on roads due to blocked culverts | Infrastructural |

> I believe, and I have said so a few times now, that we will need to adapt harvest operations to the new situation. (NIPF, Group 4)

Finally, the participants were generally eager to discuss their forest management regime and any recent management adjustments they had made, in the context of climate change. Many of FDMs had made adjustments that at first sight could be interpreted as climate adaptation, but that in fact had been motivated by other objectives. A commonly uttered reflection was that near all forest management decisions have multiple underlying factors, and that they seldom could isolate one or several underlying motivation behind their actions.

## Discussion

The overall objective of this article was to survey whether, and if so how and why FDMs in Southeast Norway are adapting their forest management to climate change. To asses this, we conducted a study based on focus groups interviews. We recruited the respondents according to certain criteria. The sampling approach, and the methodology, has implications for the external and internal validity of the results. We did not use a random sampling approach. Instead, we contacted the forest owners associations in Southeastern Norway asking them to assist us in recruiting candidates for the focus groups. Our objective was to recruit participants likely to have interest in and opinions about climate change adaptation. Therefore, the results of this study could be assumed to represent not the entire population of FDMs in Southeast Norway, but a subset of this population who is interested in the climate change debate.

In a focus group, the participants exchange views and are allowed to discuss topics introduced by the moderator (Bryman 2001). We strived to engage all participants in the discussion, and emphasized creating an open and safe atmosphere. Still, there is a risk that dominating group members not only were influencing the other participants through exchange of opinions, but also were affecting the others to not voice their opinions at all. Although there is no way to guarantee that there were no such effects, we strived to avoid this through active moderation.

Because all but one of the focus groups were pre-existing groups, there is also a risk that pre-existing group roles limited or guided their responses. However, as pointed out by Bryman (2001), using pre-existing groups may accommodate an increased chance of more genuine replies, since the group members may feel safe to speak their mind in each other's company. Another issue is the risk that the framing of the questions, or perceptions among the participants regarding what the moderator wanted them to answer, may have affected the discussion. To tackle these issues, the moderator strived to formulate the questions openly. The moderator also strived to avoid influencing the discussion more than necessary.

The interview guide was semi-structured, and the order of the topics and the formulation of the questions asked by the moderator varied according to the subjects that surfaced in each interview. The moderator has therefore adapted the discussion to each group and sought to hand over some control of the discussion to the participants, rather than forcing the order of the topics or framing the questions in a particular way. Letting the participants discuss without too much moderation may increases the probability genuine responses (Bryman 2001).

We conducted 10 group interviews. Our combined sample consisted of 54 participants. By conducting a large number of focus group interviews ($N = 10$; Bryman 2001), which we believe strengthens the credibility of our results, we reduced the possibility that our results would be dramatically affected by a single focus group or methodological choices (Carlsen and Glenton 2011). One moderator conducted, transcribed, and analyzed all the interviews. This has both advantages and disadvantages. On one hand, the perceptions and bias of the moderator may influence the interpretation of the data. We strived to avoid this by regular discussions between authors. In addition, the moderator made active use of a research log, successively writing down perceptions, ideas, feelings, doubts, and reviewing and assessing whether this throughout the process trying to identify eventual biases. On the other hand, the use of a single researcher has the advantage of ensuring consistency in interpretation and reliability of the results. In addition, having conducted the interview, interacted with the participants, and listened to the audio files multiple times during the transcription process offers nuance and context to the recorded data.

Summarizing our results, we found that all but one of the participants believed that the climate was changing. There was however uncertainty regarding the cause of this change. We could not find any sign of deep worry. On the contrary, we found a widespread belief that climate change could be an opportunity rather than a threat to Norwegian forestry. Most believed that they had experienced the effects of climate change, but there was uncertainty also regarding this. There was little evidence of proactive adaptation of forest structure and composition. Planned adaptation of infrastructure was more common. The most common forms of adaptation were responses to experienced events. Also in the latter case, the FDMs were more occupied with infrastructure and operational issues than forest ecosystems.

One noteworthy finding is the way the majority of the FDMs in our sample view climate change as an opportunity for the Norwegian forestry sector has seldom been reported in the literature. To the best of our knowledge, there has been little emphasis on possible positive effects of climate change in other studies. There is therefore limited basis for comparison, and positive expectations related to climate change may exist also among FDMs from in other countries. This results in a knowledge gap, and we argue that future research should address also possible positive expectations related to climate change among FDMs.

Both FDMs that expressed uncertainty and those who strongly believed in climate change and were convinced they had experienced climate change effects, substantiated their views with own experiences. With very few exceptions, all FDMs who participated in our survey reported to have experienced and observed the same kind of climate change impacts. These were increased growth, increased precipitation, and shorter frozen ground season which had led to longer periods of low ground carrying capacity and road slippages. However, perceptions of the causality between the same type of experience and climate change varied among the respondents. This suggests that the FDMs expectations can have influenced the interpretation of their experiences, an idea first proposed by Francis Bacon in 1620 (Jardine and Silverthorne 2000). Many recent studies (e.g. Blennow and Persson 2009; Blennow 2012; Blennow et al. 2012; Furness and Nelson 2012; van Gameren and Zaccai 2015) show that beliefs motivate changes in behavior. Since all participants had experienced or observed similar environmental changes (e.g. in the length of the frozen ground season, in precipitation, or in forest growth), but disagreed on the causal relation between this and climate change, it seems that their experiences had not necessarily formed their beliefs. We therefore agree with Yousefpour et al. (2013) and Blennow (2012) in that understanding forming of beliefs is important for understanding adaptive behavior.

Promotion of mixed forests and diversity in species generally seems to be one of the most widely applied adaptive practices (Blennow 2012; Milad et al. 2013; Lawrence and Marzano 2014; van Gameren and Zaccai 2015; Sousa-Silva et al. 2016). Yet, our respondents had not implemented such practices as a response to climate change, and they generally rejected the idea of altering forest structure and composition until proven necessary. The deviance from Blennow (2012) was unexpected because Sweden and Norway are neighboring countries and share cultural similarities.

We found only one example of active adaptation of forest structure motivated by climate change. Weber (2006) writes that concern and worry are drivers of adaptive behavior. Our respondents did not express such worry. Thus, Weber's argument seems a possible explanation for the lack of active adaptation of forest structure to climate change. The reasons given for not implementing adaptive actions are very much in line with those found by Lidskog and Sjödin (2014) among Swedish forest owners: uncertainty associated with alternative management practices, and economical assessments. There were, however, several cases of active adaptation related to infrastructure, addressing projected increase in precipitation (amount and intensity) and shorter frozen ground periods. By adapting the infrastructure, the FDMs were trying to avoid road slippages and periods of low road carrying capacity mainly caused by heavy rain or lack of frost. The prospect of not being able to transport timber out of the forest is concrete and palpable, contrary to, for example, the response of a forest ecosystem to an increase in mean temperature or precipitation. In addition, these measures are directly designed to tackle the undesired effects of climate change. In essence, there might be less cognitive barriers (Weber 2006; Etkin and Ho 2007) toward adapting infrastructure than toward adapting forest ecosystems. In addition, many FDMs had already experienced problems related to rain and short frozen ground periods. Such experiences may increase the likelihood of adaptation (Akerlof et al. 2013).

There might be other motivations for climate adaptation than reducing economic risk. Such motivations could be high emphasis on preservation of biodiversity or patrimonial attachment increasing the likelihood of adaptation (van Gameren and Zaccai 2015). Apart from abiding to the Norwegian PEFC standard (PEFC Norway 2015), which is a prerequisite for selling roundwood through the forest associations (PEFC Norway 2016), none of the FDMs we interviewed mentioned biodiversity preservation as an objective or as something they considered in their forest management. A family inheritance perspective on forest ownership may also influence forest owner objectives and behavior (Boon et al. 2004; Ingemarson et al. 2006). A few NIPFs in our sample explicitly mentioned the importance of the holding being transferred to other family members at some point in the future. These NIPFs did not express more motivation for implementing climate adaptive actions than the other NIPFs.

Before generalizing the results from this study, the findings need to be verified by further research. Larger surveys could provide more definitive evidence to what extent our findings exist in a larger population. A further study could usefully combine survey data with forest field data to map actual adaptive behavior. In addition, it seems important to explore the relationship between NIPFs and forest advisors, and study who are the actual decision-makers in Norwegian forest management. This is crucial information for designing policies promoting behavioral change. Finally, further research should study how FDMs form their perceptions and opinions to better understand why FDMs perceive climate change as they do, and consequently how they behave. An interesting approach would be to explore whether a forest owner typology based on owner objectives (Boon et al. 2004; Ingemarson et al. 2006) might explain adaptive behavior.

## Notes

1. Glommen, Viken, and Mjøsen are regional forest owners associations in the Norwegian Forest Owners Association structure, while Norskog is an independent forest owner organization traditionally organizing the owners of the largest forest properties in Norway.
2. The coming forest owners were close relatives (sons/daughters or fiancées) of the current forest owners. The future owners were planning to take over/become co-owners of the forest holding in the near future.
3. The previous owners had already transferred their former forest holding to a son or daughter. The previous owners we interviewed were still involved in the running of their former forest holding, but no longer formally in charge.

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## References

Akerlof K, Maibach E, Fitzgerald D, Cedeno A, Neuman A. 2013. Do people "personally experience" global warming, and if so how, and does it matter? Global Environ Change. 23:81–91.

Alam A, Kilpeläinen A, Kellomäki S. 2008. Impacts of thinning on growth, timber production and carbon stocks in Finland under changing climate. Scand J For Res. 23:501–512.

Berg BL. 1998. Qualitative research methods for the social sciences. 3rd ed. Boston, MA: Allyn and Bacon.

Blennow K. 2012. Adaptation of forest management to climate change among private individual forest owners in Sweden. For Policy Econ.24:41–47.

Blennow K, Andersson M, Bergh J, Sallnäs O, Olofsson E. 2010. Potential climate change impacts on the probability of wind damage in a south Swedish forest. Clim Chang. 99:261–278.

Blennow K, Persson J. 2009. Climate change: motivation for taking measure to adapt. Glob Environ Chang. 19:100–104.

Blennow K, Persson J, Tomé M, Hanewinkel M, Krueger F. 2012. Climate Change: believing and seeing implies adapting journal [Internet]. [cited 2016 Oct 7], 7. Available from: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0050182

Bolte A, Ammer C, Löf M, Madsen P, Nabuurs G-J, Schall P, Spathelf P, Rock J. 2009. Adaptive forest management in central Europe: climate change impacts, strategies and integrative concept. Scand J For Res. 24:473–482.

Boon T, Meilby H, Thorsen B. 2004. An empirically based typology of private forest owners in Denmark: improving communication between authorities and owners. Scand J For Res. 19:45–55.

Bryman A. 2001. Social research methods. Oxford: Oxford University Press.

Carlsen B, Glenton C. 2011. What about N? A methodological study of sample-size reporting in focus group studies. BMC Med Res Methodol. 11:26.

Central Bureau of Statistics Norway: Commercial roundwood removals, 2016, quarterly preliminary figures [Internet]. 2016a. Oslo: Author; [cited 2016 Nov 1]. Available from: https://www.ssb.no/jord-skog-jakt-og-fiskeri/statistikker/skogav/aar-endelige.

Central Bureau of Statistics Norway, Forest owners' income 2014 [Internet]. 2016b. Oslo: Author; [cited 2016 Jun 5]. Available from: http://www.ssb.no/en/jord-skog-jakt-og-fiskeri/statistikker/skoginnt/aar/2016-02-18#content

Central Bureau of Statistics Norway: Forestry, structural statistics, 2014 [Internet]. 2015a. Oslo: Author; [cited 2016 Jun 5]. Available from: http://www.ssb.no/en/jord-skog-jakt-og-fiskeri/statistikker/stskog/aar/2015-09-22#content.

Central Bureau of Statistics Norway: The National Forest Inventory, 2010–2014 [Internet]. 2015b. Oslo: Author; [cited 2016 Nov 7]. Available from: http://www.ssb.no/en/jord-skog-jakt-og-fiskeri/statistikker/lst

Cook J. 1996. Implications of modern successional theory for habitat typing: a review. For Sci. 42:67–75.

Etkin D, Ho E. 2007. Climate change: perceptions and discourses of risk. J Risk Res. 10:623–641.

Furness E, Nelson H. 2012. Community forest organizations and adaptation to climate change in British Columbia. For Chron. 88:519–524.

Hanewinkel M, Cullmann D, Schelhaas M-J, Nabuurs G-J, Zimmermann N. 2013. Climate change may cause severe loss in the economic value of European forest land. Nat Clim Chang. 3:203–207.

Hanssen-Bauer I, Drange H, Førland E, Roald L, Børsheim K, Hisdal H, Lawrence D, Nesje A, Sandven S, Sorteberg A, et al. 2009. Klima i Norge 2100. Bakgrunnsmateriale til NOU Klimatilplassing[Climate in Norway 2100. Background material for the Official Norwegian report on climate adaptation]. Oslo Norsk klimasenter.

Ingemarson F, Lindhagen A, Eriksson L. 2006. A typology of small-scale private forest owners in Sweden. Scand J For Res. 21:249–259.

Intergovernmental Panel on Climate Change. 2014. Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: Switzerland IPoC Change.

Jardine L, Silverthorne M. 2000. Francis Bacon: the new organon. Cambridge, UK: Cambridge University Press.

Jönsson A, Harding S, Bärring L, Ravn H. 2007. Impact of climate change on the population dynamics of *Ips typographus* in southern Sweden. Agric For Meteorol. 146:70–81.

Keenan R. 2015. Climate change impacts and adaptation in forest management: a review. Ann For Sci. 72:145–167.

Kellomäki S, Peltola H, Nuutinen T, Korhonen K, Strandman H. 2008. Sensitivity of managed boreal forests in Finland to climate change, with implications for adaptive management. Philos Trans R Soc B. 363:2339–2349.

Koca D, Smith B, Sykes M. 2006. Modelling regional climate change effects on potential natural ecosystems in Sweden. Clim Chang. 78:381–406.

Lawrence A, Marzano M. 2014. Is the private forest sector adapting to climate change? A study of forest managers in North Wales. Ann For Sci. 71:291–300.

Lidskog R, Sjödin D. 2014. Why do forest owners fail to heed warnings? Conflicting risk evaluations made by the Swedish forest agency and forest owners. Scand J For Res. 29:275–282.

Lindner M, Fitzgerald J, Zimmermann N, Reyer C, Delzon S, van der Maaten E, Schelhaas M-J, Lasch P, Eggers J, van der Maaten-Theunissen M. 2014. Climate change and European forests: what do we know, what are the uncertainties, and what are the implications for forest management? J Environ Manage. 146:69–83.

Lindner M, Maroschek M, Netherer S, Kremer A, Barbati A, Garcia-Gonzalo J, Seidl R, Delzon S, Corona P, Kolström M, et al. 2010. Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. For Ecol Manage. 259:698–709.

Milad M, Schaich H, Konold W. 2013. How is adaptation to climate change reflected in current practice of forest management and conservation? A case study from Germany. Biodivers Conserv. 22:1181–1202.

Millar C, Stephenson N, Stephens S. 2007. Climate change and forests of the future: managing in the face of uncertainty. Ecol Appl. 17:2145–2151.

The Norwegian Parliament. 2015. State budget 2016. Oslo Stortingets administrasjon, Konstitusjonell avdeling [Parliamentary Administration, Constitutional Department]. p. 162.

NVivo qualitative data analysis Software for WINDOWS [2015]. Version 11. Release Nvivo Pro qsrinternational.com QSR International Pty Ltd.

Ogden A, Innes J. 2007. Incorporating climate change adaptation considerations into forest management planning in the boreal forest. Int For Rev. 9:713–733.

Peltola H, Ikonen V-P, Gregow H, Strandman H, Kilpeläinen A, Venäläinen A, Kellomäki S. 2010. Impacts of climate change on timber production and regional risks of wind-induced damage to forests in Finland. For Ecol Manage. 260:833–845.

PEFC Norway. 2016. PEFC Norway: About PEFC. [cited 2016, Nov 16]. Availble from http://www.pefcnorway.org/side.cfm?ID_kanal=26.

PEFC Norway. 2015. Norwegian PEFC Forest Standard In: PEFC N 02 Oslo PEFC Norway p. 31.

PEFC Norway: About PEFC [Internet] Oslo: PEFC Norway. Available from: http://www.pefcnorway.org/side.cfm?ID_kanal=26

Schelhaas M-J, Nabuurs G-J, Hengeveld G, Reyer C, Hanewinkel M, Zimmermann N, Cullmann D. 2015. Alternative forest management strategies to account for climate change-induced productivity and species suitability changes in Europe. Reg Environ Chang. 15:1581–1594.

Schlyter P, Stjernquist I, Bärring L, Jönsson A, Nilsson C. 2006. Assessment of the impacts of climate change and weather extremes on boreal forests in Northern Europe, focusing on Norway spruce. Clim Res. 31:75–84.

Schoene D, Bernier P. 2012. Adapting forestry and forests to climate change: a challenge to change the paradigm. For Policy Econ. 24:12–19.

Sousa-Silva R, Ponette Q, Verheyen K, Van Herzele A, Muys B. 2016. Adaptation of forest management to climate change as perceived by forest owners and managers in Belgium. Journal [Internet]. [cited 2016 Nov 10]; 3. Available from: https://forestecosyst.springeropen.com/articles/10.1186/s40663-016-0082-7

Spittlehouse D, Stewart R. 2004. Adaptation to climate change in forest management. Journal [Internet]. [cited 2016 Aug 21]; 4. Available from: http://www.forrex.org/jem/2003/vol4/no1/art1.pdf

Sykes M, Prentice I. 1996. Climate change, tree species distributions and forest dynamics: a case study in the mixed conifer/northern hardwoods zone of Northern Europe. Clim Chang. 34:161–177.

Tabel 07412. 21.03.2017. 23.01.2017 ed. Oslo: Author; [cited 2017 March 25]. Available from: https://www.ssb.no/statistikkbanken/selectvarval/Define.asp?subjectcode=&ProductId=&MainTable=AvvirkSalg13&nvl=&PLanguage=0&nyTmpVar=true&CMSSubjectArea=jord-skog-jakt-og-fiskeri&KortNavnWeb=skogav&StatVariant=&checked=true

van Gameren V, Zaccai E. 2015. Private forest owners facing climate change in Wallonia: adaptive capacity and practices. Environ Sci Policy. 52:51–60.
Weber E. 2006. Experience-based and description-based perceptions of long-term risk: why global warming does not scare us (yet). Clim Chang. 77:103–120.
Weber EU. 2010. What shapes perceptions of climate change? Wiley Interdiscipl Rev Clim Chang. 1:332–342.
Yousefpour R, Hanewinkel M. 2015. Forestry professionals' perceptions of climate change, impacts and adaptation strategies for forests in south-west Germany. Clim Chang. 130:273–286.
Yousefpour R, Jacobsen J, Thorsen B, Meilby H, Hanewinkel M, Oehler K. 2012. A review of decision-making approaches to handle uncertainty and risk in adaptive forest management under climate change. Ann For Sci. 69:1–15.
Yousefpour R, Temperli C, Bugmann H, Elkin C, Hanewinkel M, Meilby H, Jacobsen JB, Thorsen BJ. 2013. Updating beliefs and combining evidence in adaptive forest management under climate change: A case study of Norway spruce (Picea abies L. Karst) in the Black Forest, Germany. J Environ Manage. 122:56–64.

## Appendix

**Table A1.** The Interview guide with questions, keywords and notes

| Subject | Possible Formulations | Keywords (if necessary) | Notes and supplements |
|---|---|---|---|
| Climate change, beliefs and experiences | Do the group believe that we (Earth) are in the beginning of period with substantial climate change?<br>Have group members experienced or observed changes in/on forest ecosystems/forestry/forest infrastructure/operational conditions that they attribute to climate change?<br>Do you think climate change will impact forest ecosystems<br>If yes, how?<br>Will forestry change because of climate change?<br>Which climate related events do you believe we will experience more often<br>Which climate related effects do the group think will have most impact on forest ecosystems and forestry? | Human made/natural variability<br>Impact and consequence, World and Norway<br>Evolution/Shock<br>Own holding<br>All forest<br>Local/Norway<br>Evolution/shock<br>Time perspectives: 5 years, 20 years, towards 2100<br>Positive/Negative<br>Economically/ecologically | Describe and explain<br>If needed:<br>Wind, water, snow, invading species, drought, fire, insects, fungus, growth<br>Possibility: other groups believe in climate change? |
| Knowledge | How do you assess your knowledge about climate change/climate change in a forest/forestry perspective?<br>What is the origin of the knowledge the group possess?<br>How do the group assess the different providers of knowledge about climate change?<br>Is there any need for/demand for silvicultural advice in a climate change context among the participants? | Compared to the "average Norwegian"<br>Radio/TV/Newspapers (which kinds?) Forest media/ research publications/official information/internet/ friends and family/education/colleagues/ conferences<br>Media, scientists, forest organizations and associations<br>Whom do they trust?<br>What kind of demand? | Active pursuit of knowledge? |
| Adaptation to climate change | Do any of the group members make other assessments/make other decisions when making management decisions because of climate change?<br>How can forest management be adapted to reduce climate change risk and uncertainty?<br>Have the group members assessed implementing such measures? Have they implemented such measures?<br>How do the group assess their own knowledge about adaption of silviculture with respect to climate change?<br>Have any of the group members been recommended/ recommended others to change their forest management with respect to climate change?<br>Has any of the group members assessed change of main production species? | Regeneration, Silviculture, old growth, Etc.<br>Invest less/Risk diversification trough changed forest composition/Changed silviculture?<br>Why/why not?<br>Do they know how to adapt?<br>Who recommended the adjustment?<br>Spruce – vulnerable? | |
| Risk and uncertainty | How do the group perceive the degree of risk and uncertainty in forest management/forestry?<br>Is the degree of risk and or uncertainty changing?<br>What is the origin of risk and uncertainty?<br>What is the perceived as the major and the minor risks and sources of uncertainty?<br>Is the forest based sector perceived to be a sector with much risk and uncertainty? | Marked, technical, politicians, physical (weather and climate)<br>Increasing/Decreasing<br>Why? | |
| | Is this (climate change and forestry) considered an important subject? | Is this something the participants talk about with other FDMs?<br>Is climate change/climate change adaptation a focus in the associations?<br>Is climate change a focus among the advisors that the NIPFs are in contact with?<br>Is it a focus in the forest- media? | |
| | Is there anything else the participants want to ad? | | |

# Paper II

# Forest management and climate change—decision-maker perceptions in Norway and Sweden

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# Forest management and climate change—decision-maker perceptions in Norway and Sweden


## Abstract

In this article, we report results from the first quantitative study on climate change beliefs and perceptions, expected climate impacts on forests and forestry, and assessments of climate- adapted management practices among forest management decision-makers in Norway. Data were collected through a web-based questionnaire distributed in both Sweden and Norway to enable comparison. The survey received 1745 responses, achieving a response rate of 17.5%. The questionnaire consisted primarily of statements to which respondents indicated their agreement level along a 7-point Likert scale. Most Norwegian respondents believed that the climate is changing, is human-made, and will lead to increased damage to their forests. The Swedes had however been even more confident in their responses to these questions.  Except for when asked if they would consider “turning from planting to natural regeneration” and “avoiding thinnings”, to which approximately two-thirds completely agreed, the Norwegians had frequently answered no opinion when asked to consider implementation of climate-adaptive management options. The Swedes had more frequently sought and received advice about adaptive management. They were furthermore more confident than the Norwegians in that they would consider choosing better-adapted seedlings and earlier final harvests, and that they would not consider replacing or avoiding thinnings. Possible explanations for this could be that most had forest insurance, and that many believed climate change would increase the volume-growth, income-potential and value of their forest holding.



*Keywords: Climate change, forestry, climate change adaptation, non-industrial private forest owners, attitudes, perceptions.*

## Introduction

Forest ecosystems have adapted to changing climatic conditions in the past, but the changes they now potentially face are occurring so rapidly and at such magnitude that they are beyond the inherited adaptive capacity of species and ecosystems (GFEP, 2009). In Norway, for example, with a rotation period of 50–150 years (Tveite, 1977; Tveite 1976), stands established today will live in, and must cope with, a (dramatically) changing climate (IPCC, 2014; Hanssen-Bauer et al., 2009).

Scandinavia is part of the boreal forest belt, and boreal forests are vulnerable to climate change (Adger et al., 2007). Forest scientists have stressed the need for planned adaptation in this area for over a decade ( e.g. Lindner et al., 2014; Schoene & Bernier, 2012; Kolström et al., 2011; Lindner et al., 2010). However, adapting forest management in anticipation of a changing climate may represent a paradigm shift for forestry decision-makers used to management principles and growth and yield tables developed over decades (Schoene & Bernier, 2012). Forestry decision-makers must make decisions based on uncertain assumptions about the future climate and impacts of climate change on forests and forestry, policy and demand for forest products, and other ecosystem services. According to Bernier and Schoene (2009), they have three main strategy choices: continue with business as usual, rely on reactive adaptation (e.g. salvage logging or updated harvest scheduling), or implement planned or proactive adaptation in anticipation of (climate) change. Regarding this latter, several researchers have reviewed possible proactive strategies (e.g. Bolte et al., 2009; Millar et al., 2007; Ogden & Innes, 2007; Spittlehouse & Stewart, 2004). These include passive adaptation (i.e. deliberately limiting silvicultural interventions and letting natural adaptive processes unfold) or active adaptation (promoting change or resilience to change, i.e. increasing the forest's ability to rapidly return to its prior state after a shock).

Quantitative surveys of climate change adaptation in forestry across Europe (e.g. Sousa-Silva et al., 2018; Blennow et al., 2012) show that some forestry decision-makers have already implemented adaptive actions. The most frequent (self-)reported adaptive actions include mixed-species forests, and adaptation through choice of species or plant material ( e.g. Sousa-Silva et al., 2018; Laakkonen et al., 2018; Sousa-Silva et al., 2016; van Gameren & Zaccai, 2015; Milad et al., 2013; Blennow et al., 2012; Blennow, 2012). The proportion of 'adaptors', respondents who say they will adapt[1], differs between countries and studies. Sousa-Silva et al. (2018) found that the proportion of adaptors ranged from 57% in Slovakia (n=116) to 14% in Portugal (n=115). Blennow et al. (2012), on the other hand, found the proportion of adaptors in Portugal to be more than 50% (n=69), and that

[1] The measured concept differs between studies.

the proportion of adaptors were larger in Portugal than in Germany (47%, n=410) and Sweden (20%, n=341).

This last study is one of only a handful of adaptation studies among Swedish non-industrial private forest owners (NIPF). The first of these was conducted in 1999 (Blennow & Sallnäs, 2002), when 11% (n=160) of the respondents had implemented adaptive measures, and the second in 2004 (Blennow, 2012), when the proportion had risen to 19% (n=112)[2]. Blennow et al. (2012) reported the proportion of adaptors at 20% in 2009 (Blennow, 2012). In 2014, Vulturius et al. (2018) found that 40% of the surveyed NIPFs intended to adapt, only 20% perceived a need to do so (n=836).

Theories, models and frameworks from several academic traditions (e.g. economics, sociology, psychology and institutional economics) may offer insights into why some decision-makers have adapted to climate change, while others have not. Using an institutional framework, Moser and Ekstrom (2010) for example described how decision-makers, the larger context in which they act, and the system of concern (e.g. the forest) may contribute barriers that prevent adaptation arising. They provided a comprehensive list of common barriers to climate change adaptation at different stages in the adaptation process (i.e. understanding, planning and management as described by Simon (1960)). The authors shows how the three elements (i.e. decision-maker, context and system) are interconnected. Thus, sometimes, the context must change (e.g., public communication about potential problems, focus of media, discourse and conduct of politicians) before decision-makers can overcome barriers (e.g. perceive a problem-signal).

Societal context, including forestry traditions and norms, a society's dependency on forest-based industries, and roundwood demand, may not only influence whether potential barriers arise, but also which adaptive practices are considered feasible (Keskitalo et al., 2013). It is thus less likely that decision-makers living in societies dependent on forest-based industries, where forest owners foremost have roundwood production and maximizing forestry income, or where forests have traditionally been intensely managed, ( as defined by Duncker et al., 2012) will consider management approaches involving passive adaptation. Likewise, it is less likely that decision-makers from areas where "back to nature" or "pro Silva" ( as defined by Gamborg & Larsen, 2003) approaches are common would consider options requiring intense management.

Grothmann and Patt (2005) have developed a socio-cognitive model of private proactive adaptation to climate change (MPPACC) that focuses on the adaptation decision from the perspective of the individual, within a societal context. The outcome is either an intention to adapt, or avoidant maladaptation (e.g. wishful thinking). The model identifies the psychological steps individuals take,

[2] It is worth noting that the data underlying these studies were collected before the hurricane Gudrun, which in January 2005 stormfelled around 75 mill. $m^3$ roundwood in southern Sweden, roughly equal to an annual roundwood harvest of the country.

and associated bottlenecks, when making the decision to act in response to a threat, and differentiates between two perceptual processes. In the *risk appraisal process*, the individual assesses the probability of a negative event occurring and its impact on valued objects; here, the model assumes that the process is influenced by social discourse and public adaptation, which impact both perception and cognitive biases. These cognitive biases not only influence the individual's appraisal of risk, they also affect the *adaptation appraisal process*, which only occurs if the individual's risk appraisal exceeds a certain threshold of concern. This process is influenced by the individual's resources, social and instrumental support, and social discourse, and has three components: perceived adaptation efficacy (the effectiveness of a response); perceived self-efficacy (the ability to implement a response); and perceived adaptive cost (the assumed cost, e.g. money, time or effort, of implementing a response).

Blennow and Persson (2009), however, argue that the MPPACC model only indirectly sheds light on the importance of cognitive aspects (i.e. beliefs) on adaptation. For example, with regard to belief in climate change, the lack of robust knowledge on climate change makes assessing the associated risks difficult, creating variation in strength of belief among individuals. They also write that since Weber (1997),researchers had largely overlooked this link between cognitive aspects and adaptation. Adaptation had instead been seen as "local adjustments to deal with changing conditions within the constraints of the broader economic–social–political arrangements" (Smit & Wandel, 2006). To test these two views, Blennow and Persson (2009) surveyed Swedish NIPFs in 2004, and found that forestry decision-makers' strength of belief in climate change significantly influenced self-reported adaptation. The influence of beliefs on adaptation have since been confirmed by others (e.g. Vulturius et al., 2018; Sousa-Silva et al., 2016; van Gameren & Zaccai, 2015). van Gameren and Zaccai (2015), however, found that as long as the decision-maker considers climate change adaptive responses beneficial for objectives other than adapting to climate change, strong belief in climate change need not be a decisive factor for adaptation.

However, while MPPACC links risk experience appraisal directly to the risk appraisal process, and Blennow et al. (2012) found a significant, positive relationship between experienced climate change and (self-)reporting, recent studies (Sousa-Silva et al., 2016; Vulturius et al., 2018) found no such relationship. Moreover, Lidskog and Sjödin (2014), studying Swedish decision-makers' regeneration choices after hurricane Gudrun in 2005, found that the regeneration choices had not changed, despite the authorities recommending species other than spruce and providing monetary support for this change. The authors argue that this was due to short-term economic considerations, the perception that calamities are impossible to influence through management choices, and unfamiliarity with future management of alternative species.

This finding is in line with Uggla and Lidskog (2016), who argue that previous management schemes make owners path-dependent, that uncertainty associated with both forestry and climate change provides an unclear basis for decision-making, and that changing forest management practices to something that deviates from the norm (e.g. abandoning clear-cuts) might be considered risky and costly. With regard to the adaptation appraisal process detailed in the MPPACC model, this could indicate that perceived adaptation efficacy is considered low, while perceived adaptation costs are considered high.

The impact of risk appraisal, or risk perception, on adaptation in forestry has also been tested empirically. Blennow (2012) found that Swedish NIPFs who had adapted to climate change perceived greater increased risk of climate change leading to increased damages by wind, drought, fungi and insects. More recently, Vulturius et al. (2018) identified personal risk perceptions as an influential driver of Swedish NIPFs' intentions and perceived need to adapt, when they tested the relative importance of cognitive (i.e. beliefs, risk appraisal, adaptation appraisal) experiential (i.e. experiences and affect) and structural (i.e. social discourse and objective adaptive capacity) factors on individual adaptation. Eriksson (2014), in another Swedish study, found that Swedish NIPFs remained relatively unconcerned about climate change-related risks. Finally, in a quantitative study of NIPFs in Norway, the authors found that Norwegian NIPFs worried more about risks related to timber prices and policy changes (Størdal et al., 2007).

Results from several studies further suggest that the belief that climate change will have severe and negative impacts in other parts of the world does not necessarily translate into similar beliefs about one's own region ( e.g. Bissonnette et al., 2017; Heltorp et al., 2018; Grotta et al., 2013; Vulturius et al., 2018). In a recent focus-group-based study of Norwegian forestry decision-makers, (Heltorp et al., 2018) found that although participants believed the climate is changing and had observed changes in their forest that they attributed to climate change, they remained relatively unconcerned. Many thought climate change would increase volume-growth and boost demand for bio-based solutions, and assessed that climate change could be an opportunity rather than a threat for the forest-based sector. Laakkonen et al. (2018) found a similar stance when they interviewed NIPFs in Finland.

A final aspect regarding risk perceptions worth noting is that individual risk perceptions may differ quite substantially from objective risk descriptions (Hoogstra, 2008; Couture & Reynaud, 2008; Hansson, 2010), termed "cognitive biases and heuristics" by Grothmann and Patt (2005). Both Grothmann and Patt (op. cit.) and Smit and Wandel (2006) further argue that perceived risk, or perceived severity of risk, is dependent on values and vulnerability. Thus, an individual who highly values or depends on something may perceive the risk of this item being harmed as higher than another might. However, when Vulturius et al. (2018) tested if dependency and magnitude of forestry income and holding size significantly affected Swedish NIPFs' propensity to adapt, they found no significant correlation. Of the variables they tested, the individuals' risk assessment, perceived salience of climate change and personal level of trust in climate change were identified as those most important. According to Moser (2010), the trust an individual puts in climate science will influence how he/she interprets all climate change-related information, and thus the whole adaptation process. Finally, results from qualitative studies show how some forestry decision-makers place low trust in climate change science because they suspect e.g. that climate scientists are motivated by grants or ideology (Uggla & Lidskog, 2016; Grotta et al., 2013).

There are several alternative theories explaining individuals' lack of trust in climate science, linking this issue to belief systems, values and norms, and cognitive biases based on group-dependent pre-existing views (McCright & Dunlap, 2011; Kahan et al., 2011; Kahan et al., 2012; Krange et al., 2019). Blennow et al. (2016), however, using university education as a proxy, showed how literacy and numeracy can be a better explanation for trust in climate change science than values and objectives (Blennow et al., 2016). Questionnaire-based studies have further shown that lacking knowledge about climate change impacts and how to adapt has been shown to constrain adaptation, while knowing how to adapt and believing adaptation will have a positive effect are more common traits among adaptors (Sousa-Silva et al., 2018; Sousa-Silva et al., 2016; Blennow & Persson, 2009).

Several studies also report that forestry decision-makers who perceive they lack knowledge about climate change impacts on forests and adaptation would welcome more information and recommendations (Laakkonen et al., 2018; Bissonnette et al., 2017; Uggla & Lidskog, 2016; Yousefpour & Hanewinkel, 2015; Lawrence & Marzano, 2014; Grotta et al., 2013). Mostegl et al. (2017) even concluded that, to motivate small-scale owners in Austria to adapt, knowledge and advice from trusted sources would be a more efficient tool than economic incentives. Finally, van Gameren and Zaccai (2015) found that owners who partook in forestry networks were more prone to adapt, while results from another study indicate that knowledge sharing in owner networks only had minor impact on adaptation (André et al., 2017).

Empirical studies on these issues in Norway is scarce. Only two of the cited articles are based on data collected in Norway (Heltorp et al., 2018; Størdal et al., 2007), one is based on qualitative data from southeast Norway (i.e.  Heltorp et al., 2018), while the other (i.e. Størdal et al., 2007) focuses on general risk perceptions rather than climate change. More studies have focused on Swedish decision-makers, using both qualitative ( i.e. Eriksson, 2018; Uggla & Lidskog, 2016; Lidskog & Sjödin, 2014; Eriksson, 2014) and quantitative ( e.g. Blennow & Persson, 2009; Blennow et al., 2012; Blennow, 2012; Blennow et al., 2016; Vulturius et al., 2018) methodologies. In many respects, Norway and Sweden are similar. The countries share a 1630-km-long border and have similar language, socioeconomic characteristics, culture, climate and forest composition (Statistics Norway, 2015b;

Kungl. Skogs- och Lantbruksakademien, 2015); further, decision-makers in both Norway and Sweden are free to manage their forests within the limitations of national law, regulations and voluntary certification schemes (e.g. PEFC Norway, 2015; PEFC Sweden, 2018; FSC, 2018). However, the forest sector is a large contributor to the Swedish economy and contributes to approximately 10% of the nation's employment, exports and sales (Kungl. Skogs- och Lantbruksakademien, 2015), compared to less than 1% of the gross domestic product (GDP) in Norway (Espelien & Jakobsen, 2013).

Moser and Ekstrom (2010) framework, detailed above, highlights how the context in which the decision-maker acts may contribute to barriers to adaptation arising, while the MPPACC model (Grothmann & Patt, 2005) shows how social discourse on climate change and social and institutional support influence risk and adaptation appraisal. In Norway, public support is limited to a web-portal with climate-adaptive advice (klimatilpasning.no, 2016). The forestry section of the site contains links to the Norwegian PEFC certification standard (PEFC Norway, 2015), road building standards, and a flyer promoting wind-resistant management issued by a forest insurance company (Skogbrand, 2014). Apart from this, official forest climate policy has largely focused on mitigation, and the government has issued subsidies promoting higher plant density (for planting of spruce) and fertilization (Stortinget, 2015).

Although there do not appear to be governmental subsidies promoting mitigation or adaptation in Sweden, the Swedish Forest Agency has issued a report (Skogstyrelsen, [Swedish Forets Agency], 2017) summarizing likely impacts and recommending concrete climate-adaptive actions. Considering the differences between the two countries regarding the focus of the official offices and the societal importance of the forest-based sector, we hypothesised that awareness of climate change-related threats and adaptation would prove higher in Sweden than in Norway. For the same reasons, we also hypothesised that Norwegian forestry decision-makers would have weaker beliefs, perceive lower risks, and be less prone to consider adaptation compared to their Swedish colleagues.

Given the above, the first objective of this study was therefore to conduct a quantitative survey of climate change beliefs, observations, related risk perceptions, and intentions to adapt among Swedish and Norwegian forestry decision-makers, and for the first time to present quantitative measures of Norwegian forestry decision-makers' climate change beliefs, risk perceptions and propensity to adapt. Our second objective was to compare and validate the results of the Norwegian survey with those of Sweden, and test whether there is evidence to support the hypothesis that Swedish decision-makers have stronger beliefs, perceive higher risks and be more prone to adapt.

## Materials and methods

*Study areas*

Norway has the largest share of privately owned forests (Hirsch & Schmithüsen, 2010) in Europe, and NIPFs own approximately 79% (Statistics Norway, 2015b) of Norway's 86600 $km^2$ productive forested land (NIBIO, 2018). In Sweden, NIPFs own 50% (Statistics Sweden, 2014) of the 280000 $km^2$ productive forested land (Riksskogstaxeringen, 2017). In total, there are approximately 330000 NIPFs in Sweden (Statistics Sweden, 2014) and 125000 privately owned forest holdings in Norway (Statistics Norway, 2019). The majority of NIPFs own small holdings: in Norway, 20% of the forest owners own approximately 80% of the forest area and vice versa (Statistics Norway, 2017), similar to Sweden (Statistics Sweden, 2014). While the annual harvest in Sweden varies between 80 and 100 million $m^3$ (top and bark included) (Skogstyrelsen, [Swedish Forest Agency], 2017), the annual harvest in Norway is between approximately 12 and 13 million $m^3$ (top and bark included) (Statistics Norway, 2016). Many NIPFs, approximately 35,000 Norwegians (≈30% of all Norwegian NIPFs) and 106,000 Swedes (≈32% of Swedish NIPFs), are members of forest owner associations. In Norway, there are six regional forest owner associations, organized as cooperatives. These 6 are members of the National Forest Owner Federation, and in between them, they handle 84% of the national roundwood trade (Norges Skogeierforbund, 2017). They also provide training, information and services. In addition comes Norskog, an independent owners association in Norway with around 300 members who supply 15% of the annual national volume. Norskog also provides advice, training and political representation for members (Norskog.no, 2018). In Sweden, there are four regional forest owner associations, organized as cooperatives and members of the Federation of Swedish Farmers (LRF, 2013 ). In addition to roundwood trade, the associations offer various forest services (Kungl. Skogs- och Lantbruksakademien, 2015). The members of the forest owner associations control approximately 50% of Sweden's NIPF-owned forestland (LRF, 2013 ), and handles approximately 50% of the nation's roundwood harvest from NIPF-owned holdings[3] (Mellanskog, 2017; Norra Skogsägarna, 2018; Norrskog, 2017; Södra, 2017). Table 1 presents number of members and affiliated area for each association.

Current climate predictions are relatively similar in Norway and Sweden. Both countries are likely to experience a rise in temperatures, particularly during winter and in the north, and increased precipitation (SMHI, 2018; Skogstyrelsen, [Swedish Forets Agency], 2017; Tveito, 2014; Hanssen-Bauer et al., 2009). Forest productivity has increased due to a longer growing season (Boisvenue & Running, 2006). Modelling efforts indicate that this may continue (Bergh et al., 2010; Bergh et al.,

[3] 60% of the harvested yearly volume in Sweden originates from holdings owned by non-industrial private forest owners (Skog Sverige, 2018 ).

2003; Pussinen et al., 2009) if the growth remains unrestricted by water deficiency (Briceno-Elizondo et al., 2006); however, increased frequency and intensity of disturbances may cancel out this effect (Reyer et al., 2017; Subramanian et al., 2015). Other impacts include northward shifts in insect herbivores and tree-species habitats (Netherer & Schopf, 2010; Koca et al., 2006), increased frequency and duration of spring temperature backslash, summer drought, and longer periods with high ground moisture (Lindner et al., 2010).

*Sampling*

We assumed that membership in forest owners associations, since these function as networks, services providers and roundwood cooperatives, could be a proxy for interest in forestry and monetary forestry objectives. We therefore considered it likely that members both would have a relatively high objective adaptive capacity (e.g. resources, knowledge, Grothmann and Patt (2005)), and would consider their forest to be of value. We also considered it likely that association members would have received information about forestry and climate change through newsletters, meetings, magazines and advisors.

Moreover, following the model of Grothmann and Patt (2005), we assumed that forest management decision-makers who are members of a forest owner association are more likely than other forest management decision-makers to have appraised climate change-related risks and adaptation and thus have opinions about climate change and climate change adaptation in forestry. In addition, members of forest owner associations own a relatively large share of the non-industrial privately owned forest in Norway and Sweden (see table 1) and we knew that a relatively large share of the harvested roundwood from non-industrial private holdings in Norway and Sweden comes from members of associations. Thus, we assumed that recruiting respondents from the associations' membership bases would ensure that our sample would be representative of a relatively large proportion of the non-industrial privately owned forest area in the two countries. Therefore, we contacted forest owners associations and asked them to assist us in selecting a random sample of email addresses from their member registers and distributing our questionnaire. We defined the sample sizes proportionally based on the number of members in each association, with the exception of Norskog in Norway, from whom we asked for a sample of 100 members (see Table 1).

*Table 1 Overview of samples and responses*

| | Association | Region | Coverage in 1000 hectares | Members (N) | Gross sample | Responses, net sample (n) | Responses rate (%) |
|---|---|---|---|---|---|---|---|
| Norway | Glommen Skog SA | East | 690 | 3650 | 518 | 117 | ≈ 22.5 % |
| | Mjøsen Skog SA | East | 550 | 3700 | 526 | 99 | ≈ 19 % |
| | Viken Skog SA | East | 950 | 9400 | 1420 | 211 | ≈ 15% |
| | AT Skog SA | South | 740 | 7300 | 1037 | 250 | ≈ 24 % |
| | Vestskog SA | West | 120 | 2750 | 391 | 112 | ≈ 28.5 % |
| | ALLSKOG SA | Middle and North | 350 | 7500 | 1065 | 178 | ≈ 17 % |
| | Norskog | - | 1300 | 300 | 100 | 45 | 45 % |
| | **Total, Norway** | | **4700** | **34600** | **5057** | **1012** | **≈ 20 %** |
| Sweden | Södra Skogsägarna | South | 2517 | 51000 | 2406 | 332 | ≈ 13.5 % |
| | Skogsägarna Mellanskog | Middle | 1530 | 26000 | 1226 | 156 | ≈ 13 % |
| | Norrskog | North | 965 | 12000 | 566 | 96 | ≈ 16.5 % |
| | Norra Skogsägarna | Northernmost | 1000 | 17000 | 799 | 149 | ≈ 18.5 % |
| | **Total, Sweden** | | **6012** | **106000** | **4997** | **733** | **≈ 14.5 %** |
| | **Combined sample** | | **10712** | **140600** | **10054** | **1745** | **≈ 17.5 %** |

*Questionnaire*

Following the recommendations of Dillman et al. (2009), we designed a questionnaire with 32 questions, out of which 10 were follow-ups dependent on previous answers. Most questions were statements requesting that the respondents express agreement/disagreement on a seven-point Likert-scale. We pre-tested the questionnaire in three steps: 12 forestry practitioners responded to an initial version; 5 researchers at the Norwegian University of Life Sciences reviewed a second version; and administrative staff from the associations then provided their input on a third version.

Questions about climate change beliefs, observations and experiences comprised the start of the questionnaire, followed by questions regarding risk perceptions (i.e. whether the respondents expected increased forest damages caused by climate change). Respondents were then asked how they expected climate change to influence volume-growth, forest products demand, and forest income. For questions involving assessments about the future, we asked the respondents to assess adaptive options in relation to a time horizon in the range of a typical rotation (60–120 years). Next, we asked whether the respondents would consider implementing specific alternative adaptive practices recommended by Søgaard et al. (2017), Skogstyrelsen, [Swedish Forets Agency] (2017) or (Skogbrand, 2014). Finally, respondents were asked questions about knowledge and advice related to adaptation, followed by some background questions.

As some forest owners employ forest managers to whom they delegate strategic and operative responsibility, we specified that in these cases we would prefer that the manager answer the questionnaire; we also included a question to distinguish between NIPFs and professional managers. We formulated the questionnaire in Norwegian, and a native Swedish speaker translated it into Swedish. For an English translation of the questions and information letter, please see the supplementary material.

Emails with an invitation to participate in the survey were distributed from the forest owner associations to the entire sample. The invitations contained a description of the purpose of the study and a link to the questionnaire in Questback (Questback, 2017-2018). The Norwegian version was open from March 19$^{th}$ to April 9$^{th}$, and after 8–10 days the respondent received a reminder, to encourage participation. The Swedish version was open from April 10$^{th}$ to April 27$^{th}$. Reminders were sent by two Swedish associations.

*Data analysis*

The data were analysed using the free statistical software R (R Core Team, 2018 ). To test whether group membership had significant influence on the replies, we coded the categorical Likert-scale variables with numeric values (1–7), where 1, 2, 3  equals completely, mainly, and somewhat disagree,4 equals neutral and 5, 6 and 7 equals somewhat, mainly and completely agree. To test for differences between respondents with different levels of education and holding sizes, we split the Norwegian sample into four groups according to whether  participants had attended university or university collage (i.e. whether they had “higher” or “lower” education), and whether they represented holdings larger than 99 hectares (i.e. whether they represented a “large” or a “small” holding). To test for differences between regions, we organised the respondents into groups according to the map enclosed in figure 1.

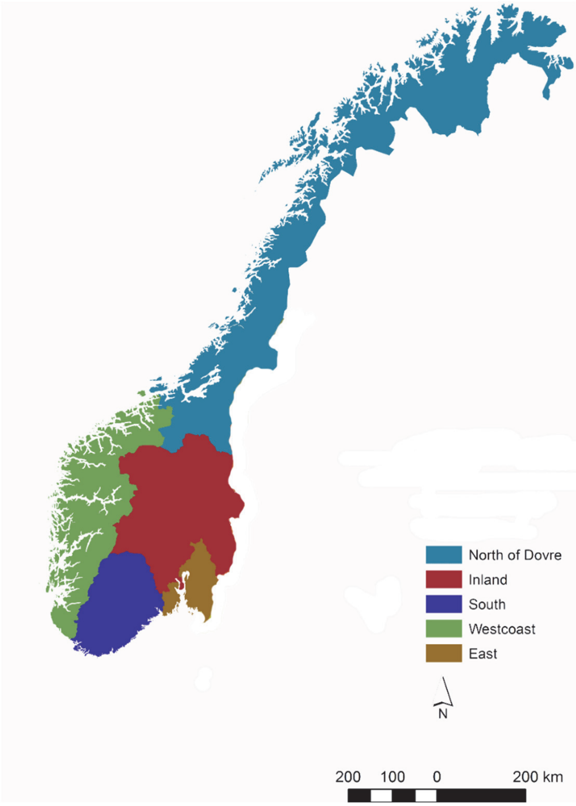



*Figure 1 Map showing Norwegian regions*

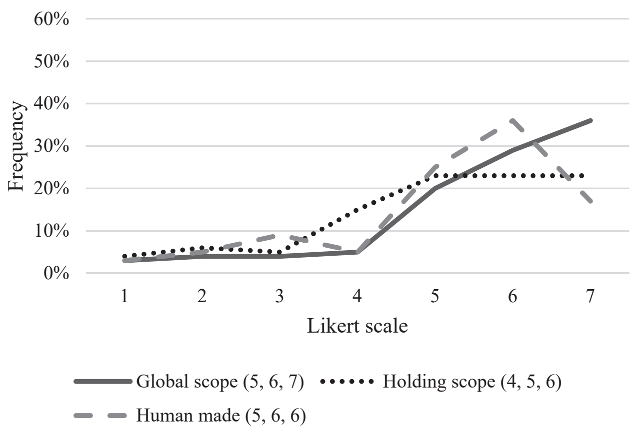
Often, the Likert-scale responses were non-normally distributed. Therefore, we applied the Whitney-Mann-U test (Mann & Whitney, 1947), called a two-sample Wilcoxon test (W) in R, when testing whether two groups had answered the same question similarly. In the six cases where we had paired observations, we specified the one-sample Wilcoxon test. When comparing more than two groups, we used the Kruskal-Wallis test (KW) (Kruskal & Wallis, 1952). If the test results showed significant differences, we then used a post-hoc Dunn test (D) (Dunn, 1964) with Benjamini-Hochberg adjustments (Benjamini & Hochberg, 1995). For comparing group differences in proportions of binary variables, we used a proportion test (prop.) (Crawley, 2012 s. 365), while we used the Pearson chi-squared test (chi.) (Crawley, 2012 s. 367) for other categorical variables. To assess effect sizes, we compared basic statistic summaries (e.g. quartiles, median and mean in the groups) and plotted the answer distributions. All such plots are enclosed in supplementary materials. We organized the results according to the three main stages of Simons' (1960) decision process model. For each phase (i.e. understanding, planning and managing), we fist present the Norwegian result, then comparisons of Norwegian regions, then comparisons of education and holding size groups. Finally, we present the Swedish results in contrast with the Norwegian results.

# Results

The survey received 1012 unique and valid responses in Norway and 733 in Sweden, giving an overall response rate of 17.5% (see Table 1). Compared to national statistics, our samples contained few females and large proportions of the respondents representing holdings consisting of more than 100 hectares (i.e. 40%) and with higher education (i.e. 46% in Norwegian sample, 48% in Swedish sample) (cf. Sweden, 2018; Statistics Norway, 2015a; Statistics Norway, 2015b; Statistics Sweden, 2014). Most respondents managed or owned spruce-dominated (≈60%) or mixed forests (22% in Norway, 31% in Sweden), while only 1.5% represented holdings dominated by deciduous trees. A table in supplementary material contains a more detailed presentation of the data, and corresponding population parameters.

*Understanding phase – believing and seeing*

Many Norwegians were more convinced about the climate changing globally than about the climate changing at their holding. The difference in strength of belief was significant on the 5% confidence level (W=587020, p=0.000 n=1002(global), and 965(holding scope)), and clearly visible in Figure 1 (basic descriptive statistics is included in the figure text). Participants who (completely, mainly or somewhat) agreed that the climate is changing were presented with the follow-up statement: “I believe that climate change is fully or partly human-made” and asked to signal their level of agreement. Approximately 80% of those who answered (n=658) completely, mainly or somewhat agreed, which equals just above 50% of the full Norwegian net sample. The answer distribution is included in Figure 2. Of the respondents who agreed that the climate is changing at their holding, 45% (n=670) had observed or experienced climate change-related changes within the past 5 years (29% of the Norwegian sample). Most frequently, respondents had observed shorter frozen ground seasons or changed conditions for forest operations in spring and autumn (≈60% of those having



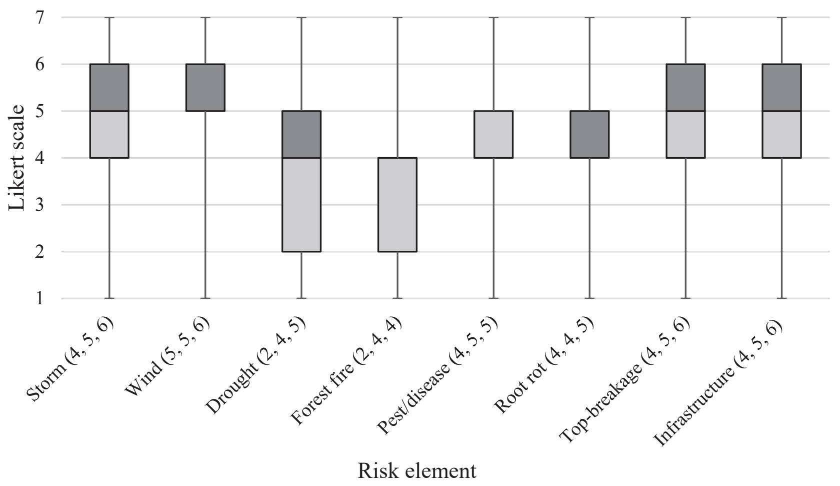

*Global scope: n=1002, mean=5.66, SD=1.69, Holding scope: n=965, mean=5.11, SD=1.81*
*Human made: n=658, mean=5.19, SD=1.56*

*Figure 2 The Norwegian respondents’ replies to the statements: 1) “The climate is changing …” i. “Globally”, ii. “At my forest holding” and 2) “I believe that climate change is fully or partly human-made”. The 1st, 2nd and 3rd quartiles for each variable is enclosed in parenthesis in the legends.*

observed change, ≈19% of the Norwegian sample), or increased volume-growth (≈50% of those having observed change, ≈16% of the Norwegian sample).

*Understanding phase – perceiving risk.*

Nearly 90% of the Norwegians (somewhat, mainly or completely) agreed that climate change would increase damages in their forests due to one or several of the following: wind (single trees/small areas), storm (continuous areas), drought, forest fires, pests and diseases, root rot, top-breakage (due to heavy snow), or damages to infrastructure (n=1006)[4]. Near 25% completely agreed that damages due to one or several of these would increase. Figure 3 is a boxplot that visualizes the answer distribution. It is clearly visible from the plot that the Norwegians were most confident that damage due to wind, storm, and precipitation (i.e. infrastructure and top-breakage) would increase, while a relatively large proportion disagreed that climate change would increase damages due drought and forest fires.



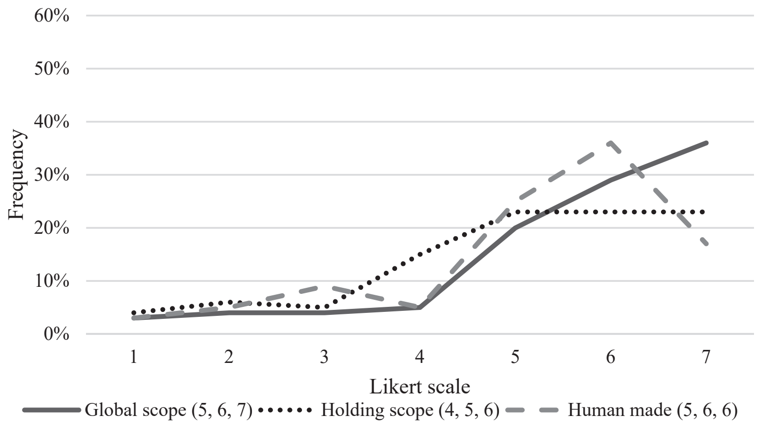

*Storm: n=977, mean=4.59, SD=1.52. Wind: n=985, mean=5.03, SD=1.46. Drought: n=945, mean=3.53, SD=1.50. Forest fire: n=945, mean=3.41, SD=1.42. Pests and disease: n=964, mean=4.47, SD=1.32. Root rot: n=941, mean=4.28, SD=1.36. Top-breakage n=983, mean=4.83, SD=1.58. Infrastructure: n=981, mean=4.98, SD=1.52*

*Figure 3 Boxplot showing to the Norwegian respondents replies to the statement "I believe that the projected climate change will increase damages in my forest" – for eight risk elements. The lower light grey area of the boxplot marks the interval between the 1st quartile and the 2nd quartile (median), and the dark grey marks the interval between the 2nd and 3rd quartile. The 1st, 2nd, and 3rd quartile for each risk element is enclosed in parenthesis in legends.*

Despite the majority believing that damages would increase, only 29% (n=1002) thought this would affect the overall income-potential and value of their holding negatively. Out of the 29%, only nine respondents believed in a major decrease, 58 thought the decrease would be moderate, and the

[4] 1006 replied to at least 1 of the 8 questions in the matrix measuring expected climate change-induced increase in forest damages.

rest that the decrease would be minor. The largest group believed there would be no change (40%), or that climate change would cause a (minor, moderate or major) increase in holding value and income-potential (32%). In addition, many thought climate change would increase the demand for roundwood, and the volume-growth in their forest. Figure 4 shows the answer distributions for these three questions and for expected climate change impact on quality growth (i.e. saw-wood proportion of growth).




*Volume Impact: n=991, mean=4.49, SD=1.06, Saw-wood impact: n=988, mean=3.87, SD=0.97*
*Demand impact: n=980, mean=4.87, SD=1.06, Overall impact: n=1002, mean=4.01, SD=1.02*

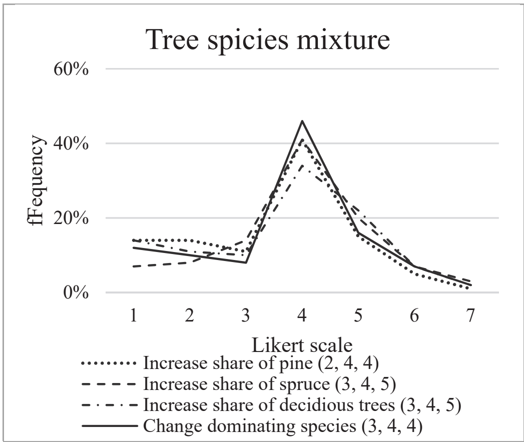
*Figure 4 The Norwegian respondents' replies to the statements 1) "I believe the predicted climate changes will influence …" i. "the volume-growth in my forest"), ii. "the quality growth in my forest (i.e. the saw log proportion)" iii. "the roundwood demand" , and 2) "I believe the predicted climate changes will influence the income-potential and value of my forest holding". The $1^{st}$ $2^{nd}$ and $3^{rd}$ quartiles for each variable is enclosed in parenthesis in legends.*

### *Planning and management phase*

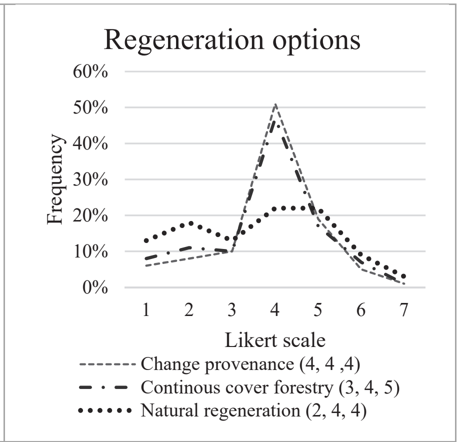
Approximately 60% (n=1004) of the Norwegians did not agree that they possessed necessary knowledge about adaptive forestry. Few had received (18%, n=1002) advice about adaptation, and even fewer (12%) had themselves sought advice (n=1004). Those who had received advise, had most frequently done so from the forestry media (11.5 %), the forest owners associations (8.5 %) and employees in these associations (7%).

Respondents had most frequently been advised to "conduct pre-commercial thinnings early in the rotation" (55% of the 184 who had received advice, 10% of the Norwegians), "avoid late and heavy thinnings" (50% of the 184 who had received advice, 9% of the Norwegians) or "increase plant density" (44.5% of the 184 who had received advice, 7% of the Norwegians). Out of the 63 who gave the source from which they had sought advice, 25 listed owners associations, and 8 participants listed public offices. Interestingly, only one listed a research institution (i.e. the Norwegian Institute of Bioeconomic Research), but two listed forestry students from the Norwegian University of Life sciences. Nobody reported having sought advice on the public web portal on adaptation (klimatilpasning.no, 2016). Of those who had neither sought nor received advice (n=715), the minority (17.5%) disagreed (completely, mainly or somewhat) while the majority (65%) agreed that they needed advice.

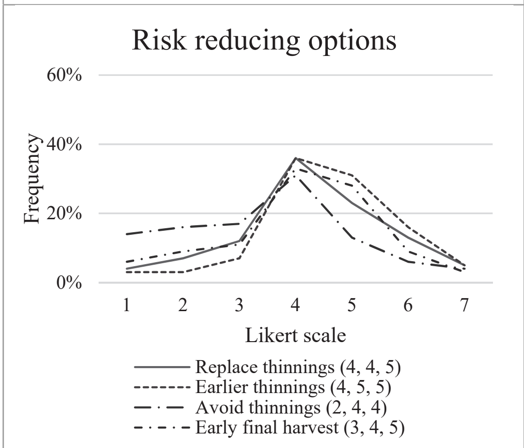
As shown in Figure 5, many Norwegians had no opinion on whether they would consider implementing adaptive management options. Those who had expressed an opinion had often chose the somewhat agree or somewhat disagree options (i.e. the low confidence option). The proportion who completely agreed was not above 5% for any option, while the proportion who mainly agreed they would consider implementing an adaptive option was above 10% twice: for “replace commercial thinnings with pre-commercial thinnings” and for “when conducting thinnings, thin earlier in the rotation”. The latter was the only adaptive option that more than 50% of the respondents (somewhat, mainly or completely) agreed they would consider. Finally, relatively large proportions disagreed that they would consider “avoiding thinnings” or “turn to natural regeneration”.



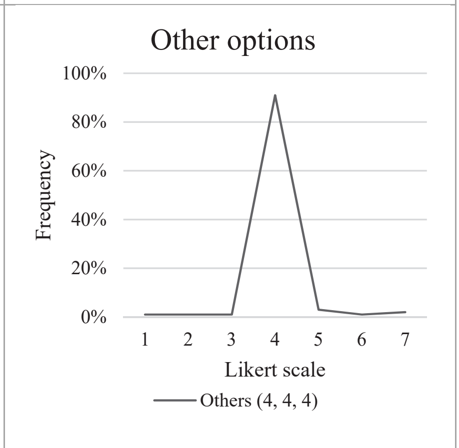

*Increase share of pine: n=945, mean=3.47, SD=1.44. Increase share of spruce: n=962, mean=3.92, SD=1.35. Increase share of deciduous trees: n=946, mean=3.67, SD=152. Change dominating species: n=936, mean=3.70, SD=1.43.*




*Change provenance: n=985, mean=3.85, SD=1.20. Continuous cover forestry: n=978, mean=3.79, SD=1.32. Natural regeneration: n=987, mean=3.60, SD=1.66.*




*Replace thinnings: n=973, mean=4.26, SD=1.38. Earlier thinnings: n=967, mean=4.55, SD=1.21. Avoid thinnings: n=955, mean=3.43, SD=1.56. Earlier final harvest: n=962, mean=4.07, SD=1.40.*




*Other options: n=694, mean=4.03, SD=0.60.*

*Figure 5 The Norwegian respondents' replies to the statements: 1) "To adapt my forest to climate change I will consider …" i. "choosing plant material from lower provenances", ii. "turn from even-aged stands to continuous cover forestry", iii. "turn from planting to natural regeneration". 2) "In order to adapt my forest to climate change I will consider …" i. "increasing the share of pine", ii. "increasing the share of spruce", iii. "increasing the share of deciduous trees", iv. "change dominating tree species in some stands", and 3) "In order to reduce risks relate to climate change, I will consider …" i. "comprehensive young growth tending as replacement for thinnings", ii. "when conducting thinnings, thin earlier in the rotation", iii. "avoid thinnings", iv. "earlier final harvest", v. "other options". The 1st 2nd and 3rd quartile is enclosed in parenthesis in legends.*

### *Regional differences in risk-perceptions*

There were differences between regions in responses to the statement "the climate is changing at my holding". The respondents from North of Dovre (n=132) had answered significantly different compared to respondents from Inland Norway (D, z=3.67, p=0.00, n=317), the Westcoast (D, z=3.28, p=0.00, n=144) and East (D, z=2.71, p=0.00, n=107). Respondents from the South (n=241) were further different from respondents from the Inland (D, z=2.63, p=0.02, n=317) and Westcoast (D, z=2.27, p=0.04, n=144). The differences were visible: while the median equalled somewhat agree and the third quartile equalled mainly agree North of Dovre and in the South, these parameters was one Likert scale point higher in the other two regions[5].

Compared to the other regions, a relatively large proportion of the respondents from the Inland reported having observed or experienced climate change. 59% of the Inland respondents (n=233) had answered "yes" on this question, the proportion in the other regions was around 50%[6]. Regarding assessments of increased risk of damages due to climate change, the Westcoast respondents stood out as most confident that storm and wind would increase and respondents from Inland Norway, East and South were more confident than the other respondents were in that drought, forest fires, and top-breakage would increase. In addition, the respondents from Inland Norway were most confident that damages from pest and disease would increase, and the respondents from North of Dovre stood out as less confident than the others of increased damages due to climate change. Table 2 shows the significant differences and test-statistics[7] for eight risk elements.

With regard to climate impact on volume-growth, the Inland respondents (n=326) were more confident of increase than respondents from North of Dovre (D z=4.22, p=0.00, n=134), the South (D, z=3.47, p=0.00, n=250) and the Westcoast (D, z=4.08, p=0.00, n=138). The Inland- (n=330) and Eastern (n=112) respondents were finally marginally, but significantly, more confident than those from the South (D, z=-2.63, p=0.02, n=252 (for Inland), and z=-2.44, p=0.03 (for East) and Westcoast (D, z=-3.84, p=0.00, n=150 (for Inland) and z=-3.49, p=0.00 (East)) in that climate change would have no impact or a positive impact on holding value and forestry income-potential[8].

[5] Figure 1 in supplementary material shows the answer distribution, and additional details.
[6] See Figure 2 in supplementary material.
[7] Figure 3 and 4 in supplementary material shows answer distributions and additional details.
[8] Figure 5 in supplementary material shows answer distributions and additional details.

*Table 2 Significant (CI 95%) results from Kruskal-Wallis and Dunn tests for differences in risk-perceptions between respondents from five Norwegian regions*

| Groups | | | Kruskal Wallis | Dunn | Difference (effect) | | | |
|---|---|---|---|---|---|---|---|---|
| | | | $\chi^2$, df, (p-value) | z (p-value) | 1st Q | 2nd Q | 3rd Q | Mean |
| **Storm** | Inland | **Westcoast** | 18.11, 4, (0.00) | -2.65 (0.02)* | -1 | 0 | 0 | -0.34 |
| | North of Dovre | **Westcoast** | | -3.32 (0.00)* | -2 | 0 | -1 | -0.51 |
| | South | **Westcoast** | | -3.99 (0.00)* | -2 | 0 | -1 | -0.63 |
| | **Westcoast** | East | | 2.48 (0.03)* | 2 | 0 | 0 | 0.43 |
| **Wind** | **Inland** | North of Dovre | 14.44, 4, (0.00) | 2.45 (0.04)* | 1 | 0 | 0 | 0.67 |
| | North of Dovre | **Westcoast** | | -3.20 (0.01)* | -1 | -1 | 0 | -0.81 |
| | South | **Westcoast** | | -2.85 (0.02)* | -1 | -1 | 0 | -0.42 |
| **Drought** | **Inland** | North of Dovre | 48.26, 4, (0.00) | 3.72 (0.00)* | 1 | 1 | 1 | 0.58 |
| | North of Dovre | **South** | | -3.24 (0.00)* | 0 | -1 | 0 | -0.52 |
| | **Inland** | Westcoast | | 4.09 (0.00)* | 1 | 1 | 1 | 0.62 |
| | Inland | **East** | | -2.91 (0.00)* | 0 | 0 | 0 | -0.48 |
| | North of Dovre | **East** | | -5.47 (0.00)* | -1 | -1 | -1 | -1,06 |
| | South | **East** | | -3.12 (0.00)* | -1 | 0 | -1 | -0.54 |
| | Westcoast | **East** | | -5.78 (0.00)* | -1 | -1 | -1 | -1,1 |
| **Forest-fires** | **Inland** | North of Dovre | 48.26, 4, (0.00) | 3.86 (0.00)* | 0.5 | 1 | 0 | 0.58 |
| | North of Dovre | **South** | | -3.74 (0.00)* | 0 | -1 | -1 | -0.58 |
| | **Inland** | Westcoast | | 3.08 (0.00)* | -0.5 | 0 | -1 | 0.44 |
| | **South** | Westcoast | | 2.98 (0.00)* | -1 | 0 | -1 | 0.44 |
| | North of Dovre | **East** | | -3.97 (0.00)* | -1 | -1 | 0 | -0.73 |
| | Westcoast | **East** | | -3.34 (0.00)* | 0 | 0 | 1 | -0.59 |
| **Pests and disease** | **Inland** | North of Dovre | 15.94, 4, (0.00) | 2.64 (0.02)* | 0 | 1 | 0 | 0.37 |
| | **Inland** | South | | 3.00 (0.02)* | 0 | 0 | 0 | 0.38 |
| | **Inland** | Westcoast | | 2.75 (0.02)* | 0 | 1 | 0 | 0,37 |
| **Top-breakage** | **Inland** | North of Dovre | 59.45, 4, (0.00) | 6.46 (0.00)* | 1 | 1 | 1 | 1.01 |
| | North of Dovre | **South** | | -6.01 (0.00)* | -2 | -2 | -1 | -1,08 |
| | **Inland** | Westcoast | | 4.56 (0.00)* | 1 | 0 | 0 | 0.74 |
| | **South** | Westcoast | | 4.18 (0.00)* | 2 | 1 | 0 | 0.81 |
| | North of Dovre | **East** | | -3.47 (0.00)* | -1 | -1 | -1 | -0.69 |
| **Infra-structure** | **Inland** | North of Dovre | 30.36, 4, (0.00) | 5.40 (0.00)* | 1 | 0.5 | 1 | 0.81 |
| | North of Dovre | **South** | | -3.51 (0.00)* | 0 | 0 | -1 | -0.51 |
| | North of Dovre | **Westcoast** | | -3.92 (0.00)* | -1 | 0 | -1 | -0.71 |
| | North of Dovre | **East** | | -2.72 (0.01)* | 0 | 0 | -1 | -0.53 |

*Regional differences in proneness to adapt*

Moving to planning and management, we found that only 3% of the respondents from North of Dovre had sought advice on adaptive management, while the proportion in the other regions varied between 9% and 16%. Respondents from the Inland and East could furthermore remember receiving advice without deliberately seeking them out more often than the other respondents[9]. Regional differences in need for advice on adaptive management (KW, $\chi^2$=9.314, df=4) and perceived sufficiency of own knowledge on climate change and forestry (KW, $\chi^2$=8.96, df=4) were not significant on the 95% confidence level.

With a few exceptions, large proportions of respondents from all regions had chosen the no opinion alternatives for all adaptive management options. The clearest division from this was for natural

[9] Details in figure 6, supplementary material.

regeneration, were opinions varied within all regions so that the distributions looked relatively flat[10]. There were some significant differences between regions: respondents from the South were least confident in that they would not consider natural regeneration, and respondents from Inland Norway and North of Dovre most confident in that they would not consider increasing the share of deciduous trees. The Inland respondents were also most confident in that they would not increase the share of spruce in their forest, and most confident (median and 3rd quartile equalled somewhat agree) in they would consider earlier thinnings. The same group was also, together with respondents from the East and South somewhat more confident in that they would consider earlier final harvest. As for avoiding thinnings, respondents from Inland Norway and North of Dovre were the most confident in that this option would not be considered. However, the mean response in all regions were below 4 (i.e. no opinion). Table 4 shows significant test results (95% confidence interval) and differences between regions.

*Table 3 Significant (CI 95%) results from Kruskal-Wallis and Dunn tests for differences in proneness to consider implementing adaptive management actions between respondents from five Norwegian regions*

| Groups | | | Kruskal Wallis $\chi^2$, df, (p-value) | Dunn z (p-value) | Difference (effect) 1st Q | 2nd Q | 3rd Q | Mean |
|---|---|---|---|---|---|---|---|---|
| **Continuous forestry** | | | 9.85, 4, (0.04) | test did not identify any differences | | | | |
| **Natural regeneration** | Inland | **South** | 23.31, 4, (0.00) | -4.75 (0.00)* | -1 | -1 | 0 | -0.68 |
| | **South** | Westcoast | | 2.89 (0.01)* | 1 | 0 | 0 | 0.5 |
| **Increase pine** | | | 9.86, 4, (0.04) | test did not identify any differences | | | | |
| **Increase spruce** | Inland | **North of Dovre** | 17.11, 4, (0.00) | -3.02 (0.01)* | -1 | 0 | 0 | -1.03 |
| | Inland | **Westcoast** | | -3.33 (0.00)* | -1 | 0 | 0 | -0.48 |
| **Increase deciduous trees** | Inland | **South** | 29.68, 4, (0.00) | -3.53 (0.00)* | -1 | 0 | -1 | -0.45 |
| | North of Dovre | **South** | | -2.34 (0.03)* | -0.25 | 0 | -1 | -0.35 |
| | Inland | **Westcoast** | | -4.14 (0.00)* | -2 | 0 | -1 | -0.68 |
| | North of Dovre | **Westcoast** | | -3.07 (0.00)* | -1.25 | 0 | -1 | -0.58 |
| | Inland | **East** | | -3.64 (0.00)* | -1 | 0 | -1 | -0.63 |
| | North of Dovre | **East** | | -2.75 (0.01)* | -0.25 | 0 | -1 | -0.53 |
| **Early thinnings** | **Inland** | South | 16.66, 4, (0.00) | 2.44 (0.00)* | 0 | 1 | 0 | 0.43 |
| | **Inland** | Westcoast | | 2.96 (0.014)* | 0 | 1 | 0 | 0.38 |
| **Avoid thinnings** | Inland | **South** | 17.82, 4, (0.00) | -3.00 (0.01)* | 0 | -1 | -1 | -0.40 |
| | Inland | **Westcoast** | | -3.59 (0.00)* | -1 | -1 | 0 | -0.58 |
| | North of Dovre | **Westcoast** | | -2.50 (0.04)* | -1 | 0 | 0 | -0.5 |
| **Early final harvest** | **Inland** | North of Dovre | 17.89, 4, (0.00) | 3.32 (0.00)* | 0 | 0 | 0 | 0.46 |
| | North of Dovre | **South** | | -2.38 (0.03)* | -1 | 0 | 0 | -0.31 |
| | **Inland** | Westcoast | | 2.67 (0.02)* | 0 | 0 | 0 | 0.34 |
| | North of Dovre | **East** | | -3.09 (0.00)* | -1 | 0 | 0 | -0.51 |
| | Westcoast | **East** | | -2.56 (0.02)* | -1 | 0 | 0 | -0,39 |

### *Education and holding size*

The respondents with higher education and large holding (n=217) were significantly more confident on the climate changing globally than the other three groups (i.e. high education, smaller holding

[10] Answer-distributions and details in figures 9-12 in supplementary material.

(n=255) D, z=2.31, lower education, smaller holding (n=332) D, z=7.48, lower education, large holding (n=198), D z=7.09). The median response in this group equalled completely agree, which was one point higher than in the other groupings. The second most confident group was the respondents with high education and small holdings (i.e. lower education, small holding D, z=5.28, lower education, large holding d, z=5.10). For climate change at holding scope and belief in climate change being human made, the two groups with higher education were more confident than the other two groups[11].

A comparatively large proportion of the high education, large holding group reported to having observed or experienced climate change (see figure 6). Then, the respondents in this group were systematically more confident than other groups were in that climate change would cause damages in their forest and to forest infrastructure. Interestingly, considering that damage intuitively could be expected to decrease growth and thus income- the high education, large holding group was most confident also in that volume-growth, demand, and income-potential and holding value going to increase due to climate change (see table 4 for details)[12]. Finally, a relatively large proportion of the high education, large holding group reported having both sought (23%, n=213) and received (29%, n=213) advice[13]. The proportions reporting the same in the other groups varied between 7% and 13% (n=197-337) and 12%-20% (n=197-338), for having sought and having received advice, respectively[14].

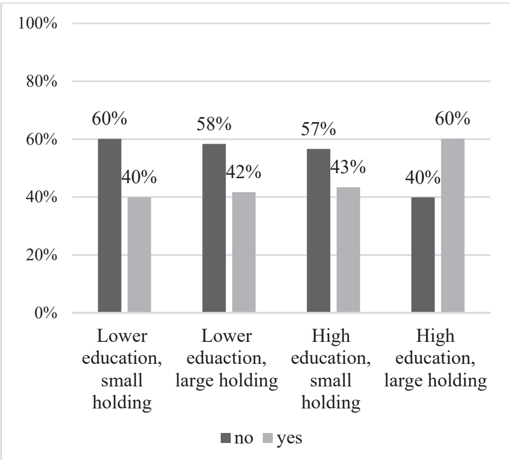



*Figure 6 Proportion of respondents with different levels of education and different holding size reporting having seen or experienced climate change at their holding the last 5 years.*

*Lower education, small holding: n=188, Lower education, large holding: n=128 High education, small holding: n=156, High education, large holding: n=173. The proportions are calculated based on responses (i.e. those who answered the question).*

[11] For holding scope: Respondents with higher education from large holdings (n=212) vs low education, small holding (n=317) D, z=6.57 and vs. low education, large holdings (n=190) D, z=5.18. Respondents with higher education from small holdings (n=246) vs. low education, small holding (n=317) D, z=4.68, respectively and vs. low education, large holdings (n=190) D, z=3.44, respectively. For climate change being human made; for high education, large holdings (n=170) vs. lower education, small holding (n=182) D, z=4.87, and vs. lower education, large holding (n=119) D, z=4.63. For high education, small holding (n=184) vs. low education, small holding (n=182) D, z=3.66 and vs. lower education, large holding (n=119) D, z=3.54.
[12] Additional details in figures 14, 15 and 16 in supplementary material.
[13] Proportion is calculated based on the number of respondents that answered the questions in each group.
[14] See figure 17 in supplementary materials for histograms that visualises the differences.

*Table 4 Significant (CI 95%) results from Kruskal-Wallis and Dunn tests for differences in risk perceptions and economic impact for groups of Norwegian respondents based on holding size (large holding=100 ha or more) and education.*

| | Groups | | Kruskal Wallis χ2, df, (p-value) | Dunn z (p-value) | Differences 1st Q | 2nd Q | 3rd Q | Mean |
|---|---|---|---|---|---|---|---|---|
| **Storm** | Low education, small holding | **High education, large holding** | 15.81, 3, (0.00) | -3.90 (0.00)* | -1 | 0 | 0 | -0.54 |
| | **High education, large holding** | Low education, large holding | | 2.67 (0.02)* | 0 | 0 | 1 | 0.35 |
| **Wind** | **High education, small holding** | Low education, small holding | 20.05, 3, (0.00) | 2.49 (0.02)* | 1 | 0 | 0 | 0.32 |
| | Low education, small holding | **High education, large holding** | | -4.08 (0.00)* | -1 | -1 | 0 | -0.52 |
| | **High education, large holding** | Low education, large holding | | 3.41 (0.00)* | 1 | 1 | 0 | 0.41 |
| **Forest fire** | **High education, large holding** | Low education, small holding | 10.14, 3, (0.01) | 2.73 (0.03)* | 0 | 1 | 1 | 0.33 |
| **Pests and disease** | High education, small holding | **High education, large holding** | 30.75, 3, (0.00) | -3.95 (0.00)* | 0 | 0 | -1 | -0.45 |
| | Low education, small holding | **High education, large holding** | | -5.45 (0.00)* | 0 | -1 | -1 | -0.62 |
| | **High education, large holding** | Low education, large holding | | 3.06 (0.00) | 0 | 0 | 1 | 0.46 |
| **Top-breakage** | High education, small holding | **High education, large holding** | 14.19, 3, (0.00) | -3.31 (0.00) | 0 | 0 | 0 | -0.44 |
| | Low education, small holding | **High education, large holding** | | -3.34 (0.00) | 0 | 0 | 0 | -0.53 |
| **Infra-structure** | High education, small holding | **High education, large holding** | 52.69, 3, (0.00) | -4.91 (0.00) | -1 | -1 | 0 | -0.65 |
| | Low education, small holding | **High education, large holding** | | -6.93 (0.00) | -1 | -1 | 0 | -0.94 |
| | High education, small holding | **Low education, large holding** | | -2.15 (0.03) | -0.5 | 0 | 0 | -0.28 |
| | Low education, small holding | **Low education, large holding** | | -3.92 (0.00) | -0.5 | 0 | 0 | -0.57 |
| | **High education, large holding** | Low education, large holding | | 2.50 (0.01) | 0.5 | 1 | | 0.37 |
| **Volume impact** | High education, small holding | **High education, large holding** | 51.72, 3, (0.00) | -4.89 (0.00)* | 0 | 0 | -1 | -0.47 |
| | **High education, large holding** | Low education, small holding | | 7.03 (0.00)* | 0 | -1 | -1 | 0.59 |
| | **High education, large holding** | Low education, large holding | | 3.20 (0.00)* | 0 | 0 | 1 | 0.32 |
| | Low education, small holding | **Low education, large holding** | | -3.316 (0.00)* | 0 | -1 | 0 | -0.27 |
| **Demand impact** | High education, small holding | **High education, large holding** | 15.42, 3, (0.00) | -3.81 (0.00)* | 0 | 0 | -1 | -0.39 |
| | High education, large holding | Low education, small holding | | 2.77 (0.01)* | 0 | 0 | 0 | 0.25 |
| **Total impact** | High education, small holding | **High education, large holding** | 30.78, 3, (0.00) | -4.64 (0.00)* | -0.75 | 0 | -1 | -0.41 |
| | High education, large holding | Low education, small holding | | 4.08 (0.00)* | 0.75 | 0 | 1 | 0.36 |
| | High education, small holding | **Low education, large holding** | | -3.62 (0.0006)* | -1 | 0 | -1 | -0.3 |
| | Low education, small holding | **Low education, large holding** | | -3.01 (0.0039)* | -1 | 0 | -1 | -0.25 |

*Differences in proneness to adapt between holding size and education groups*

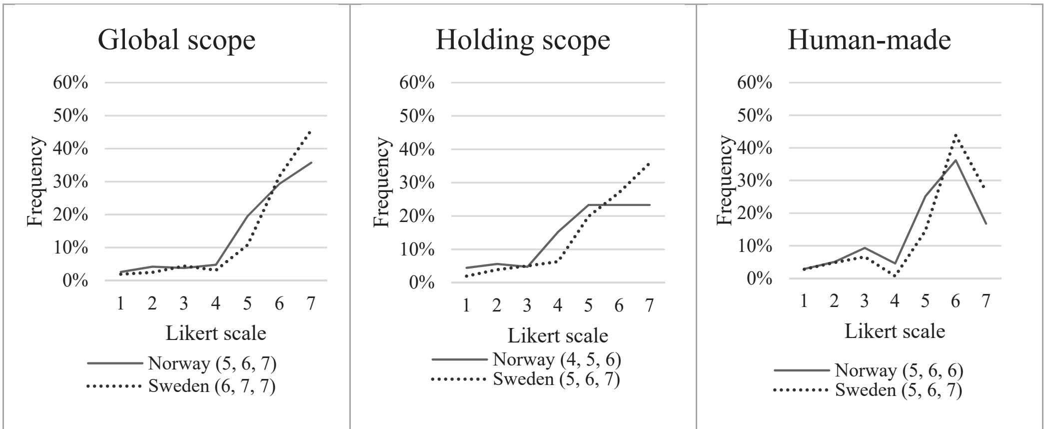
No group stood out as much more confident that they would consider implementing the suggested adaptive management options. However, there were some differences: the respondents with higher education and large holdings were most confident that they would not consider continuous forestry, but approximately 50% of this group agreed (somewhat, mainly or completely) that they would consider replacing thinnings, conducting thinnings earlier in the rotation, and earlier final harvest. The respondents with low education from small holdings was furthermore less confident that they would not consider increasing the share of spruce, increasing the share of deciduous trees, turn to continuous forestry and replace thinnings than at least one other group. Table 5 shows the significant differences and figures 20, 21, 22 and 23 in supplementary material shows the answer distributions and additional details.

*Table 5 Significant (CI 95%) results from Kruskal-Wallis and Dunn tests for differences in proneness to implement suggested adaptive actions for groups of Norwegian respondents based on holding size (large holding=100 ha or more) and education.*

| **Groups** | | | **Kruskal Wallis** | **Dunn** | **Difference (effect)** | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **$\chi^2$, df, (p-value)** | **z (p-value)** | **1st Q** | **2nd Q** | **3rd Q** | **Mean** |
| **Continuous forestry** | **High education, small holding** | High education, large holding | 13.39, 3, (0.00) | 3.06 (0.01)* | 2 | 0 | 1 | 0.41 |
| | High education, large holding | **Low education, small holding** | | -2.87 (0.01)* | -2 | 0 | -1 | -0.35 |
| **Increase spruce** | High education, small holding | **Low education, small holding** | 11.53, 3, (0.00) | -2.85 (0.02)* | 0 | 0 | -1 | -0.33 |
| **Increase deciduous trees** | **High education, small holding** | Low education, large holding | 13.00, 3, (0.00) | 3.58 (0.00)* | 1 | 0 | 1 | 0.04 |
| | **Low education, small holding** | Low education, large holding | | 2.44 (0.04)* | 1 | 0 | 1 | -0.13 |
| **Replace thinnings** | High education, small holding | **High education, large holding** | 21.17, 3, (0.00) | -4.26 (0.00)* | 0 | -1 | -1 | -0.51 |
| | High education, small holding | **Low education, small holding** | | -0.91 (0.36) | 0 | 0 | 0 | -0.09 |
| | **High education, large holding** | Low education, small holding | | 3.63 (0.00)* | 0 | 1 | 1 | 0.42 |
| **Earlier thinnings** | High education, small holding | **High education, large holding** | 19.25, 3, (0.00) | -4.11 (0.00)* | 0 | -1 | 1 | -0.39 |
| | **High education, large holding** | Low education, small holding | | 2.90 (0.01)* | 0 | 1 | 1 | 0.32 |
| | High education, small holding | **Low education, large holding** | | -2.77 (0.01)* | 0 | -1 | 0 | -0.25 |
| **Earlier final harvest** | **High education, large holding** | Low education, small holding | 10.38,3, (0.01) | 2.94 (0.01)* | 1 | 1 | 0 | 0.35 |
| | **High education, small holding** | Low education, large holding | | 0.80 (0.50) | 1 | 1 | 0 | 0.13 |
| | **High education, large holding** | Low education, large holding | | 2.67 (0.022)* | 1 | 1 | 0 | 0.35 |

*Differences between Norway and Sweden*

The Swedish sample was more confident about the climate changing bot globally (W=315880) and at their holdings (W=276180) and climate change being human-made (W=223010) (n for all groups is enclosed in figure 7). Figure 7 shows how the proportions of Swedes completely agreeing to the statements are visibly larger than the proportions of Norwegians having answered the same.




| | | |
|---|---|---|
| *Norway: n=1002, mean=5.66, SD=1.69, Sweden: n=730, mean=5.95, SD=1.39* | *Norway: n=965, mean=5.11, SD=1.81, Sweden: n=714, mean=5.62, SD=1.49* | *Norway: n=658, mean=5.19, SD=1.56, Sweden: n=575, mean=5.57, SD=1.52* |

*Figure 7 The Norwegian and Swedish respondents' answers to statements on the climate changing and climate change being human-made in contrast.*

A larger proportion of the Swedes who believed the climate is changing (49%, n=589 ≈36% of the Swedish sample) compared to the Norwegians had furthermore observed or experienced climate change at their holdings. Most frequently, the Swedes had observed shorter frozen ground seasons (48% of those having observed changes, i.e. 29% of the Swedish sample) and increased volume-growth (35% of those having observed changes, i.e. 22% of the Swedish sample). Thus, the Swedes had largely observed the same things as the Norwegians. However, and unlike the Norwegians, a relatively large proportion (27% of those having observed changes, or 17% of the total Swedish sample) of the Swedes reported having experienced increased forest damages caused by climate change.

The Swedes were also more confident that climate change will increase damage from storm (W=288220), wind (W=320520), drought (W=249620), fire (W=254000), pests and diseases (W=230980) and root rot (W0293180), while the Norwegians was more confident for top-breakage (W=365840) and Infrastructure (W=400580) (n for all groups enclosed in Figure 8). The difference in mean score was largest (≈ 0.75 Likert-scale points) for drought and for pests and diseases. Figure 8 shows the Norwegian and Swedish responses in contrast.

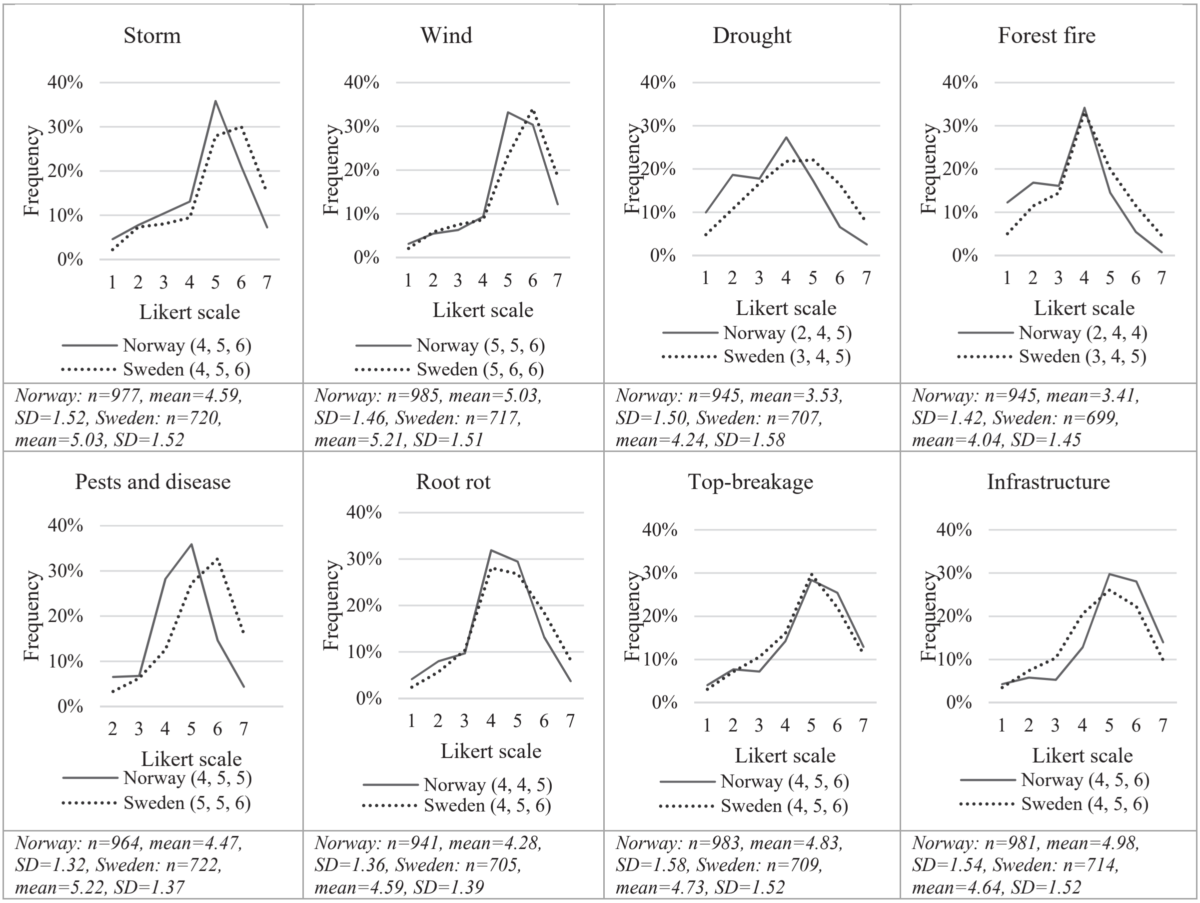



*Figure 8 The Norwegian and Swedish respondents' answers to statements on increased damages to forests due to climate change in contrast.*

However, in addition to being more confident of increasing damages, the Swedes (n=724) were also more confident than the Norwegians (n=991) in that climate change would increase the volume-growth (W=275930, p=0.00), and income-potential and value of their holding (Norway: n=1002, Sweden: n=725, W=311130, p=0.00). They (n=722) were however slightly less confident than the Norwegians (n=980) (W=382080, p=0.00) in that climate change would cause increased roundwood demand[15].

Compared to the Norwegians (n=1004), the Swedes (n=730) were furthermore slightly less uncertain of their own knowledge being adequate (W:341340, p=0.01), and they had to a larger extent both sought (37%, n=727) and received (28%, n=728) advice. The Swedes had sought advice from various sources, but most frequently from a governmental body (the Swedish Forest Agency), forest

[15] See figure 25 in supplementary materials for details.

owners associations, various newspapers and magazines (forestry-magazines or otherwise), the Swedish University of Agricultural Sciences (SLU) and other research institutions. Of the Swedish sample, 16.5% had received advice without seeking it from a forest owners association (cf. 8.5% in Norway), 14.5% from forest media (cf. 11.5% in Norway) or 13.5% from forest advisors working in owners associations (cf. 7% in Norway). A larger proportion of the Swedish sample, i.e. 13.5%, also confirmed having received advice from governmental sources (cf. 5% in Norway). Most frequently, advice given had been “avoid late and heavy thinnings” (68% of the 203 who had received advice, or 19% of the Swedes), or “conduct pre-commercial thinnings earlier in the rotation” (61% of those who had received advice, or 17% of the Swedes). Out of the 476 Swedes who had neither sought nor received advice, 12% disagreed and 71% agreed that they needed advice on adaptation, while approximately 20% completely agreed.

Finally, there were clear differences between the two samples in their assessments of adaptive options. First, the Swedish sample was more confident that they would consider using adapted plant material: while more than 50% of the Norwegian answered “no opinion”, more than 50% of the Swedes chose one of the agreeing alternatives (mean score differing by 0.9 Likert-scale points). Next, many Swedes disagreed that they would consider “replacing commercial thinnings with pre-commercial thinnings”, “turn to continuous cover forestry”, and “avoid thinnings”. Finally, the Swedish sample was significantly more in favour of conducting earlier final harvests and of increasing the share of deciduous trees. Test details in table 6.

*Table 6 Significant (CI 95%) results from Wilcoxon rank sum tests for differences between Norway and Sweden in proneness to implement suggested adaptive actions.*

| | **n** | | **W (U)** | **p-value** | **Differences** | | | |
|---|---|---|---|---|---|---|---|---|
| | Norway | Sweden | | | 1st Q | 2nd Q | 3rd Q | Mean |
| **Plant material** | 985 | 721 | 2193530 | 0.00 | 0 | -1 | -2 | -0.90 |
| **Continuous forestry** | 978 | 716 | 405860 | 0.00 | -1 | -1 | -1 | 0.47 |
| **Increase pine** | 945 | 700 | 299050 | 0.00 | -1 | 0 | -1 | -0.26 |
| **Increase spruce** | 962 | 694 | 366000 | 0.00 | 0 | 0 | 1 | 0.25 |
| **Increase deciduous trees** | 946 | 705 | 231770 | 0.00 | -1 | -1 | 0 | -0.81 |
| **Change dominating species** | 936 | 702 | 271050 | 0.00 | -1 | 0 | -1 | -0.45 |
| **Replace thinnings** | 973 | 719 | 421390 | 0.00 | 2 | 0 | 0 | 0.58 |
| **Earlier thinnings** | 967 | 719 | 314640 | 0.00 | 0 | 0 | -1 | -0.16 |
| **Avoid thinnings** | 955 | 703 | 438130 | 0.00 | 1 | 2 | 0 | 0.85 |
| **Earlier final harvest** | 962 | 716 | 303210 | 0.00 | 0 | -1 | -1 | -0.26 |
| **Other options** | 694 | 540 | 194460 | 0.02 | 0 | 0 | 0 | 0.07 |

## Discussion

Our results show that most of the Norwegian respondents were confident that that the climate is changing and in climate change being human-made. Only 10% did not (somewhat mainly or completely) agree that climate change would increase damage to their forests. However, when asked to assess what impact climate change would have on income-potential and holding value, only 29% thought the effect would be negative. Of these, all but 67 believed the effect would be minor. In relation to the risk appraisal process in the MPPACC (Grothmann & Patt, 2005), it thus appears that although the majority of Norwegian respondents perceived a relatively high probability that their forest would be exposed to climate change-related threats, the perceived severity, in terms of impact on monetary values, appeared relatively low.

As the questionnaire moved from beliefs, experiences and damages to climate change effects on production, market and income and finally to the assessment of management changes, the responses became increasingly concentrated around the "no opinion" alternative, in the middle of the Likert-scale. In general, the respondents expressed more willingness to consider options that would presumably increase the resistance of their forest to change (Millar et al., 2007), but more reluctant to consider abandoning clear-cutting and planting, i.e. switching to adaptive options mimicking natural adaptive processes (Bolte et al., 2009). This was particularly clear for "when conducting thinnings, thin earlier in the rotation", and also for "conduct final harvests earlier in the rotation" and "(do) pre-commercial thinnings as replacement for thinnings". There was one exception to this, however: for "turn to natural regeneration", there was a relatively broad spread in responses between negating replies, no opinion and somewhat agree so that the distribution appeared relatively flat. A likely explanation for this is that the consequences of "turning to natural regeneration" are well-known and easy to visualize, possibly making it easier for the respondents to assess this option. The responses to the 12 suggested adaptive options could serve as a measure of the outcome of the MPPACC model: that is, adaptation intention or avoidant maladaptation. Taken together, the responses to these questions suggest that few respondents had clear intentions of adapting. This could be due to low perceived severity leading to avoidant maladaptation in the form of wishful thinking. However, our interpretation of the clear centring of responses around "no opinion" with few confident responses was not that most respondents saw no need to respond (i.e. wishful thinking), but that they were still in the process of risk and adaptation appraisal.

The Swedish respondents were more confident than the Norwegians that the climate is changing and that it is human-made. Considerably larger proportions of the Swedish sample had also experienced climate change-related changes in their forest and had received or sought advice about climate change adaptation. In most cases, the Swedes expressed higher risk perceptions than the Norwegians, but the shape of the answer distributions was still similar between the two countries.

Before analysing the data, we hypothesised that the reported risk perceptions would be influenced by the importance of forestry in Swedish society. Thus, results may be interpreted as supporting this hypothesis. It is however worth noting that Swedes in general are among the most convinced and concerned about climate change in Europe. An EU survey, comparing the climate change perceptions of EU-citizens from all member countries, shows that a large proportion of Swedes regard climate change as the most serious problem the world is facing (TNS political & social, 2017). Sweden's general social discourse on climate change, which is one of the external factors highlighted by Grothmann and Patt (2005) in the MPPACC, is likely to be affected by this.

Norwegian citizens were not part of the EU-survey, and directly comparable data do not exist. However, in a recent climate attitude study, the authors found that Norwegians were less concerned about climate change than citizens in EU countries like Spain and Great Britain (Buckley et al., 2017). The way Swedish respondents were consistently more confident in their responses could be interpreted as support to the hypothesis that the higher societal importance of forestry within a country will impact forestry decision-makers' risk appraisal. It could also be, however, that the consistent difference between the Swedes and Norwegians reflects the general perceptions of Norwegian and Swedes, or differences in social discourse within the two neighbouring countries, rather than being linked to the importance of the forest sectors within the two countries.

As a whole, the Swedes were not clearly more in agreement with considering implementing the suggested adaptive options or the alternative "other option". There were four clear exceptions. For the options "using better adapted plant material", "earlier final harvest", "when conducting thinnings, thin earlier in the rotation", and "increase the share of deciduous trees", the Swedes were significantly and visibly more in agreement than the Norwegians. For other options, however, in particular, "avoiding thinnings", "replacing thinnings" and "turn to continuous cover forestry", the Swedes were significantly and visibly more in disagreement. There was thus no clear support for the second element of our hypothesis: that is, that the greater importance of forestry in Sweden would lead to a more widespread intention to adapt in Sweden when compared to Norway. A possible interpretation of this finding is that the Swedes' stronger negating opinions show that they are further along in the risk and adaptation appraisal processes (Grothmann & Patt, 2005) or the planning and assessment of adaptive options (Simon, 1977). As such, the more confident responses, whether confirming or negating, would indicate that they have already considered adaptive practices, rejecting some but not others. In addition, the relatively large proportion who confidently disagree that they would consider certain adaptive options could also be due to different forestry norms and traditions within the countries (Keskitalo et al., 2013). Thinnings, for example, are much more common in Sweden than in Norway, and results suggest that Sweden has a strong sense of what constitutes the "right" or "appropriate" forest management approach (Uggla & Lidskog, 2016).

Although nearly all respondents from both countries expected increased damage to forests and forest infrastructure, relatively few expected volume-growth, income-potential and holding value to be negatively impacted. Instead, most respondents in both countries expected there to be either no change or a positive change in growth and economic impacts. In addition, a relatively large proportion expected demand to increase as a consequence of climate change. Respondents representing large holdings had more positive expectations than those from smaller holdings. Careful optimism is not without parallels in literature. Based on qualitative data from personal interviews and focus groups, several authors (Heltorp et al., 2018; Laakkonen et al., 2018) have identified optimistic expectations related to climate change among forestry decision-makers in the Nordic countries. Our results, based on quantitative data, confirm that the proportion of forestry decision-makers who not only remain relatively unworried but actually have positive expectations is relatively large. Focus on forestry's role in the bioeconomy, and climate predictions involving longer growing seasons combined with no water deficiency might be unique for the Nordic countries and are a possible explanation for this "positive" attitude. However, we recommend that future surveys in other countries include questions to determine whether such positive expectations exist elsewhere.

An alternative explanation for why so few respondents expected negative impacts from climate change on their incomepotential and holding value is the fact that a majority of the respondents report having insurance covering their forest against damage caused by e.g. fires or storms. This safeguarding might reduce concern and thus the incentive to seek new knowledge and to employ adaptive strategies to reduce the impacts of the expected increase in climate-induced forest damage.

*Seeking and receiving advice*

Only a minority of the Norwegians reported having sought advice, and few remembered having received advice about adaptive forestry without having sought it. This is surprising, since all respondents who had taken out insurance (75% of the Norwegian respondents) in 2014 would have received a flyer with adaptive advice, distributed by the only insurance company in Norway offering forestry insurance to their customers(Skogbrand, 2014). Thus, a much larger proportion than those who answered "yes" to the question must in fact have received adaptive advice, but had either not acknowledged it or recognized it as such. This suggests that informing Norwegian forestry decision-makers about adaptive management might be more challenging than expected, particularly since the Norwegians, like decision-makers in many countries (Sousa-Silva et al., 2016; Sousa-Silva et al., 2018), perceived their knowledge on adaptive forestry to be low, and welcomed advice and recommendations. The responses thus seem somewhat contradictory: needing advice and stating a lack of knowledge on the one hand, and neither recognizing nor seeking out advice on the other.

One possible explanation for not seeking advice is that, although recommendations would have been welcomed, the respondents, like many of those studied by Vulturius et al. (2018), felt little sense of urgency. It is also possible that some other barrier (Moser & Ekstrom, 2010) prevented them from taking action. It could be, as we have already commented, that having taken out insurance against damages caused by e.g. forest fires and storm (75% of the Norwegians and 86% of the Swedes had taken out insurance), limits the perceived risk as well as the need for changing and adapting the forest and its management. However, an alternative explanation is that the negating alternatives to the "I have sufficient knowledge about adaptive management"-statement, and the confirming alternatives for "I need advice about adaptive forest management", were perceived by many as "right" and "appropriate" (Dillman et al., 2009), and that the contradiction is due to a yes-saying bias (Ferrando & Lorenzo-Seva, 2010). Still, our results add to the body of research that finds that respondents would like more information, recommendations and advice about adapting forest management to climate change ( e.g. Bissonnette et al., 2017; Uggla & Lidskog, 2016; Grotta et al., 2013).

*Differences among groups of respondents*

Regarding differences between regions, we assessed these to be quite logical when considering existing practices, topography and existing climatic patterns. For example, the respondents situated at the Westcoast of Norway, where strong wind are relatively common and it rains quite often (Hanssen-Bauer et al., 2009), expected higher increased damage from storm, but not from forest fires and drought. Similarly, it was the respondents from the Inland and the South, where snow-rich winters are common, who were most confident that top-break would increase, and the respondents from the Inland, the South and particularly the East who were least confident in that drought would not increase. These are areas with less precipitation falling as rain compared to for example the Westcoast. However, and quite curiously considering that drought and fires often are "linked", more than 25% of the respondents coming from this area thought forest fires would increase. When assessing economic impact of climate change on forestry, it was the Inland respondents together with those from the East, who comes from the area of Norway with strongest forestry traditions and most forest resources, who thought they would benefit most economically. To some extent, this this pattern continued in reactions to suggested adaptive management options. The Westcoast respondents, coming from an area where thinnings are less common than for example in Inland Norway, were least confident than they would not avoid thinnings. The Inland respondents, on the other hand, were most confident that they would consider early thinnings. These respondents were (together with those from North of Dovre), also most confident in that they would not consider increasing the share of deciduous trees, which are considered the least economically beneficial species in Norway. This seem quite logic considering relatively strong historically focus on roundwood-production in the area. Thus, it seems plausible that forestry traditions and experiences with forest types and management strategies influenced responses when considering future management. This is consistent with theory and earlier studies (Uggla & Lidskog, 2016; Lidskog & Sjödin, 2014; Keskitalo et al., 2013).

When testing for differences between groups of respondents within Norway, we found that the combination of higher education and large forest holdings seemed to have a relatively strong effect on strength of beliefs, expecting increased damages and the likeliness of having seen or experienced climate change. However, and as Blennow et al. (2016) suggest, the reason respondents from large holdings are more likely to have experienced climate change-related changes in their forest might simply be that larger holdings require more maintenance and thus more time spent in the forest. The profound effect of education and holding size in combination, however, did only partly extend to the planning and management phase: that is, agreeing to consider adaptive options.

It should be remarked that differences, although statistically significant often were rather modest in size. For example, the difference in mean score between groups was seldom larger than the within-group standard deviation, and the difference in median and quartiles was only rarely more than one point on the Likert-scale.

*Methods and representativeness*

The methodological approach and representativeness of the net sample compared to the population, influences the validity of the results and whether and for which groups of the population we can generalize our results. Following (Dillman et al., 2009), we attempted to ask questions clearly and openly, and not lead the respondents towards particular answers; we also included a neutral alternative so respondents would not feel forced to express opinions where they had none, and ensured that scales were balanced.

That climate change is occurring was, however, an explicitly- or implicitly-stated assumption in many of the questions. The responses from climate change sceptics may therefore represent a possible bias in our material. When asked to assess various risks and adaptive options in response to climate change, this group of respondents may either have chosen one of the disagreeing alternatives or the "no opinion" alternative. Thus, among those who answered "no opinion", for example to questions about whether they would consider implementing an adaptive measure, there could be respondents who did not believe the climate is changing, respondents who did not understand the question and respondents who in fact had no opinion. This is a possible measurement error, which we could have avoided by including an "I do not know" alternative, and possibly an alternative along the lines of "I don't believe in climate change". However, during the three stages of pilot-testing, we had no indication of this kind of confusion or that these questions were difficult to understand.

An additional consideration, following Dillman et al. (2009), is that respondents, if they are unable to reply the questions, may feel 'dumb' and quit the questionnaire before finishing. This might also have influenced both the overall response rate and the response rate for individual questions. However, it is also possible that the large proportion who answered "no opinion" reflect a general lack of views or preference on these matters, and/or that the idea of changing behaviour in response to climate change was new and unfamiliar.

A high response rate is always considered beneficial when using data based on questionnaires (Dillman et al., 2009). The overall response rate in this study was 17.5%. To increase response rates, short questionnaires are encouraged (Dillman et al., 2009). Our questionnaire was rather extensive, with more than 20 standard questions. While Questback does not offer statistics on aborted questionnaire forms, such information would indicate whether the length or complexity of the form influenced the respondents' motivation to complete it. The forest owners associations administered the sampling and the distribution of invitations and reminders to participate. The Norwegian sample and members of Norrskog and Norra received reminders. In Sweden, response rates were highest in Norrskog and Norra, indicating that additional reminders could have increased the overall response rate from Sweden.

Our response rate was lower than that of comparable studies conducted in Sweden (e.g. Vulturius et al., 2018; Blennow et al., 2016; Blennow, 2012). A possible explanation is our choice of media. According to Nulty (2008), online surveys typically receive about 10% fewer responses than postal surveys (not an option for our study); our response rate was in fact close to 10% lower than the most recent of the Swedish studies (Vulturius et al., 2018), which was a postal survey. However, even though the response rate was lower than previous Swedish studies, our data contain a comparatively larger number of responses. Dillman et al. (2009) argue that considering non-responses and sampling errors may be as important as a high response rate for avoiding biases and erroneously generalizing findings. In addition, they (op. cit.) show how a sufficient response rate depends on the size of the population: a sufficient response for ensuring a level of confidence of 95% when the population consists of 100,000 or more is around 383 responses, assuming maximum heterogeneity. If the respondents reflect the heterogeneity in the populations, our sample should undoubtedly suffice for estimating population parameters.

Conducting a non-response analysis of our sample was challenging, as the population parameters of our gross sample—i.e. the population of forest association members—were not available. However, comparing the characteristics of the respondents with corresponding parameters from national statistics[16], we found some indications of the samples' assumed representativeness: it is likely that many of those who did not respond represented smaller holdings and had lower education. We chose members of the Norwegian and Swedish forest owners associations as our population, knowing that not all forest owners are members of these associations. As mentioned, we assumed that the most engaged forest owners and managers would be members of these associations, and that our sample would thus reach those most likely to have opinions on climate change impacts on forestry and adaptation. Moreover, personal interest in the topic of a questionnaire typically influences the likelihood of a respondent replying (Martin, 1994). It is therefore reasonable to assume that our net sample primarily represents forestry stakeholders who are interested in forestry and climate change-related issues, and our results should not be generalized without reservation to all members of the forest owner associations or the overall populations of forest owners and managers. Comparing the representativeness of our sample to previous studies is difficult, as few authors report such matters. Interestingly, however, the latest questionnaire-based study among Swedish NIPFs had some of the same properties (e.g. the relatively large mean holding and  high share of respondents with higher education in Vulturius et al., 2018).

*Further research and Concluding remarks*

[16] see Table 1 in the supplementary material

The first objective of this study was for the first time to present quantitative measures of Norwegian forestry decision-makers' climate change beliefs, risk perceptions and propensity to adapt, using data from a questionnaire distributed to forestry decision makers in Norway (and Sweden). Our results showed that most Norwegian forestry decision makers believed that the climate is changing globally and at their holding. Most also believed that climate change is human-made, and that it will cause increased damages to their forests. However, many also believed that climate change would increase growth and demand, and only a minority believed that climate change would decrease the income-potential and value of their forest holding. When asked to assess whether they would consider implementing 12 suggested adaptive measures, the most frequent response was "no opinion". Our second objective was to compare and validate the results of the Norwegian survey with those of Sweden, and test whether there is evidence to support the hypothesis that Swedish decision-makers have stronger beliefs, perceive higher risks and be more prone to adapt. When comparing the Norwegian results with results from Sweden, we found that the Swedes more strongly believed that the climate is changing and that risk would increase. However, just as the Norwegians, the Swedes did not signal that they expected income-potential and holding value to decrease. The Swedes were more decisive about the adaptive measures, but they were not in general more prone to adapt than the Norwegians were. The results can be interpreted as partially supporting the hypothesis, i.e. that Swedish forestry decision-makers, coming from a country where forestry is of high national importance, have stronger beliefs and perceive higher risks. Our findings do however not support that Swedish forestry decision makers are more prone to implement any type of adaptive measure. Future research directions include exploring the role of insurance and willingness to take out additional insurance to reduce climate change related risks and identifying the variables, if any, which characterize those prone to adapt and separate them from other forestry decision makers.

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## Literature


Adger, W. N., Agrawala, S., Mirza, M. M. Q., Conde, C., O'Brien, K., Pulhin, J., Pulwarty, R., Smit, B. & Takahashi, K. (2007). *Assessment of adaptation practices, options, constraints and capacity. In: Climate Change 2007.: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* . In Parry, M., Canziani, O., Palutikof, J., van der Linden, P. & Hanson, C. (eds). Cambridge.

André, K., Baird, J., Swartling, Å. G., Vulturius, G. & Plummer, R. (2017). Analysis of Swedish forest owners' information and knowledge-sharing networks for decision-making: insights for climate change communication and adaptation. *Environ Manage*, 59 (6): 885-897.

Benjamini, Y. & Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *J royal stat soc. Series B (Methodological)*: 289-300.

Bergh, J., Freeman, M., Sigurdsson, B., Kellomäki, S., Laitinen, K., Niinistö, S., Peltola, H. & Linder, S. (2003). Modelling the short-term effects of climate change on the productivity of selected tree species in Nordic countries. *For Ecol Manage*, 183 (1-3): 327-340. doi: https://doi.org/10.1016/S0378-1127(03)00117-8.

Bergh, J., Nilsson, U., Kjartansson, B. & Karlsson, M. (2010). Impact of climate change on the productivity of silver birch, Norway spruce and Scots pine stands in Sweden and economic implications for timber production. *Ecol Bull*, 53: 185-196.

Bernier, P. & Schoene, D. (2009). Adapting Forests and Their Management to Climate Change: An Overiew. *Unasylva*, 60 (231/232): 5-11.

Bissonnette, J.-F., Dupras, J., Doyon, F., Chion, C. & Tardif, J. (2017). Perceptions of small private forest owner's vulnerability and adaptive capacity to environmental disturbances and climate change: Views from a heterogeneous population in Southern Quebec, Canada. *Small-scale for*, 16 (3): 367-393.

Blennow, K. & Sallnäs, O. (2002). Risk perception among non-industrial private forest owners. *Scand J For Res*, 17 (5): 472-479. doi: https://doi.org/10.1080/028275802320435487.

Blennow, K. & Persson, J. (2009). Climate change: Motivation for taking measure to adapt. *Glob Environ Chang*, 19 (1): 100-104. doi: 10.1016/j.gloenvcha.2008.10.003.

Blennow, K. (2012). Adaptation of forest management to climate change among private individual forest owners in Sweden. *For Policy Econ*, 24: 41-47. doi: https://doi.org/10.1016/j.forpol.2011.04.005.

Blennow, K., Persson, J., Tomé, M. & Hanewinkel, M. (2012). Climate Change: Believing and Seeing Implies Adapting *PLoS ONE* 7 (11): 7. doi: doi.org/10.1371/journal.pone.0050182.

Blennow, K., Persson, J., Persson, E. & Hanewinkel, M. (2016). Forest Owners' Response to Climate Change: University Education Trumps Value Profile. *PloS one*, 11 (5): e0155137. doi: doi:10.1371/journal.pone.0155137.

Boisvenue, C. & Running, S. W. (2006). Impacts of climate change on natural forest productivity–evidence since the middle of the 20th century. *Global Change Biol*, 12 (5): 862-882. doi: https://doi.org/10.1111/j.1365-2486.2006.01134.x.

Bolte, A., Ammer, C., Löf, M., Madsen, P., Nabuurs, G.-J., Schall, P., Spathelf, P. & Rock, J. (2009). Adaptive forest management in central Europe: climate change impacts, strategies and integrative concept. *Scand J For Res*, 24 (6): 473-482. doi: 10.1080/02827580903418224.

Briceno-Elizondo, E., Garcia-Gonzalo, J., Peltola, H., Matala, J. & Kellomäki, S. (2006). Sensitivity of growth of Scots pine, Norway spruce and silver birch to climate change and forest management in boreal conditions. *For Ecol Manage*, 232 (1-3): 152-167. doi: https://doi.org/10.1016/j.foreco.2006.05.062.

Buckley, P. J., Pinnegar, J. K., Painting, S. J., Terry, G., Chilvers, J., Lorenzoni, I., Gelcich, S. & Duarte, C. M. (2017). Ten thousand voices on marine climate change in Europe: different perceptions among demographic groups and nationalities. *Front Mar Sci*, 4: 17.

Couture, S. & Reynaud, A. (2008). Multi-stand forest management under a climatic risk: do time and risk preferences matter? *Environ Model Assess*, 13 (2): 181-193.

Crawley, M. J. (2012). *The R book*: John Wiley & Sons.

Dillman, D. A., Smyth, J. D. & Christian, L. M. (2009). *Internet, mail, and mixed-mode surveys*. The tailored design method, vol. 3. Hoboken, New Jersey: John Wiley & sons
Duncker, P. S., Barreiro, S. M., Hengeveld, G. M., Lind, T., Mason, B., Ambrozy, S. & Spiecker, H. (2012). Classification of forest management approaches: a new conceptual framework and its applicability to European forestry. *Ecol Soc*, 17 (4). doi: http://dx.doi.org/10.5751/ES-05262-170451.
Dunn, O. J. (1964). Multiple comparisons using rank sums. *Technometrics*, 6 (3): 241-252.
Eriksson, L. (2014). Risk perception and responses among private forest owners in Sweden. *Small-scale for*, 13 (4): 483-500.
Eriksson, L. (2018). Effects of Policy Measures and Moderating Factors on Climate Change Adaptation Among Private Forest Owners in Sweden. *Soc Nat Res*, 31 (4): 409-423.
Espelien, A. & Jakobsen, E. (2013). *Skog og trenæringen, status og utvikling 2005-2011 [Forestry and the forest sector, status and development 2005-2011]*. MENON-PUBLIKASJON, 18. Oslo: Menon Economics. p. 43.
Ferrando, P. J. & Lorenzo-Seva, U. (2010). Acquiescence as a source of bias and model and person misfit: A theoretical and empirical analysis. *Brit J of Math Stat Psy*, 63 (2): 427-448. doi: https://doi.org/10.1348/000711009X470740.
FSC, F. S. C. (2018). *Om oss [About us]*. Forest Stewardship Council: Forest Stewardship Council. Available at: https://se.fsc.org/se-se (accessed: 16.03 2018).
Gamborg, C. & Larsen, J. B. (2003). 'Back to nature'—a sustainable future for forestry? *For Ecol Manage*, 179 (1-3): 559-571. doi: https://doi.org/10.1016/S0378-1127(02)00553-4.
GFEP, G. F. E. P. o. A. o. F. t. C. C. (2009). *Adaptation of forests and people to climate change – A Global Assessment Report*. World Series vol. 22. Helsinki International Union of Forest Research Organizations (IUFRO).
Grothmann, T. & Patt, A. (2005). Adaptive capacity and human cognition: the process of individual adaptation to climate change. *Glo Environ Change*, 15 (3): 199-213. doi: https://doi.org/10.1016/j.gloenvcha.2005.01.002.
Grotta, A. T., Creighton, J. H., Schnepf, C. & Kantor, S. (2013). Family forest owners and climate change: Understanding, attitudes, and educational needs. *J of For*, 111 (2): 87-93. doi: https://doi.org/10.5849/jof.12-052.
Hanssen-Bauer, I., Drange, H., Førland, E., Roald, L., Børsheim, K., Hisdal, H., Lawrence, D., Nesje, A., Sandven, S., Sorteberg, A., Sundby, S., Vasskog, K. & Ådlandsvik, B. (2009). *Klima i Norge 2100. Bakgrunnsmateriale til NOU Klimatilplassing [Climate in Norway 2100. Background material for the Official Norwegian report on climate adaptation]*. Oslo: Norsk klimasenter [Norwegian climate center].
Hansson, S. O. (2010). Risk: objective or subjective, facts or values. *J of Risk Res*, 13 (2): 231-238. doi: https://doi.org/10.1080/13669870903126226.
Heltorp, K., Kangas, A. & Hoen, H. (2018). Do forest decision-makers in Southeastern Norway adapt forest management to climate change? *Scand J For Res*, 33 (3): 278-290. doi: https://doi.org/10.1080/02827581.2017.1362463.
Hirsch, F. & Schmithüsen, F. J. (2010). Private forest ownership in Europe. *Geneva timber and forest study papers*, 26.
Hoogstra, M. (2008). *Coping with the long term: an empirical analysis of time perspectives, time orientations, and temporal uncertainty in forestry*. Wageningen: Wageningen University.
IPCC, I. P. o. C. C. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. In Core Writing Team, R. K. P. a. L. A. M. e. (ed.). Geneva, Switzerland: Intergovernmental Panel on Climate Change.
Kahan, D., Peters, E., Wittlin, M., Slovic, P., Ouellette, L., Braman, D. & Mandel, G. (2012). The polarizing impact of science literacy and numeracy on perceived climate change risks. *Nat Clim Change*, 2 (10): 732-735.
Kahan, D. M., Jenkins-Smith, H. & Braman, D. (2011). Cultural cognition of scientific consensus. *J Risk Res*, 14 (2): 147-174. doi: https://doi.org/10.1080/13669877.2010.511246.
Keskitalo, E. C. H., Nocentini, S. & Bottalico, F. (2013). Adaptation to climate change in forest management: what role does national context and forest management tradition play? In:

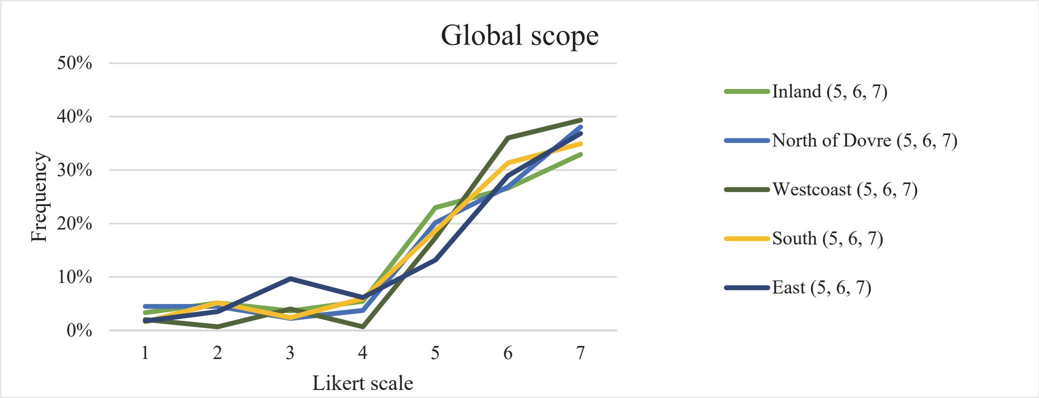
Forest management of Mediterranean forest under the new context of climate change In Lucas-Borja, M. E. (ed.) *Forest management of Mediterranean forest under the new context of climate change*, pp. 149-161. New York: Nova Science Publishers, Inc.
klimatilpasning.no, T. N. C. C. A. P. (2016). *Skogbruk [Forestry]* Offical Webpage klimatilpasning.no: Norwegian Environmental Agency Available at: http://www.klimatilpasning.no/sektorer/landbruk/oppgaver/skogbruk/ (accessed: 10.04 2018).
Koca, D., Smith, B. & Sykes, M. T. (2006). Modelling regional climate change effects on potential natural ecosystems in Sweden. *Clim Chang*, 78 (2-4): 381-406.
Kolström, M., Lindner, M., Vilén, T., Maroschek, M., Seidl, R., Lexer, M. J., Netherer, S., Kremer, A., Delzon, S., Barbati, A., Marchetti, M. & Corona, P. (2011). Reviewing the science and implementation of climate change adaptation measures in European forestry. *Forests*, 2 (4): 961-982.
Krange, O., Kaltenborn, B. P. & Hultman, M. (2019). Cool dudes in Norway: climate change denial among conservative Norwegian men. *Environ Sociol*, 5 (1): 1-11. doi: https://doi.org/10.1080/23251042.2018.1488516.
Kruskal, W. H. & Wallis, W. A. (1952). Use of ranks in one-criterion variance analysis. *J Am Stat Ass*, 47 (260): 583-621.
Kungl. Skogs- och Lantbruksakademien, R. S. A. o. A. a. F. (2015). *Forests and Forestry in Sweden*. Stockholm Royal Swedish Academy of Agriculture and Forestry
Laakkonen, A., Zimmerer, R., Kähkönen, T., Hujala, T., Takala, T. & Tikkanen, J. (2018). Forest owners' attitudes toward pro-climate and climate-responsive forest management. *For Policy Econ*, 87: 1-10. doi: https://doi.org/10.1016/j.forpol.2017.11.001.
Lawrence, A. & Marzano, M. (2014). Is the private forest sector adapting to climate change? A study of forest managers in north Wales. *Ann For Sci*, 71 (2): 291-300. doi: 10.1007/s13595-013-0326-4.
Lidskog, R. & Sjödin, D. (2014). Why do forest owners fail to heed warnings? Conflicting risk evaluations made by the Swedish forest agency and forest owners. *Scand J For Res*, 29 (3): 275-282. doi: https://doi.org/10.1080/02827581.2014.910268.
Lindner, M., Maroschek, M., Netherer, S., Kremer, A., Barbati, A., Garcia-Gonzalo, J., Seidl, R., Delzon, S., Corona, P., Kolström, M., Lexer, M. J. & Marchetti, M. (2010). Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. *For Ecol Manage*, 259 (4): 698-709. doi: https://doi.org/10.1016/j.foreco.2009.09.023.
Lindner, M., Fitzgerald, J., Zimmermann, N., Reyer, C., Delzon, S., van der Maaten, E., Schelhaas, M.-J., Lasch, P., Eggers, J., van der Maaten-Theunissen, M., Suckow, F., Psomas, A., Poulter, B. & Hanewinkel, M. (2014). Climate change and European forests: What do we know, what are the uncertainties, and what are the implications for forest management? *J Environ Manage*, 146: 69-83.
LRF, L. R. T. F. o. S. F. (2013 ). *Skogsägarföreningarna [The forest owners assosiations]*. www.lrf.se: LRF, Lantbrukarnas Riksförbund [The Federation of Swedish Farmers]. Available at: LRF, Lantbrukarnas Riksförbund [The Federation of Swedish Farmers] (accessed: 01.11 2018).
Mann, H. B. & Whitney, D. R. (1947). On a test of whether one of two random variables is stochastically larger than the other. *Ann Math Stat*, 18 (1): 50-60.
Martin, C. L. (1994). The impact of topic interest on mail survey response behaviour. *J Market Res Soc*, 36 (4): 1-11. doi: https://doi.org/10.1177/147078539403600404.
McCright, A. M. & Dunlap, R. E. (2011). Cool dudes: The denial of climate change among conservative white males in the United States. *Glo Environ Change*, 21 (4): 1163-1172. doi: https://doi.org/10.1016/j.gloenvcha.2011.06.003.
Mellanskog. (2017). *Årsredovisning [Annual report]*. Uppsala: Mellanskog.
Milad, M., Schaich, H. & Konold, W. (2013). How is adaptation to climate change reflected in current practice of forest management and conservation? A case study from Germany. *Biodivers Conserv*, 22 (5): 1181-1202.
Millar, C., Stephenson, N. & Stephens, S. (2007). Climate change and forests of the future: Managing in the face of uncertainty. *Ecol Appl*, 17 (8): 2145-2151.

Moser, S. (2010). Communicating climate change: history, challenges, process and future directions. *Wiley Interdisciplinary Reviews: Climate Change*, 1 (1): 31-53. doi: https://doi.org/10.1002/wcc.11.
Moser, S. C. & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *P Natl Acad Sci USA* 107 (51): 22026-22031. doi: 10.1073/pnas.1007887107.
Mostegl, N. M., Pröbstl-Haider, U., Jandl, R. & Haider, W. (2017). Targeting climate change adaptation strategies to small-scale private forest owners *For Policy Econ*, 99: 83-99.
Netherer, S. & Schopf, A. (2010). Potential effects of climate change on insect herbivores in European forests—General aspects and the pine processionary moth as specific example. *For Ecol Manage*, 259 (4): 831-838. doi: https://doi.org/10.1016/j.foreco.2009.07.034.
NIBIO, N. I. o. B. R. (2018). *Nøkkeltall om skog [Keynumbers forests]*. nibio.no Norwegian Institute of Bioeconomy Research. Available at: https://nibio.no/tema/skog/skog-og-miljoinformasjon-fra-landsskogtakseringen/nokkeltall (accessed: 16.03. 2018).
Norges Skogeierforbund, N. F. O. F. (2017). *Om oss (about us)*. skogeier.no: Norges Skogeierforbund [Norwegian Forest Owners' Federation],. Available at: http://www.skogeier.no/om-oss/ (accessed: 18.09 2017).
Norra Skogsägarna, N. f. o. (2018). *Om oss [About us]*. www.norraskogvirke.se: Norra Skogsägarna [Norra forest owners]. Available at: https://www.norraskogvirke.se/om-oss (accessed: 02.11 2018).
Norrskog. (2017). *Årsredovisning 2017 [Annual report 2017]*. Kramfors: Norrskog.
Norskog.no. (2018). *Om oss [About us]*. norskog.no: Norskog Available at: http://norskog.no/om-oss/ (accessed: 16.03 2018).
Nulty, D. D. (2008). The adequacy of response rates to online and paper surveys: what can be done? *Assessment & evaluation in higher education*, 33 (3): 301-314. doi: https://doi.org/10.1080/02602930701293231.
Ogden, A. & Innes, J. (2007). Incorporating climate change adaptation considerations into forest management planning in the boreal forest. *Int For Rev*, 9 (3): 713-733.
PEFC Norway. (2015). *Norwegian PEFC Forest Standard*. PEFC N 02. Oslo: PEFC Norway. p. 31.
PEFC Sweden. (2018). *Om svenska PEFC [About swidish PEFC]*. http://pefc.se/om-svenska-pefc/: Swedish PEFC,. Available at: http://pefc.se/om-svenska-pefc/ (accessed: 16.03 2018).
Pussinen, A., Nabuurs, G.-J., Wieggers, H. J. J., Reinds, G. J., Wamelink, G. W. W., Kros, J., Mol-Dijkstra, J. P. & de Vries, W. (2009). Modelling long-term impacts of environmental change on mid-and high-latitude European forests and options for adaptive forest management. *For Ecol Manage*, 258 (8): 1806-1813. doi: https://doi.org/10.1016/j.foreco.2009.04.007.
Questback. (2017-2018). *Questback* Available at: https://www.questback.com/2017-2018).
R Core Team. (2018 ). *R: A Language and Environment for Statistical Computing*. Vienna, Austria R Foundation for Statistical Computing. Available at: https://www.R-project.org2018 ).
Reyer, C. P. O., Bathgate, S., Blennow, K., Borges, J., Bugmann, H., Delzon, S., Faias, S., Garcia-Gonzalo, J., Gardiner, B., Gonzalez-Olabarria, J. R., Gracia, C., Hernández, J. G., Kellomäki, S., Kramer, K., Lexer, M. J., Lindner, M., van der Maaten, E., Maroschek, M., Muys, B., Nicoll, B., Palahi, M., Palma, J. H. N., Paulo, J. A., Peltola, H., Pukkala, T., Rammer, W., Ray, D., Sabaté, S., Mart-Jan Schelhaas, M.-J., Seidl, R., Temperli, C., Tomé, M., Yousefpour, R., Zimmermann, N. E. & Hanewinkel, M. (2017). Are forest disturbances amplifying or canceling out climate change-induced productivity changes in European forests? *Environ Res Let*, 12 (3): 034027.
Riksskogstaxeringen, S. F. I. (2017). *Forest statistics 2017*. In Fransson, J. (ed.). SKOGSDATA [Forest data]. Umeå: Statistiska centralbyrån/ Riksskogstaxeringen Sveriges Lantbruksuniversitet [Statistics Sweeden/Swedish Forest Inventory Swedish University of Agricultural Sciences].
Schoene, D. & Bernier, P. (2012). Adapting forestry and forests to climate change: A challenge to change the paradigm. *For Policy Econ*, 24 (SI): 12-19.
Simon, H. (1977). The logic of heuristic decision making. In: Models of Discovery. In Boston Studies in the Philosophy of Science, vol. 54 *Models of discovery*, pp. 154-175. Dordrecht, Holland: Springer, Dordrecht.

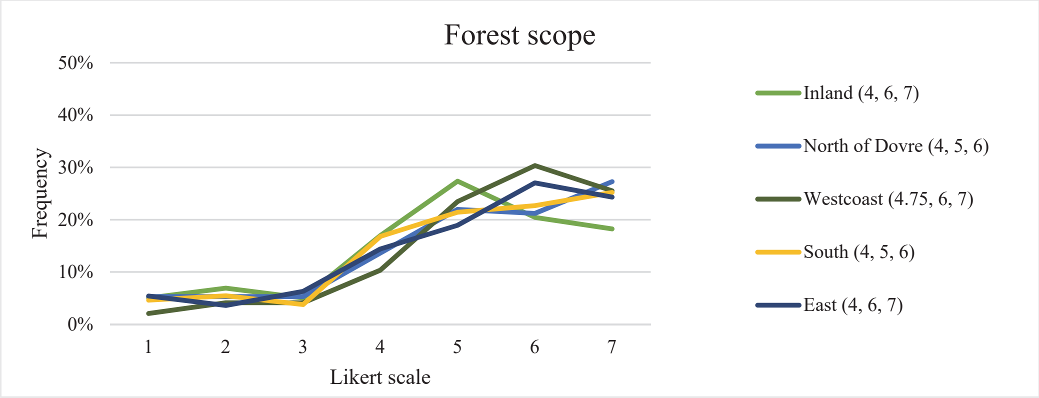
Simon, H. A. (1960). *The new science of management decitions* The Ford Distinguished Lectures. New York Harper and Brothers
Skog Sverige, F. S. (2018 ). *Skogen & ekonomin [Forests and economy]*. skogsverige.se Forests Sweeden Available at: https://www.skogssverige.se/politik-ekonomi/skogen-ekonomin (accessed: 04.04 2018).
Skogbrand, S. f. G. S. i. c. (2014). *Skogbehandling før skogen kommer [forest management before the storm]*. Oslo Skogbrand forsikringselskap Gjensidige [Skogbrand insurance company].
Skogstyrelsen, S. F. A. (2017). *Bruttoavvirkning [Gross harvest]*. In Skogstyrelsen [Swedish Forest Agency] (ed.). https://www.skogsstyrelsen.se/statistik/statistik-efter-amne/bruttoavverkning/: Skogstyrelsen [Swedish Forest Agency]. Available at: https://www.skogsstyrelsen.se/statistik/statistik-efter-amne/bruttoavverkning/ (accessed: 19.06. 2018).
Skogstyrelsen, S. F. A. (2017). *Skogsstyrelsens arbete för ökad klimatanpassning inom skogssektorn, Handlingsplan [The Swedish forest Agencys strategy for promotion of increased climate adaptation in the forest sector, Actionplan]*. RAPPORT Jönköping: Skogstyrelsen [Swedish Forets Agency].
SMHI, S. m. o. h. i. S. M. a. H. I. (2018). *Klimaet [Climate]*. smhi.se: Sveriges meterologiske och hydrologiske institut [Swedish Meteorological and Hydrological Institute]. Available at: https://www.smhi.se/klimat (accessed: 10.04. 2018).
Smit, B. & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Glo Environ Change*, 16 (3): 282-292. doi: https://doi.org/10.1016/j.gloenvcha.2006.03.008.
Sousa-Silva, R., Ponette, Q., Verheyen, K., Van Herzele, A. & Muys, B. (2016). Adaptation of forest management to climate change as perceived by forest owners and managers in Belgium. *For Ecosyst*, 3 (22): 2-11.
Sousa-Silva, R., Verbist, B., Lomba, Â., Valent, P., Suškevičs, M., Picard, O., Hoogstra-Klein, M., Cosofret, V.-C., Bouriaud, L., Ponette, Q., Verheyen, K. & B, M. (2018). Adapting forest management to climate change in Europe: Linking perceptions to adaptive responses. *For Policy Econ*, 90: 22-30. doi: https://doi.org/10.1016/j.forpol.2018.01.004.
Spittlehouse, D. & Stewart, R. (2004). Adaptation to climate change in forest management. *BC J Ecosyst Manag*, 4 (1): 1-11.
Statistics Norway. (2015a). *Befolkningens utdanningsnivå, 1 oktober 2014 [Level of education in the population, Octorber 1st 2014],* . ssb.no: Central Bureau of Statistics Norway. Available at: http://www.ssb.no/en/jord-skog-jakt-og-fiskeri/statistikker/stskog/aar/2015-09-22?fane=om#content (accessed: 20.05 2018).
Statistics Norway. (2015b). *Forest properties, 2014*. Public Webpage In Norway, C. B. o. S. (ed.). Agriculture, forestry, hunting and fishing. Forestry, Structural statistics. ssb.no: Central Bureau of Statistics Norway. Available at: http://www.ssb.no/en/jord-skog-jakt-og-fiskeri/statistikker/stskog/aar/2015-09-22?fane=om#content (accessed: 01.06. 2018).
Statistics Norway. (2016). *Commercial roundwood removals, 2016, quarterly preliminary figures*. Internet. In Norway, C. B. o. S. (ed.). Agriculture, forestry, hunting and fishing, Commercial roundwood removals. ssb.no: Central Bureau of Statistics Norway. Available at: https://www.ssb.no/en/jord-skog-jakt-og-fiskeri/statistikker/skogav/kvartal (accessed: 01.11. 2016).
Statistics Norway. (2017). *Skogeiendommer [Forest holdings]*. In ssb.no (ed.). ssb.no: Central Bureau of Statistics Norway. Available at: https://www.ssb.no/jord-skog-jakt-og-fiskeri/statistikker/stskog (accessed: 16.03 2018).
Statistics Norway. (2019). *10613: Skogeiendommer og skogareal, etter eierkategori 2013 - 2017 [forest holdings and forested area, after ownership categories]*. In Norway, C. B. o. S. (ed.). ssb.no: Central Bureau of Statistics Norway,. Available at: https://www.ssb.no/statbank/table/10613/ (accessed: 26.07 2019).
Statistics Sweden. (2014). *Skogsstatistisk årsbok 2014 [Swedish Statistical Yearbook of Forestry],*. In Christiansen, L. & Skogsstyrelsen [Swedish Forest Agency] (eds). Skogsstatistisk årsbok [Swedish Statistical Yearbook of Forestry]. Jönköping: Skogstyrelsen [Swedish Forest Agency] Official Statistics of Sweden

Stortinget, T. N. P. (2015). *Statsbudsjettet 2016 [State budget 2016]*. Stortingets administrasjon, K. a. P. a., Constitutional Department]. Oslo: Stortingets administrasjon, Konstitusjonell avdeling [Parliament administration, Constitutional Department].
Størdal, S., Lien, G. & Hardaker, J. B. (2007). Perceived risk sources and strategies to cope with risk among forest owners with and without off-property work in eastern Norway. *Scand J For Res*, 22 (5): 443-453. doi: https://doi.org/10.1080/02827580701553701.
Subramanian, N., Bergh, J., Johansson, U., Nilsson, U. & Sallnäs, O. (2015). Adaptation of forest management regimes in southern Sweden to increased risks associated with climate change. *Forests*, 7 (1): 18. doi: https://doi.org/10.3390/f7010008.
Sweden, S. (2018). *Var fjärde i Sverige är högutbildad [every forth Swede have higher education]*. scb.se: Statistics Sweeden. Available at: https://www.scb.se/hitta-statistik/sverige-i-siffror/utbildning-jobb-och-pengar/befolkningens-utbildning (accessed: 30.05 2018).
Södra. (2017). *Årsredovisning och hållbarhetsredovisning 2017 [Annual Report and Sustainability Report]*. Skogsudden, 351 89 Växjö: Södra.
Søgaard, G., Astrup, R., Allen, M., Andreassen, K., Bergseng, E., Fløistad, I., Hanssen, K., Hietala, A., Kvaalen, H. & Solberg, S. (2017). *Skogbehandling for verdiproduksjon i et klima i endring [Forest management for value production in a changing climate]*. NIBIO Rapport, 2464-1162. ÅS: NIBIO.
TNS political & social. (2017). *Special Eurobarometer 459 Climate Change*. In TNS political & social (ed.): European Commission,Directorate-General for Climate Action and co-ordinated by the Directorate-General for Communication.
Tveite , B. (1976). *Bonitetskurver for furu (Pinus Sylvestris) [Site-indexes for Scots pine (Pinus Sylvestris)]*. Ås, Internal report. : Norwegian Forest Research Institute.
Tveite, B. (1977). *Bonitetskurver for gran (Picea abies (L.) Karst) [Site-index curves for Norway spruce (Picea abies (L.) Karst)]*: Norsk Inst. for Skogforskning.
Tveito, O. E. (2014). *Klimaendringer og betydning for skogbruket [Climate change impacts on forestry]*. MET reports Oslo Norwegian Meteorological Institute
Uggla, Y. & Lidskog, R. (2016). Climate risks and forest practices: forest owners' acceptance of advice concerning climate change. *Scand J For Res*, 31 (6): 618-625. doi: https://doi.org/10.1080/02827581.2015.1134648.
van Gameren, V. & Zaccai, E. (2015). Private forest owners facing climate change in Wallonia: Adaptive capacity and practices. *Environ Sci Policy*, 52: 51-60. doi: https://doi.org/10.1016/j.envsci.2015.05.004.
Vulturius, G., André, K., Swartling, Å. G., Brown, C., Rounsevell, M. D. A., Jönsson, A. M. & Blanco, V. (2018). The relative importance of subjective and structural factors for individual adaptation to climate change by forest owners in Sweden. *Reg Environ Chang*, 18 (5): 1517-1571. doi: https://doi.org/10.1007/s10113-017-1218-1
Weber, E. U. (1997). Perception and expectation of climate change: precondition for economic and technological adaptation. In Max Bazerman, David Messick, Ann Tenbrunsel & Wade-Benzoni, K. (eds) *Psychological Perspectives to Environmental and Ethical Issues in Management*, pp. 314-341. San Francisco, CA Jossey-Bass.
Yousefpour, R. & Hanewinkel, M. (2015). Forestry professionals' perceptions of climate change, impacts and adaptation strategies for forests in south-west Germany. *Clim Chang*, 130 (2): 273-286. doi: 10.1007/s10584-015-1330-5.

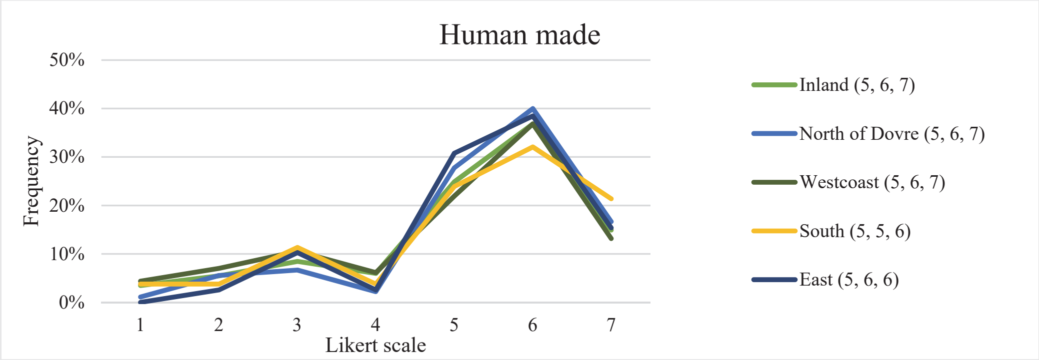
# Supplementary material




*Inland n=330, mean=5.84, SD=1.39, North of Dovre n=136, mean=5.45, SD=1.67, Westcoast n=150, mean=5.72, SD=1.49, South n=251, mean=5.48, SD= 1.56, East n=111, mean=5.70, SD=1.44*

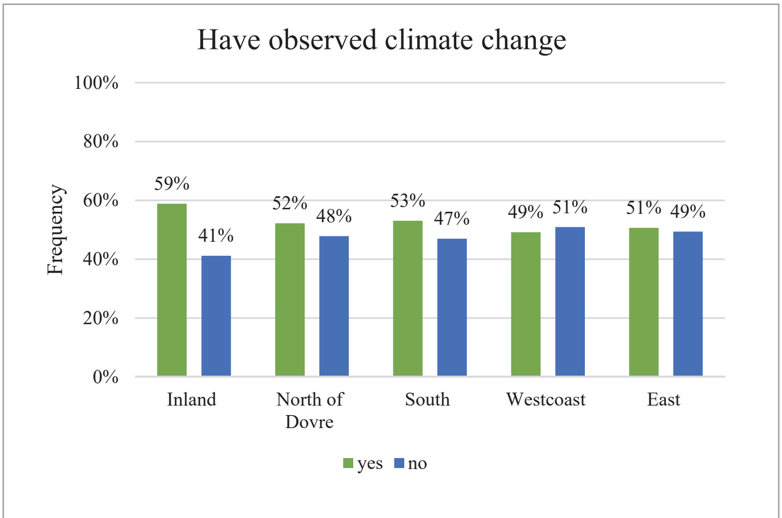



*Inland n=317, mean=5.29, SD=1.59, North of Dovre n=132, mean=4.73, Westcoast n=144, mean=5.31, SD=1.58 South n=241, mean=4.90, SD=1.75 , East n=107, mean=5.24, SD=1.58*



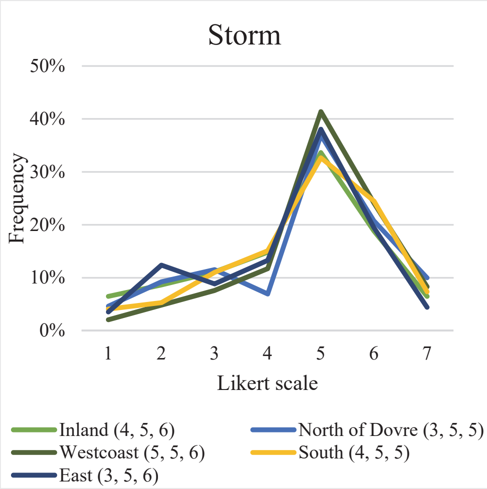

*Inland n=229, mean=5.25, SD=1.56, North of Dovre n=78, mean=5.06, SD=1.80, Westcoast n=107, mean=5.15, SD=1.47, South n=153, mean=5.18, SD=1.44, East n=75, mean=5.33, SD=1.33*

*Figure 1 Respondents from five regional groups replies to the statements: "The climate is changing …" i. "Globally", ii. "At my forest holding" and "I believe that climate change is fully or partly human-made". The 1st, 2nd and 3rd quartiles for each variable is enclosed in parenthesis in the legends.*

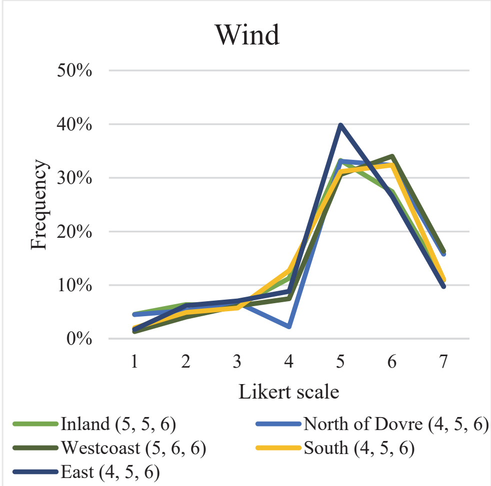



*Inland: n=233, North of Dovre: n=79, Westcoast: n=108, South: n=160, East: n=75*

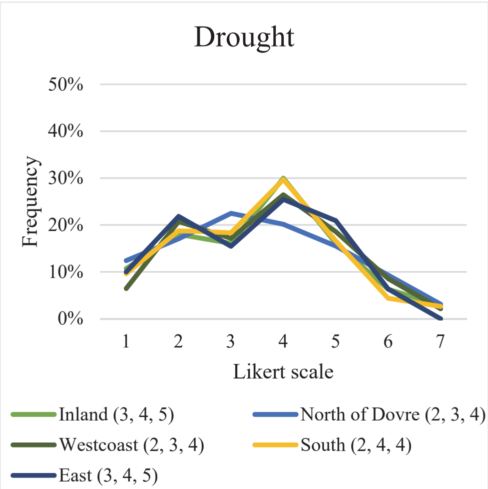
*Figure 2 Proportions of respondents from five regional groups having observed or experienced climate changing at their holding out of those agreeing that the climate is changing shown in contrast.*



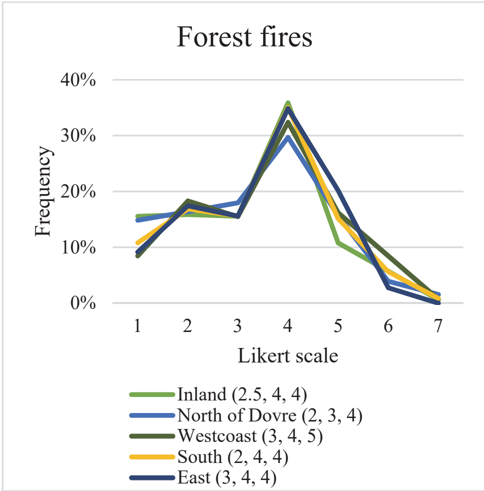

*Inland: n=318, mean=4.65, SD=1.44*
*North of Dovre: n=133, mean=4.48, SD=1.49*
*Westcoast: n=149, mean=4.99, SD=1.39*
*South: n=245, mean=4.36, SD=1.67*
*East: n=109, mean=4.56. SD=1.47*




*Inland: n=323, mean=5.15, SD=1.40*
*North of Dovre: n=133, mean=4.48, SD=1.39*
*Westcoast: n=146, mean=5.29, SD=1.39*
*South: n=250, mean=4.87, SD=1.59*
*East: n=111, mean=4.99, SD=1.42*

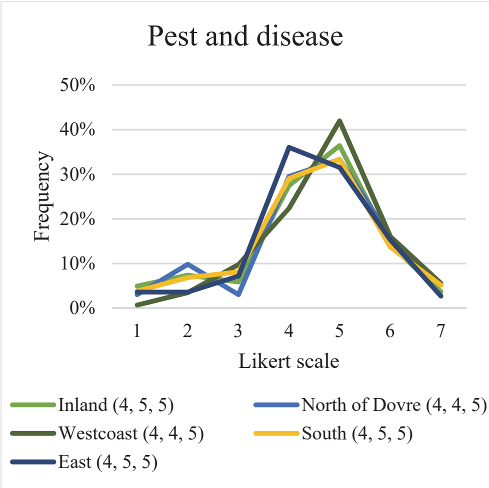



*Inland: n=311, mean=3.66, SD=1.49*
*North of Dovre: n=131, mean=3.08, SD=1.42*
*Westcoast: n=135, mean=3.04, SD=1.44*
*South: n=242, mean=3.60, SD=1.50*
*East: n=103, mean=4.14, SD=1.42*

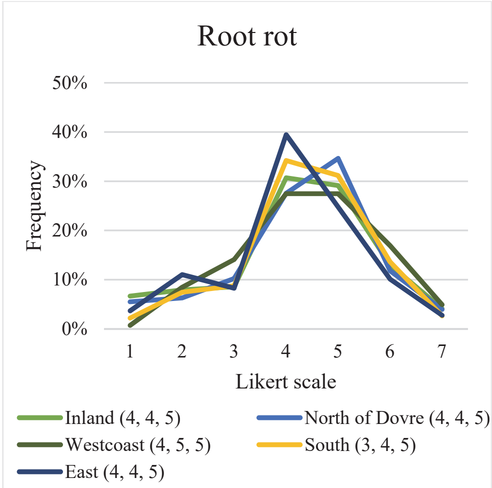



*Inland: n=311, mean=3.53, SD=1.36.*
*North of Dovre: n=130, mean=2.95, SD=1.38*
*Westcoast: n=134, mean=3.09, SD=1.37*
*South: n=243, mean=3.53, SD=1.52*
*East: n=104, mean=3.68, SD=1.26*

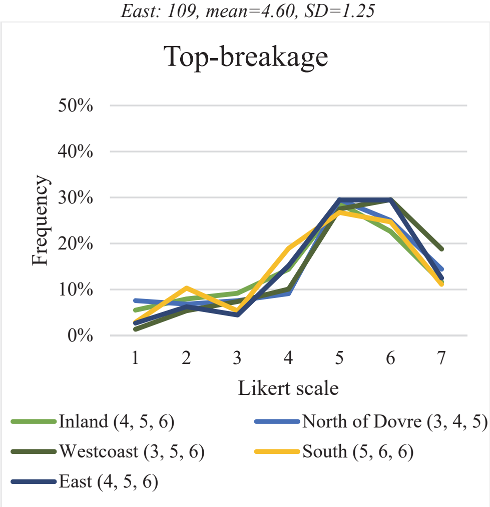
*Figure 3 Respondents from five regional groups replies to the statements: "I believe that the projected climate change will increase damages in my forest" – for four risk elements. The 1st, 2nd and 3rd quartiles for each variable is enclosed in parenthesis in the legends.*



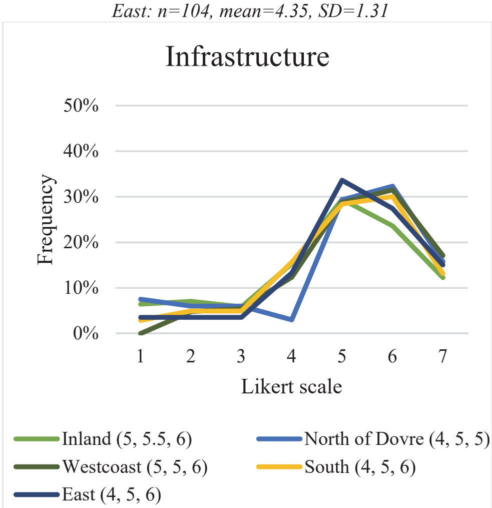

*Inland: n=317, mean = 4.69, SD=1.23.*
*North of Dovre: n=134, mean=4.32, SD=1.31*
*Westcoast: n=137, mean=4.32, SD=1.29*
*South: n=244, mean=4.31, SD=1.47*
*East: 109, mean=4.60, SD=1.25*




*Inland: n=310, mean=4.33, SD=1.32*
*North of Dovre: n=130, mean=4.29, SD=1.36*
*Westcoast: n=135, mean=4.45, SD=1.31*
*South: n=240, mean=4.12, SD=1.46*
*East: n=104, mean=4.35, SD=1.31*

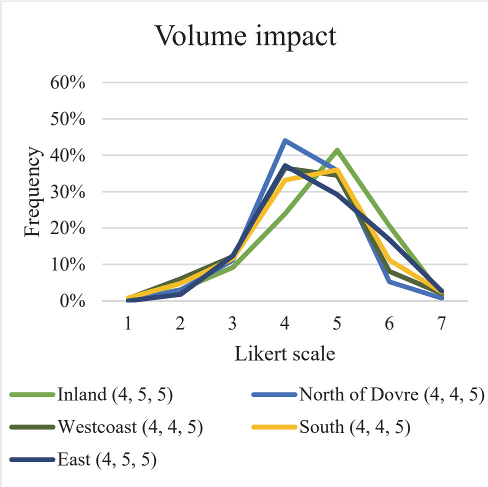



*Inland: n=328, mean=5.13, SD=1.45*
*North of Dovre, n=132, mean=4.12, SD=1.53*
*Westcoast: n=140, mean=4.39, SD=1.64*
*South: n=252 mean=5.20, SD=1.65*
*East: n=108, mean=4.81, SD=1.43*

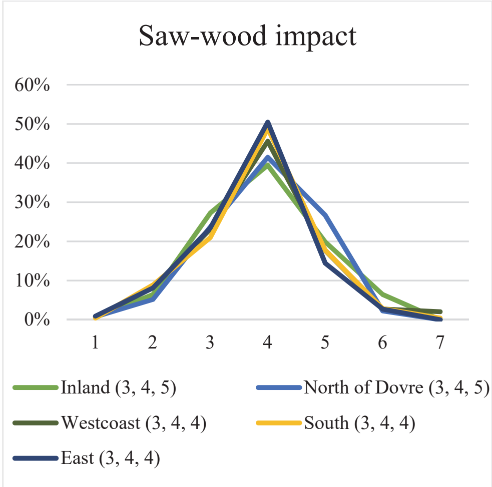



*Inland: n=324, mean=5.21, SD=1.45*
*North of Dovre n=135, mean=4.40, SD=1.59*
*Westcoast: n=143, mean=5.11, SD=1.42*
*South: n=248, mean=4.91, SD=1.63*
*East: n=108, mean=4.93, SD=1.52*

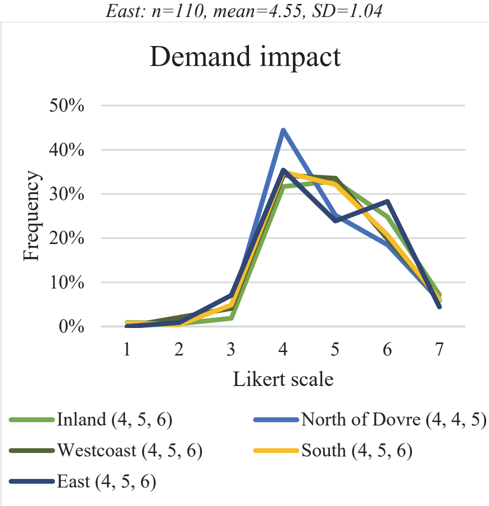
*Figure 4 Respondents from five regional groups replies to the statements: "I believe that the projected climate change will increase damages in my forest" – for four risk elements. The 1st, 2nd and 3rd quartiles for each variable is enclosed in parenthesis in the legends.*



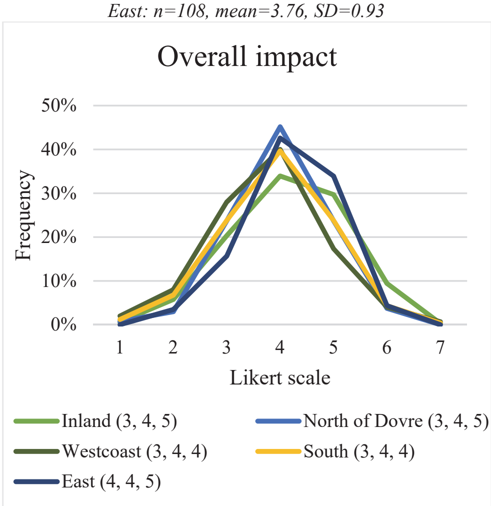

*Inland: n=326, mean=4.70, SD=1.05*
*North of Dovre: n=134, mean=4.31, SD=0.87*
*Westcoast: n=138, mean=4.32, SD=1.06*
*South: n=250, mean=4.30, SD=1.11*
*East: n=110, mean=4.55, SD=1.04*




*Inland: n=327, mean=3.90, SD=1.01*
*North of Dovre: n=135, mean=3.94, SD=0.92*
*Westcoast: n=147, mean=3.87, SD=1.03*
*South: n=248, mean=3.80, SD=0.90*
*East: n=108, mean=3.76, SD=0.93*

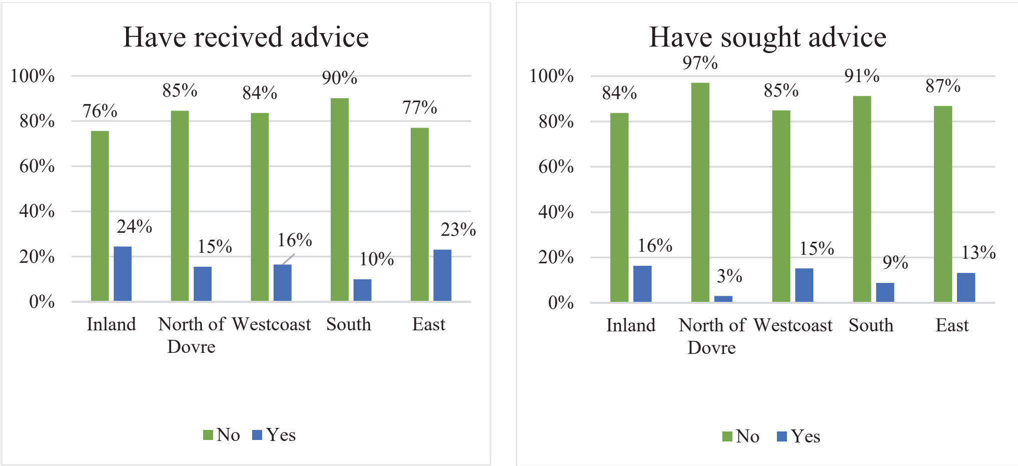



*Inland: n=322, mean=4.98, SD=1.06*
*North of Dovre: n=135, mean=4.72, SD=1.05*
*Westcoast: n=146, mean=4.83, SD=1.05*
*South: n=246, mean=4.83, SD=1.06*
*East: n=110, mean=4.86, SD=1.07*




*Inland: n=330, mean=4.15, SD=1.07*
*North of Dovre: n=135, mean=3.99, SD=0.89*
*Westcoast: n=150, mean=3.77, SD=1.05*
*South: n=252, mean=3.92, SD=1*
*East: n=112, mean=4.21, SD=0.86*

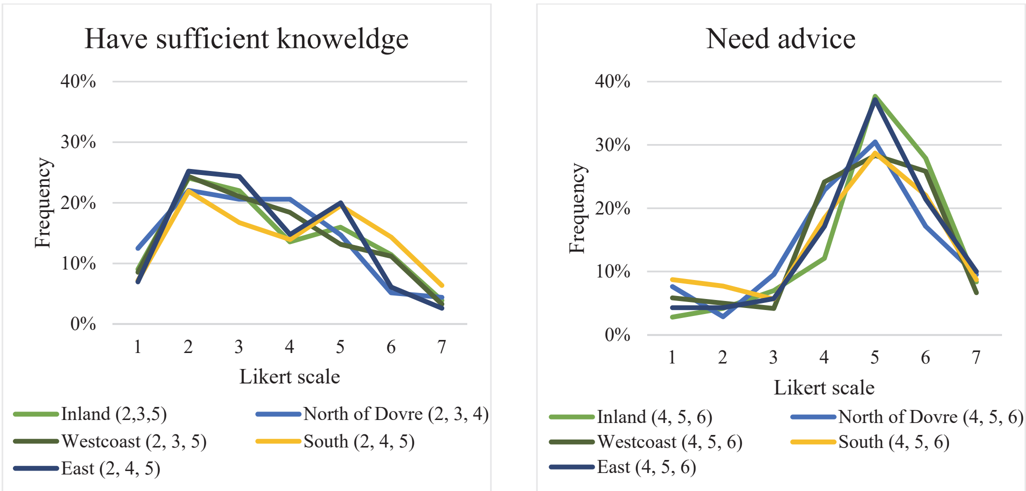
*Figure 5: Respondents from five regional groups replies to the statements: «I believe the predicted climate changes will influence …" i. "the volume-growth in my forest , ii. "the quality growth in my forest (i.e. the saw log proportion)" iii. "the roundwood demand , and "I believe the predicted climate changes will influence the income-potential and value of my forest holding". The 1st 2nd and 3rd quartiles for each variable is enclosed in parenthesis in legends.*




*Inland: n=332, North of Dovre: n=136, Westcoast: n=152, South: n=253, East: n=85*

*Inland: n=332, North of Dovre: n=135, Westcoast: n=152, South: n=251, East: n=111*

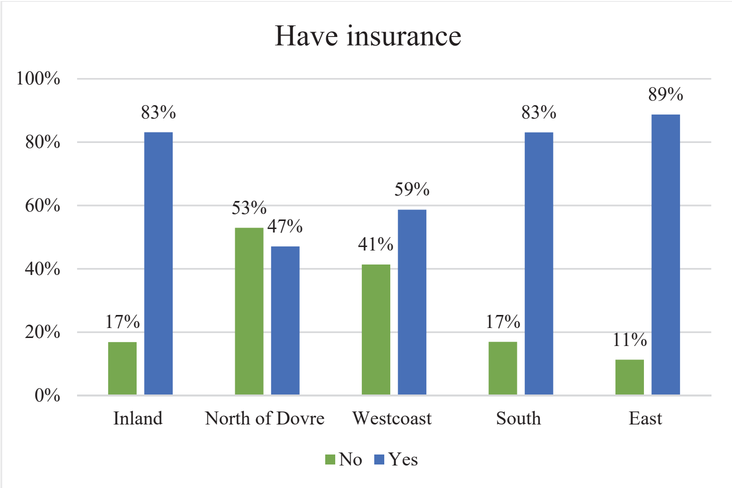
*Figure 6 Proportion of respondents from five regional groups having sought and received advice about adaptive forest management shown in contrast.*




*Inland: n=332, mean=3.53, SD=1.65*
*North of Dovre: n=136, mean=3.36, SD=1.59*
*Westcoast: n=152, mean=3.50, SD=1.60*
*South: n=251, mean=3.85, SD=1.73*
*East: n=112, mean=3.63, SD=1.47*

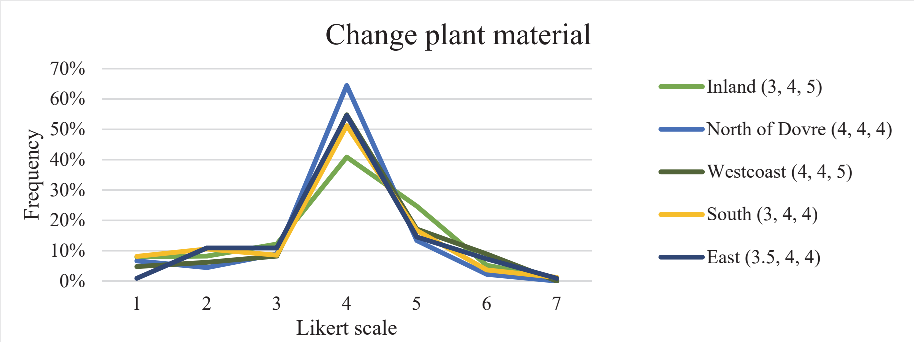
*Inland: n=215, mean=4.94, SD=1.35*
*North of Dovre: n=105, mean=4.55, SD=1.56*
*Westcoast: n=120, mean=4.68, SD=1.48*
*South: n=195, mean=4.51, SD=1.68*
*East: n=69, mean=4.85, SD=1.43*

*Figure 7 Respondents from five regional groups replies to the statements: "I have the knowledge I need about adaptive forestry" and "I need advice and recommendations about adaptive forestry". The 1st 2nd and 3rd quartiles for each variable is enclosed in parenthesis in legends.*

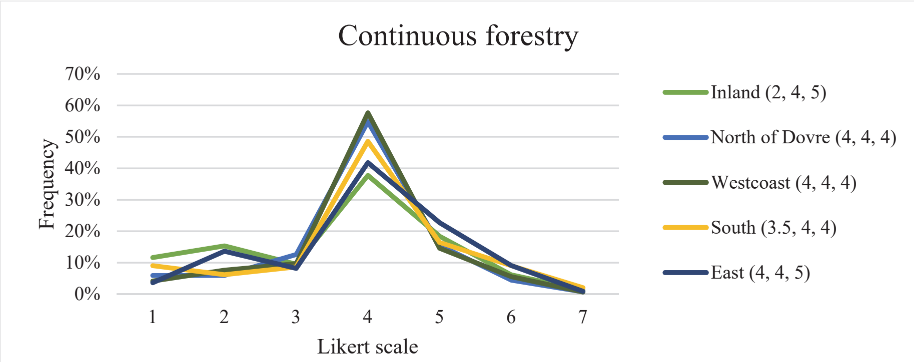



*Inland: n=322, North of Dovre: n=136, Westcoast: n=150, South: n=254, East: n=112*

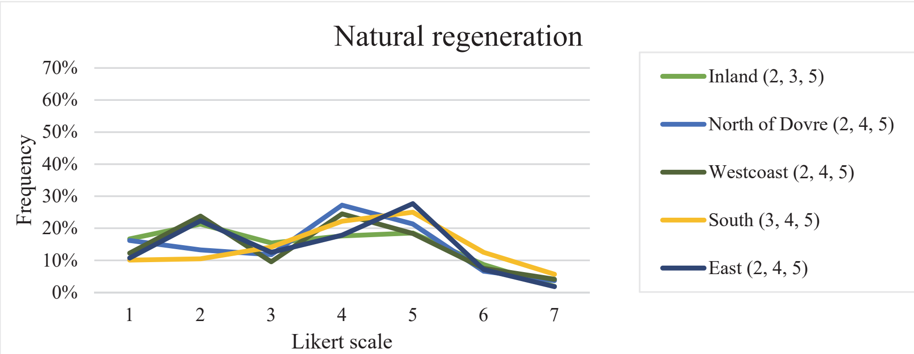
*Figure 8 Proportion of five regional groups having taken out insurance shown in contrast.*




*Inland: n=328, mean=3.85, SD=1.29, North of Dovre: n=135, mean=3.80, SD=1.02, Westcoast: n=146 mean=3.7, SD=1.26, South: n=246, mean=3.74, SD=1.26, East: n=108, mean=3.98, SD=1.06*

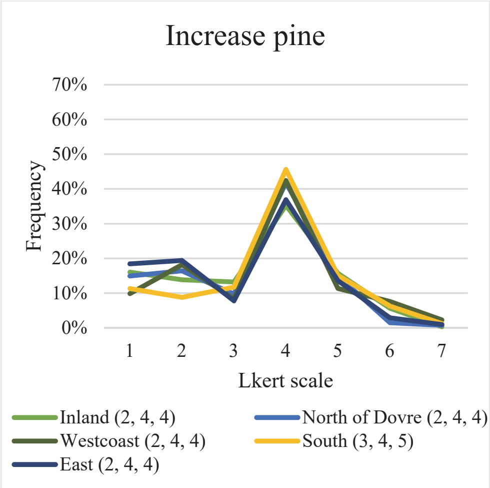



*Inland: n=326, mean=3.59, SD=1.45, North of Dovre: n=135, mean=3.84, SD=1.12, Westcoast: n=144, mean=3.9, SD=1.09, South: n=243, mean=3.92, SD=1.36, East: n=108, mean=3.99, SD=1.27*

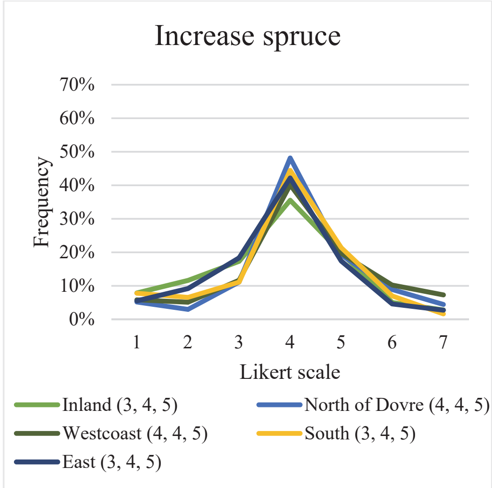



*Inland: n=324, mean=3.33, SD=1.66, North of Dovre: n=136, mean=3.58, SD=1.65, Westcoast: n=147, mean=3.51, SD=1.66, South: n=248,, mean=4.01, SD=1.65, East: n=109, mean=3.58, SD=1.58*

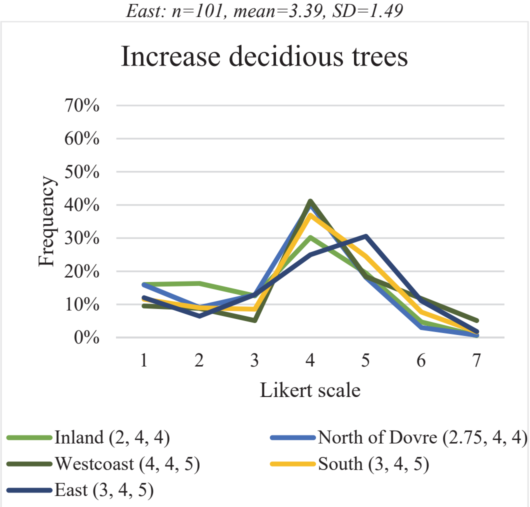
*Figure 9 Respondents from five regional groups replies to the statements: "To adapt my forest to climate change I will consider …" i. "choosing plant material from lower provenances", ii. "turn from even-aged stands to continuous cover forestry", iii. "turn from planting to natural regeneration rotation". ". The 1st 2nd and 3rd quartiles for each variable is enclosed in parenthesis in legends.*



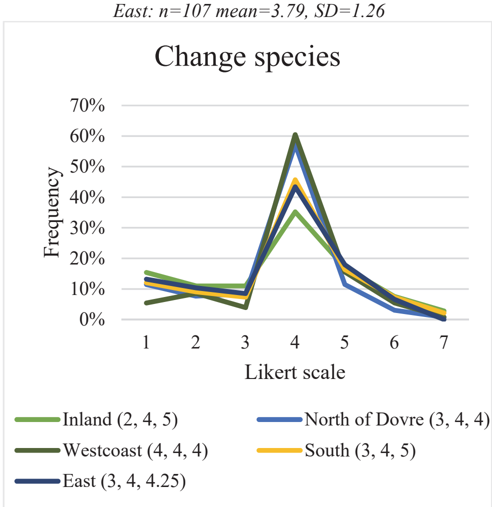

*Inland: n=318, mean=3.38, SD=1.47*
*North of Dovre: n=134, mean=3.32, SD=1.38*
*Westcoast: n=132, mean=3.59, SD=1.46*
*South: n=239, mean=3.68, SD=1.38*
*East: n=101, mean=3.39, SD=1.49*




*Inland: n=318, mean=3.74, SD=1.39*
*North of Dovre: n=135, mean=4.77, SD=1.26*
*Westcoast: n=137, mean=4.22, SD=1.43*
*South: n=243, mean=3.92, SD=1.31*
*East: n=107 mean=3.79, SD=1.26*

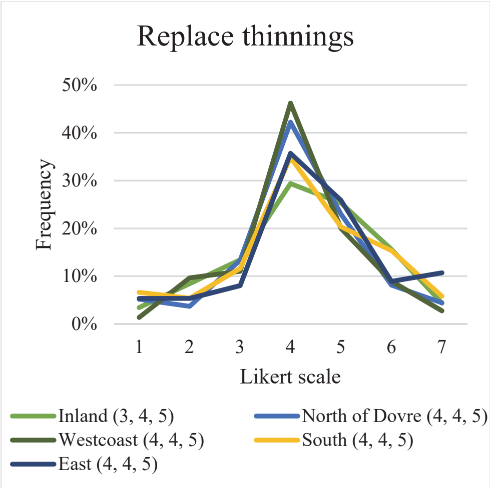



*Inland: n=318, n=3.37, SD=1.50*
*North of Dovre: n=132, mean=3.47, SD=1.42*
*Westcoast: n=136, mean=4.05, SD=1.54*
*South: n=233, mean=3.82, SD=1.47*
*East: n=106, mean=4, SD=1.53*

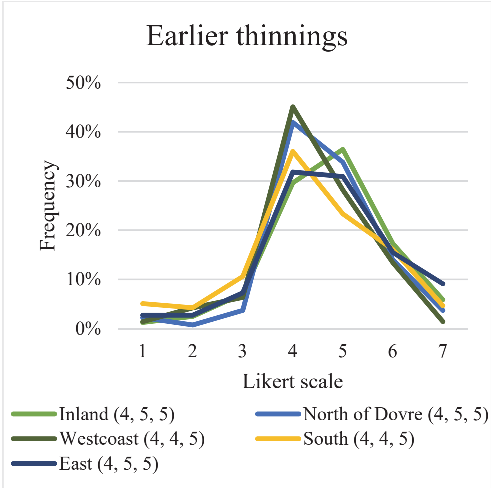



*Inland: n=318, mean=3.61, SD=1.58*
*North of Dovre: n=131, mean=3.61, SD=1.25*
*Westcoast: n=129, mean=3.91, SD=1.14*
*South: n=1232, mean=3.75, SD=1.45*
*East: n=103, mean=3.65, SD=1.36*

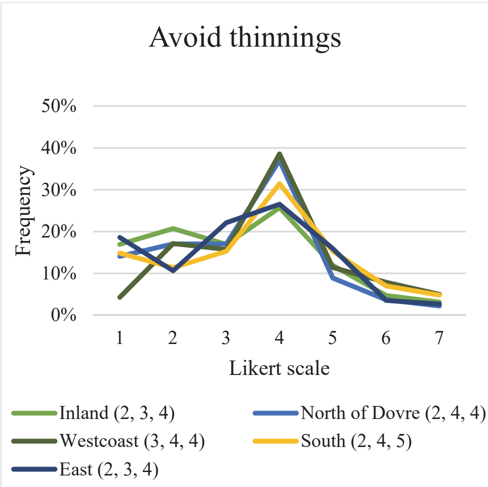
*Figure 10 Respondents from five regional groups replies to the statements: "In order to adapt my forest to climate change I will consider …" i. "increasing the share of pine", ii. "increasing the share of spruce", iii. "increasing the share of deciduous trees", iv. "change dominating tree species in some stands". ". The 1st 2nd and 3rd quartiles for each variable is enclosed in parenthesis in legends*



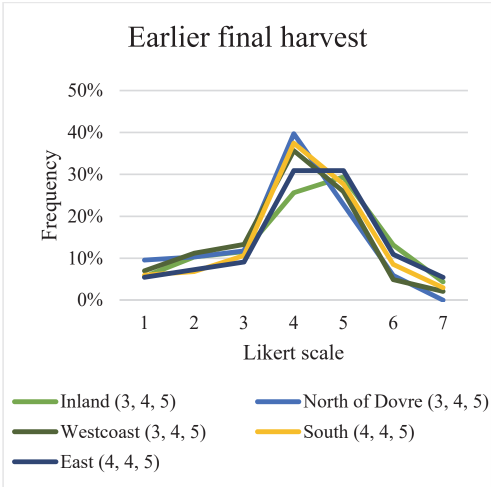

*Inland: n=320, mean=4.29, SD=1.40*
*North of Dovre: n=135, mean=4.16, SD=1.29*
*Westcoast: n=145, mean=4.11, SD=1.18*
*South: n=241, mean=4.26, SD=1.48*
*East: n=109, mean=4.43, SD=1.46*




*Inland: n=324, mean=4.78, SD=1.15*
*North of Dovre: n=136, mean=4.61, SD=1.05*
*Westcoast: n=142, mean=4.40, SD=1.06*
*South: n=236, mean=4.35,, SD=1.38*
*East: n=107, mean=4.68, SD=1.32*

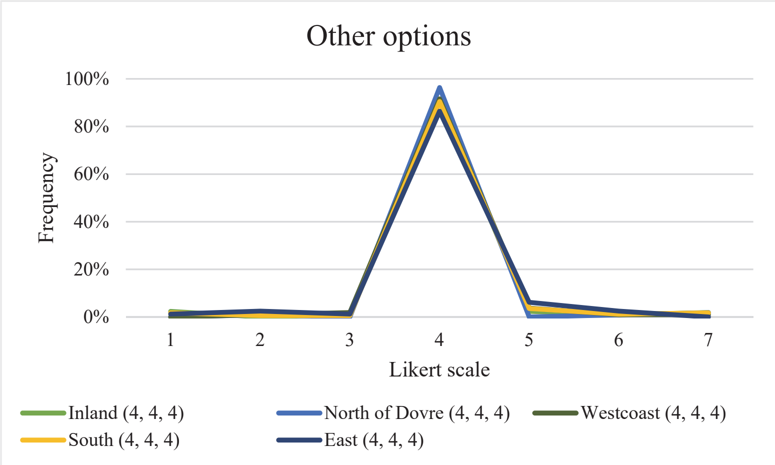



*Inland: n=319, mean=3.21, SD=1.57*
*North of Dovre: n=135, mean=3.29, SD 1.43*
*Westcoast: n=140, mean=3.79, SD=1.43*
*South: n=229, mean=3.61, SD=1.63*
*East: n=110, mean=3.28, SD=1.55*



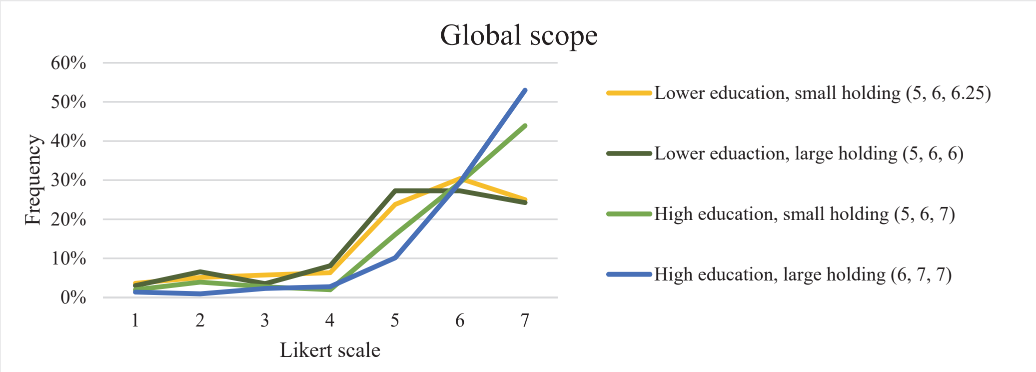

*Inland: n=320, mean=4.19, SD=1.48*
*North of Dovre: n=136, mean=3.73, SD=1.33*
*Westcoast: n=143, mean=3.85, SD=1.35*
*South: n=235, mean=4.04, SD=1.33*
*East: n=107, mean=4.24, SD=1.39*

*Figure 11 Respondents from five regional groups replies to the statements: "In order to reduce risks relate to climate change, I will consider …" i. "comprehensive young growth tending as replacement for thinnings", ii. "when conducting thinnings, thin earlier in the iii. "avoid thinnings", iv. "earlier final harvest", v. "other options". The 1st 2nd and 3rd quartile is enclosed in parenthesis in legends."*

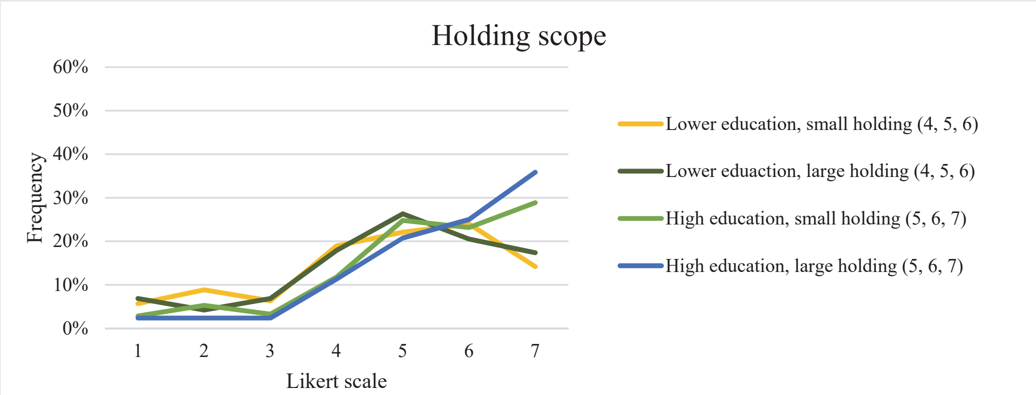



*Inland: n=213, mean=4.01, SD=0.67 , North of Dovre: n=110, mean=4.05, SD= 0.48, Westcoast: n=107, mean=4.04, SD=0.46, South: n=168, mean=4.04, SD=0.65 , East: n=79, mean=4.03, SD=0.58*

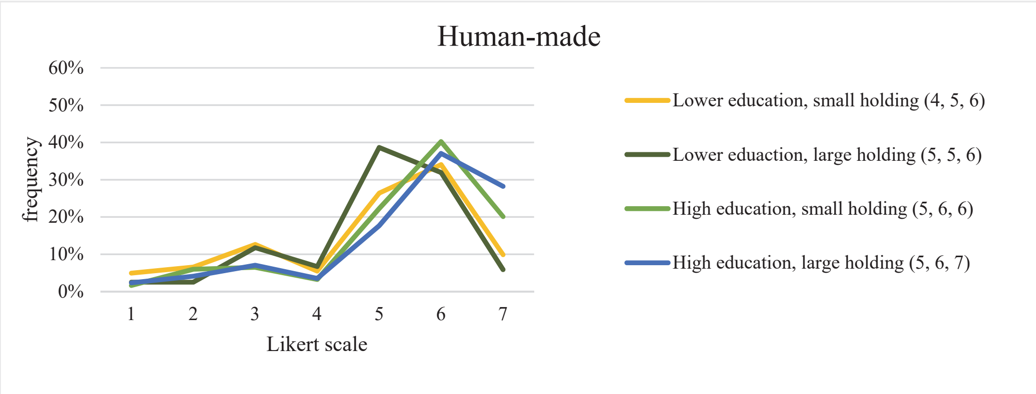
*Figure 12 Respondents from five regional groups replies to the statements: "In order to reduce risks relate to climate change, I will consider other options". 1st 2nd and 3rd quartiles for each variable is enclosed in parenthesis in legends.*




*Low education, small holding: n=332, mean=5.32, SD=1.59, Low education, large holding: n=198, mean=5.28, SD=1.57*
*High education, small holding: n=255, mean=5.90, SD=1.42, High education, large holding: n=217, mean=6.19, SD=1.18*

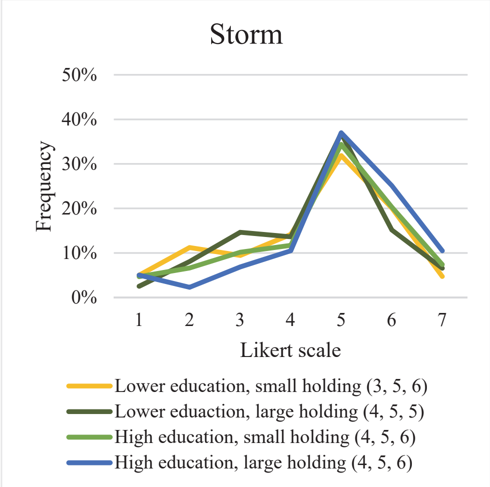



*Low education, small holding: n=317, mean=4.71, SD=1.69, Low education, large holding: n=190, mean=4.38, SD=1.67*
*High education, small holding: n=246, mean=5.35, SD=1.56, High education, large holding: n=212, mean=5.64, SD=1.44*

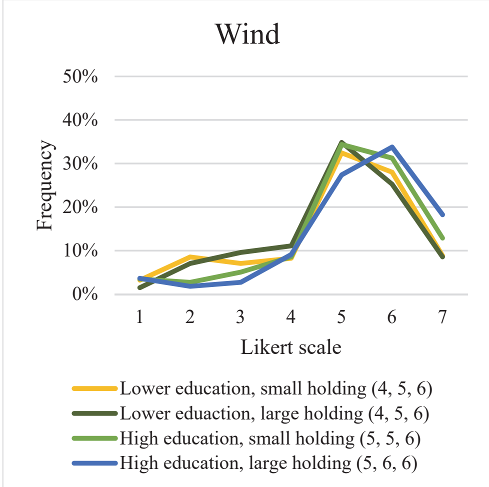



*Low education, small holding: n=182, mean=4.83, SD=1.63, Low education, large holding: n=119, mean=4.95, SD=1.31.*
*High education, small holding: n=184, mean=5.39, SD=1.46, High education, large holding: n=170, mean=5.54, SD=1,51*

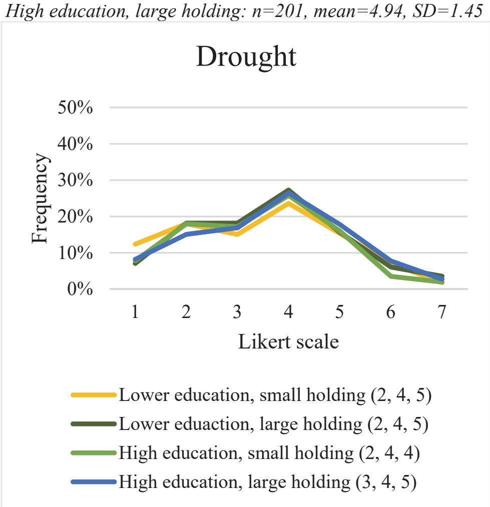
*Figure 13 Four groups based on level of education (higher education or not) and holding size (more or less than 100 hectares) replies to the statements: "The climate is changing ..." i. "Globally", ii. "At my forest holding" and "I believe that climate change is fully or partly human-made". The 1st, 2nd and 3rd quartiles for each variable is enclosed in parenthesis in the legends.*



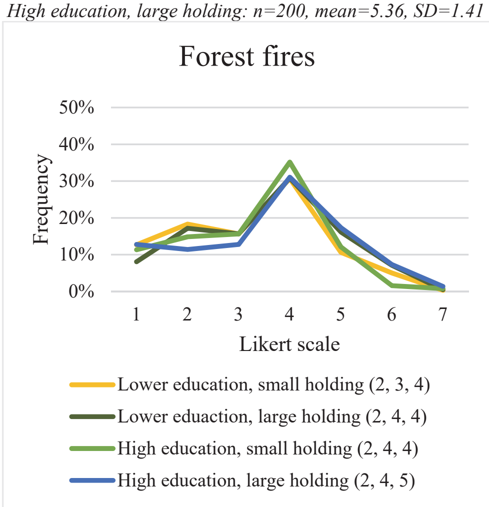

*Low education, small holding: n=327, mean=4.40, SD=1.57*
*Low education, large holding: n=193, mean=4.59, SD=1.44*
*High education, small holding: n=241, mean=4.62, SD=1.53*
*High education, large holding: n=201, mean=4.94, SD=1.45*




*Low education, small holding: n=327, mean=4.84, SD=1.53*
*Low education, large holding: n=194, mean=4.95, SD=1.34*
*High education, small holding: n=252, mean=5.16, SD=1.39*
*High education, large holding: n=200, mean=5.36, SD=1.41*

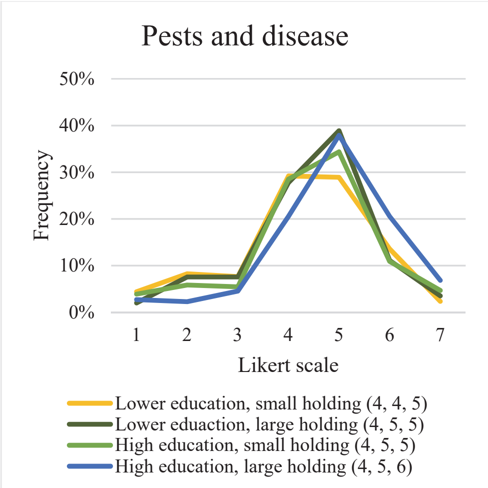



*Low education, small holding: n=316, mean=3.42, SD=1.56*
*Low education, large holding: n=190, mean=3.61, SD=1.48*
*High education, small holding: n=231, mean=3.47, SD=1.42*
*High education, large holding: n=208, mean=3.68, SD=1.50*

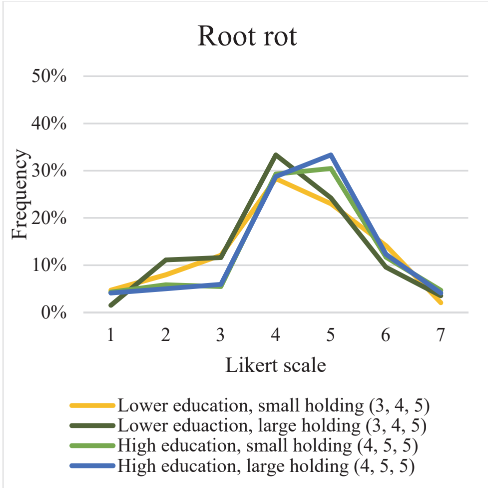



*Low education, small holding: n=316, mean=3.26, SD=1.41*
*Low education, large holding: n=189, mean=3.55, SD=1.40*
*High education, small holding: n=234, mean=3.25, SD=1.32*
*High education, large holding: n=206, mean=3.59. SD=1.52*

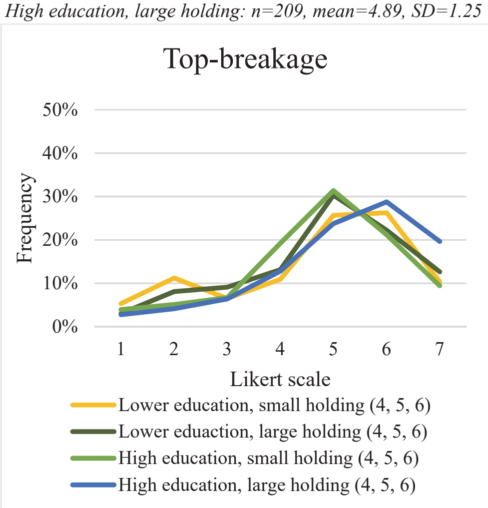
*Figure 14 Four groups based on level of education (higher education or not) and holding size (more or less than 100 hectares) replies to the statements: "I believe that the projected climate change will increase damages in my forest" – for four risk elements. The 1st, 2nd and 3rd quartiles for each variable is enclosed in parenthesis in the legends.*



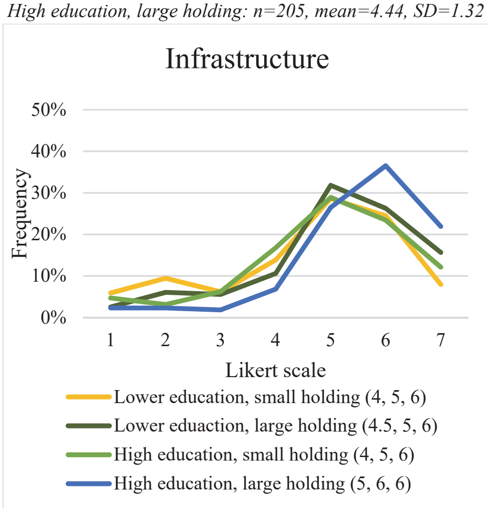

*Low education, small holding: n=320, mean=4.27, SD=1.37*
*Low education, large holding: n=195, mean=4.43, SD=1.24*
*High education, small holding: n=240, mean=4.44, SD=1.33*
*High education, large holding: n=209, mean=4.89, SD=1.25*




*Low education, small holding: n=313, mean=4.16, SD=1.40*
*Low education, large holding: n=188, mean=4.16, SD=1.30*
*High education, small holding: n=235, mean=4.41, SD=1.36*
*High education, large holding: n=205, mean=4.44, SD=1.32*

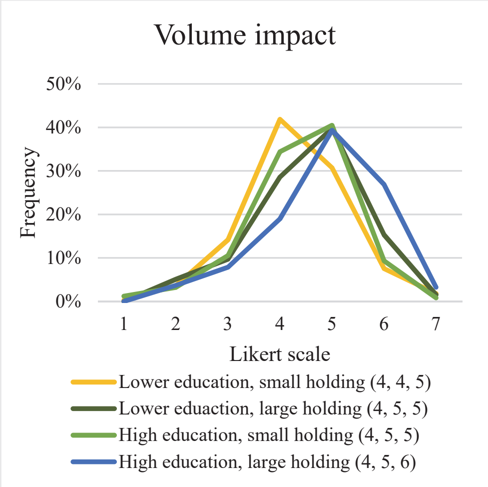



*Low education, small holding: n=326, mean=4.66, SD=1.70*
*Low education, large holding: n=195, mean=4.79, SD=1.56*
*High education, small holding: n=247, mean=4.75, SD=1.46*
*High education, large holding: n=215, mean=5.19, SD=1.50*

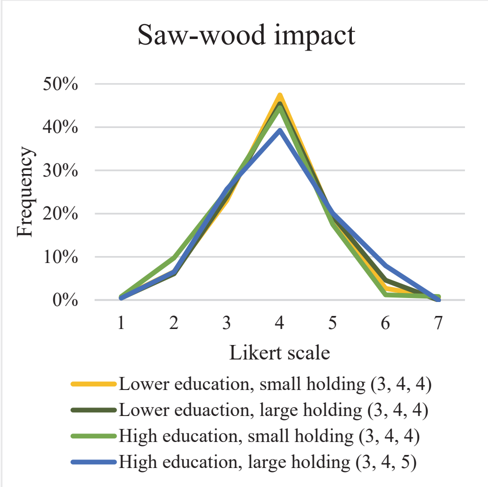



*Low education, small holding: n=327, mean=4.60, SD=1.64*
*Low education, large holding: n=195, mean=5.17, SD=1.48*
*High education, small holding: n=244, mean=4.89, SD=1.50*
*High education, large holding: n=215, mean=5.54, SD=1.30*

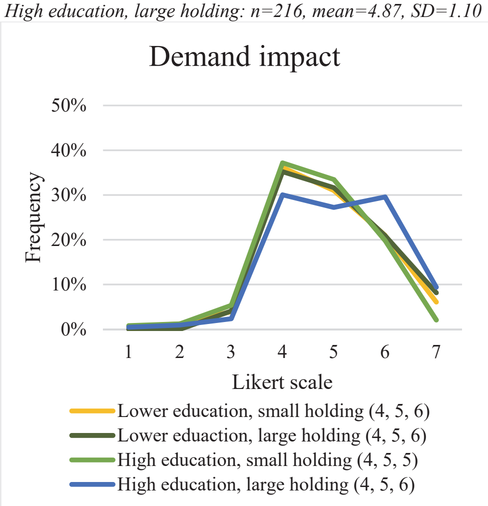
*Figure 15 Four groups based on level of education (higher education or not) and holding size (more or less than 100 hectares) replies to the statements: "I believe that the projected climate change will increase damages in my forest" – for four risk elements. The 1st, 2nd and 3rd quartiles for each variable is enclosed in parenthesis in the legends.*



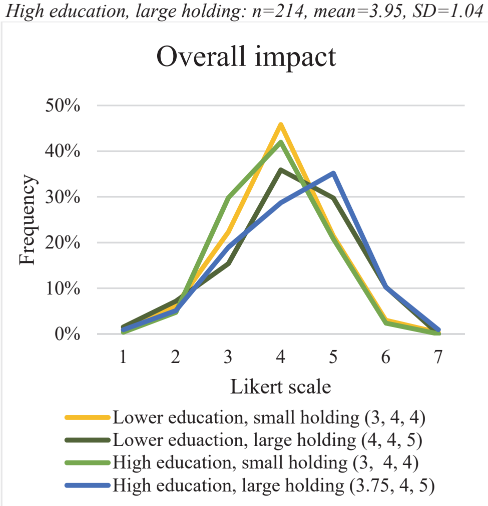

*Low education, small holding: n=332, mean=4.28, SD=1.00*
*Low education, large holding: n=196, mean=4.55, SD=1.07*
*High education, small holding: n=247, mean=4.40, SD=1.01*
*High education, large holding: n=216, mean=4.87, SD=1.10*




*Low education, small holding: n=333, mean=3.88, SD=0.94*
*Low education, large holding: n=196, mean=3.90, SD=0.95*
*High education, small holding: n=245, mean=3.75, SD=0.97*
*High education, large holding: n=214, mean=3.95, SD=1.04*

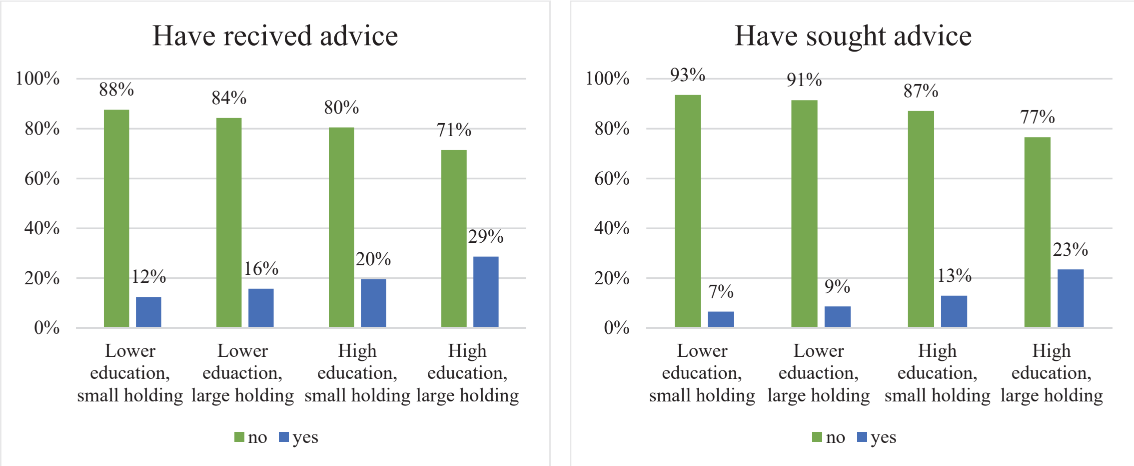



*Low education, small holding: n=336, mean=4.83, SD=1.07*
*Low education, large holding: n=196, mean=4.93, SD=1.02*
*High education, small holding: n=242, mean=4.69, SD=1.00*
*High education, large holding: n=213, mean=5.08, SD=1.10*




*Low education, small holding: n=336, mean=3.90, SD=0.95*
*Low education, large holding: n=195, mean=4.15, SD=1.12*
*High education, small holding: n=255, mean=3.85, SD=0.89*
*High education, large holding: n=216, mean=4.26, SD=1.12*

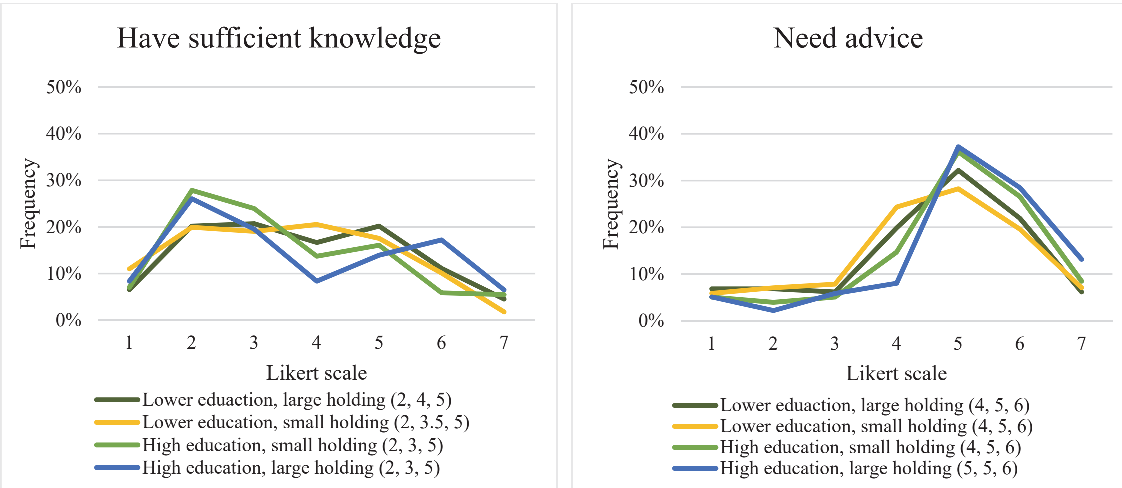
*Figure 16 Four groups based on level of education (higher education or not) and holding size (more or less than 100 hectares) replies to the statements: «I believe the predicted climate changes will influence …" i. "the volume-growth in my forest , ii. "the quality growth in my forest (i.e. the saw log proportion)" iii. "the roundwood demand , and "I believe the predicted climate changes will influence the income-potential and value of my forest holding". The 1st 2nd and 3rd quartiles for each variable is enclosed in parenthesis in legends.*




*Low education, small holding: n=338*
*Low education, large holding: n=197*
*High education, small holding: n=256*
*High education, large holding: n=213*

*Low education, small holding: n=337*
*Low education, large holding: n=197*
*High education, small holding: n=225*
*High education, large holding: n=213*

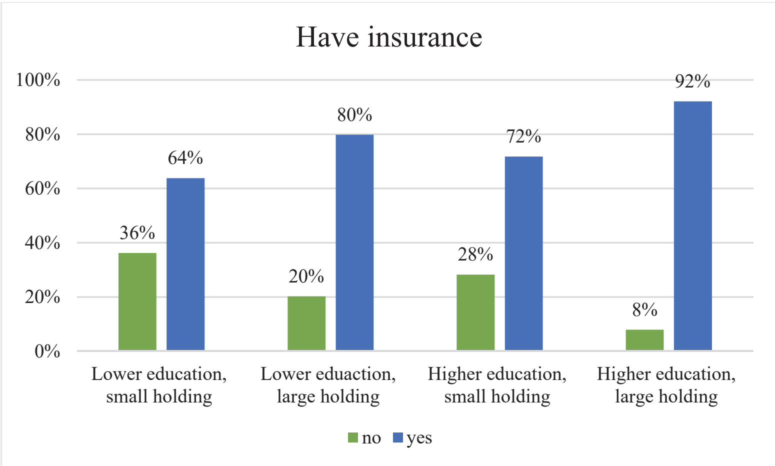
*Figure 17 Proportion of four holding and education groups having sought and received advice about adaptive forest management shown in contrast.*




*Low education, small holding: n=336, mean=3.51, SD=1.57,*
*Low education, large holding: n=198, mean=3.75, SD=1.61*
*High education, small holding: n=255, mean=3.43, SD=1.60*
*High education, large holding: n=215, mean=3.71, SD=1.82*

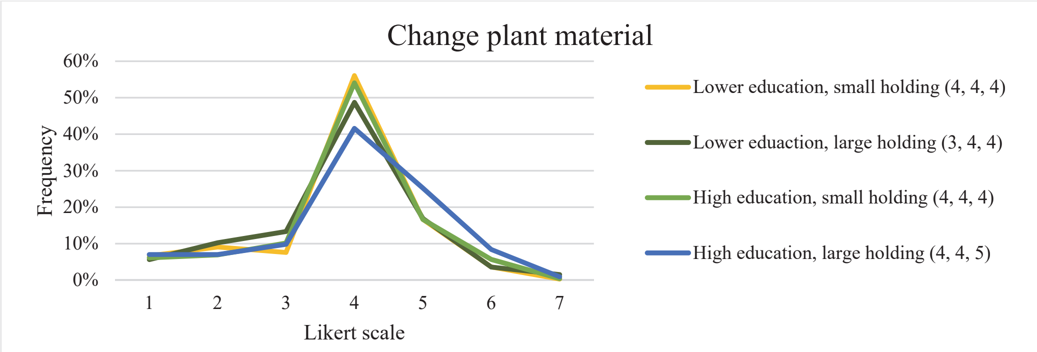
*Low education, small holding: n=255, mean=4.49, SD=1.53,*
*Low education, large holding: n=146, mean=4.54, SD=1.55*
*High education, small holding: n=177, mean=4.86, SD=1.45*
*High education, large holding: n=137, mean=5.08, SD=1.46*

*Figure 18 Four groups based on level of education (higher education or not) and holding size (more or less than 100 hectares) replies to the statements: "I have the knowledge I need about adaptive forestry" and "I need advice and recommendations about adaptive forestry". The 1st 2nd and 3rd quartiles for each variable is enclosed in parenthesis in legends.*

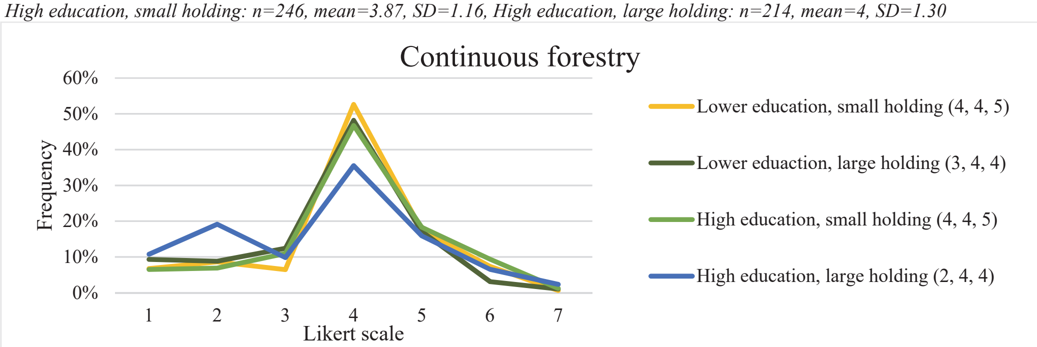



*Low education, small holding: n=337 (339), Low education, large holding: n=198 (198)*
*High education, small holding: n=255 (256), High education, large holding: n=215 (219)*

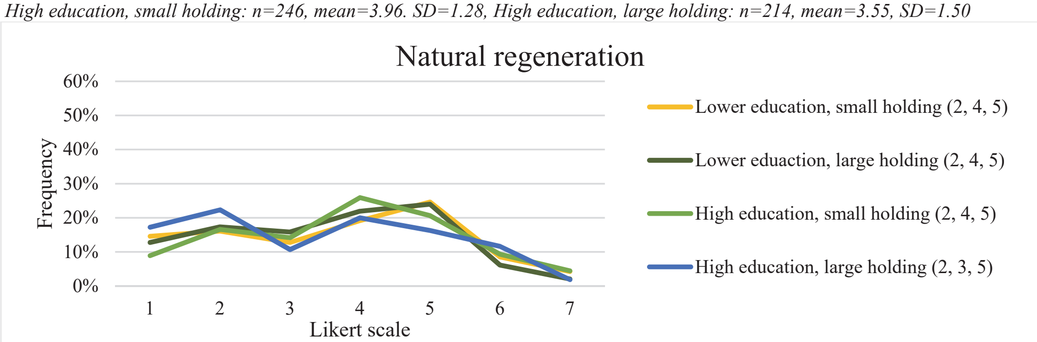
*Figure 19 Proportion of four holding and education groups having taken out insurance shown in contrast.*




*Low education, small holding: n=330, mean=3.79, SD=1.15, Low education, large holding: n=195, mean=3.77, SD=1.20*
*High education, small holding: n=246, mean=3.87, SD=1.16, High education, large holding: n=214, mean=4, SD=1.30*

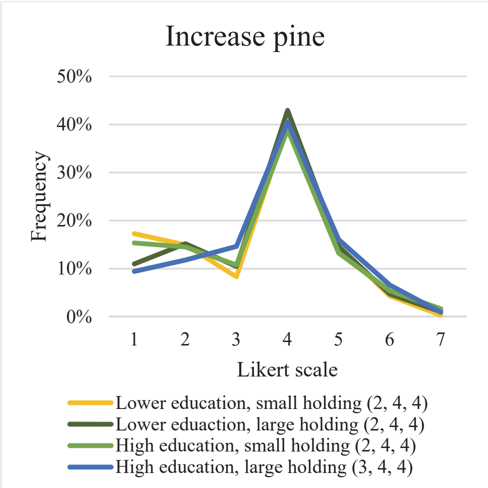



*Low education, small holding: n=325, mean=3.90, SD=1.24, Low education, large holding: n=193, mean=3.68, SD=1.27*
*High education, small holding: n=246, mean=3.96. SD=1.28, High education, large holding: n=214, mean=3.55, SD=1.50*

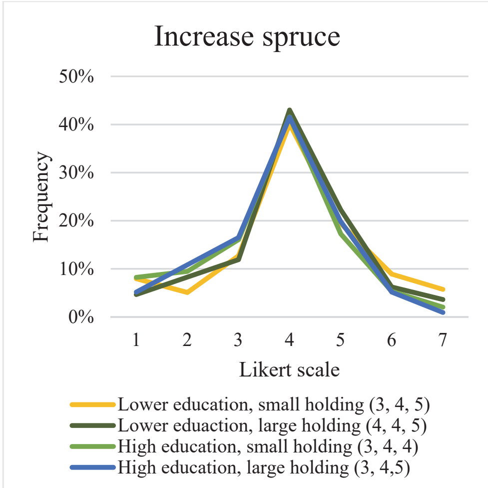



*Low education, small holding: n=329, mean=3.65, SD=1.71, Low education, large holding: n=196, mean=3.53, SD=1.57*
*High education, small holding: n=247, mean=3.78, SD=1.59, High education, large holding: n=215, mean=3.38, SD=1.72*

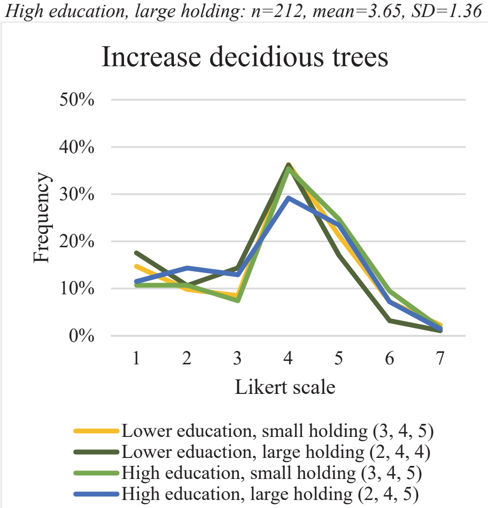
*Figure 20 Four groups based on level of education (higher education or not) and holding size (more or less than 100 hectares) replies to the statements: "To adapt my forest to climate change I will consider …" i. "choosing plant material from lower provenances", ii. "turn from even-aged stands to continuous cover forestry", iii. "turn from planting to natural regeneration rotation". ". The 1st 2nd and 3rd quartiles for each variable is enclosed in parenthesis in legends.*



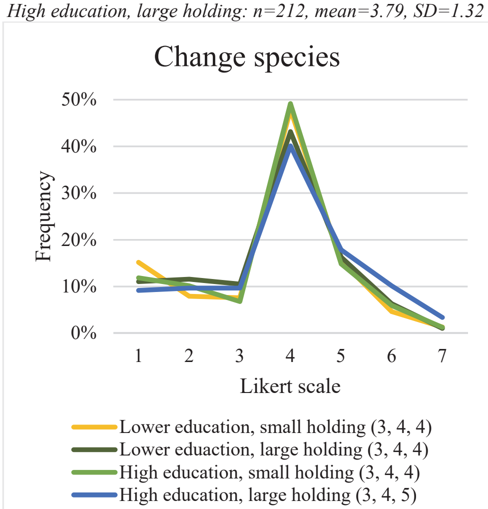

*Low education, small holding: n=301, mean=3.42, SD=1.46*
*Low education, large holding: n=191, mean=3.53, SD=1.38*
*High education, small holding: n=241, mean=3.43, SD=1.50*
*High education, large holding: n=212, mean=3.65, SD=1.36*




*Low education, small holding: n=314, mean=4.07, SD=1.45*
*Low education, large holding: n=193, mean=4.03, SD=1.29*
*High education, small holding: n=243, mean=3.74, SD=1.33*
*High education, large holding: n=212, mean=3.79, SD=1.32*

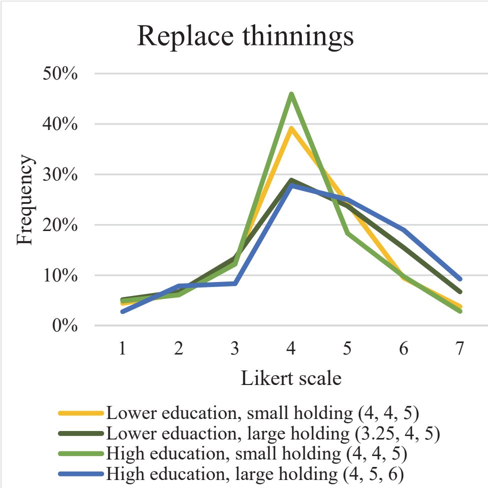



*Low education, small holding: n=306, mean=3.70, SD=1.55*
*Low education, large holding: n=188, mean=3.83, SD=1.47*
*High education, small holding: n=243, mean=3.87, SD=1.49*
*High education, large holding: n=209, mean=3.66, SD=1.51*

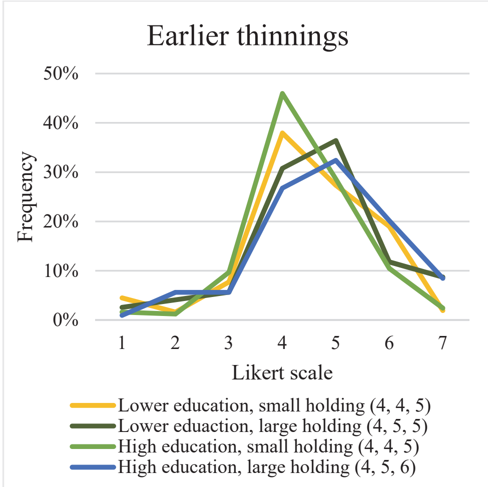



*Low education, small holding: n=303, mean=3.59, SD=1.43*
*Low education, large holding: n=190, mean=3.65, SD=1.40*
*High education, small holding: n=236, mean=3.67, SD=1.39*
*High education, large holding: n=207, mean=3.91, SD=1.48*

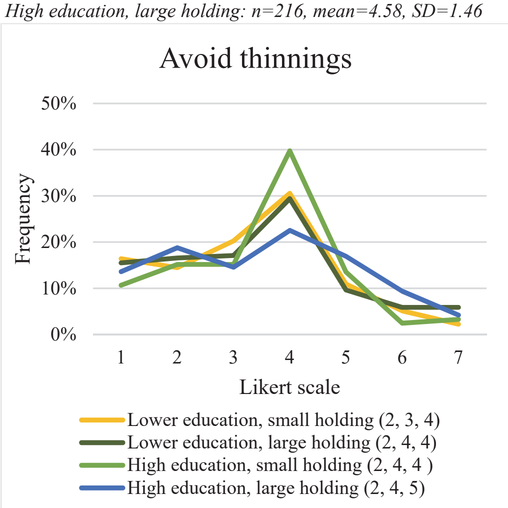
*Figure 21 Four groups based on level of education (higher education or not) and holding size (more or less than 100 hectares) replies to the statements: "In order to adapt my forest to climate change I will consider …" i. "increasing the share of pine", ii. "increasing the share of spruce", iii. "increasing the share of deciduous trees", iv. "change dominating tree species in some stands". ". The 1st 2nd and 3rd quartiles for each variable is enclosed in parenthesis in legends.*



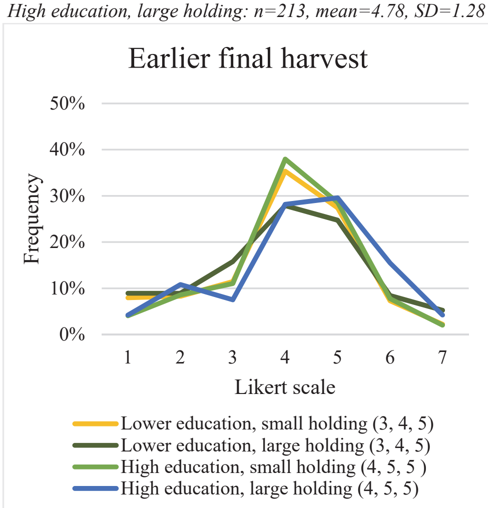

*Low education, small holding: n=317, mean=4.16, SD=1.31*
*Low education, large holding: n=194, mean=4.32, SD=1.49*
*High education, small holding: n=246, mean=4.07, SD=1.27*
*High education, large holding: n=216, mean=4.58, SD=1.46*




*Low education, small holding: n=311, mean=4.46, SD=1.24*
*Low education, large holding: n=195, mean=4.64, SD=1.28*
*High education, small holding: n=248, mean=4.39, SD=1.02*
*High education, large holding: n=213, mean=4.78, SD=1.28*

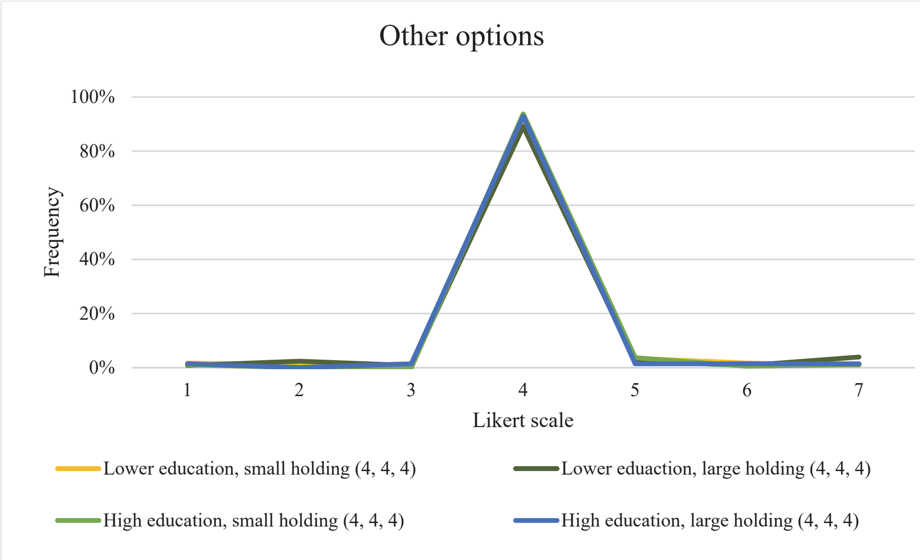



*Low education, small holding: n=311, mean=3.29, SD=1.51*
*Low education, large holding: n=187, mean=3.42, SD=1.66*
*High education, small holding: n=244, mean=3.50, SD=1.41*
*High education, large holding: n=213, mean=3.55, SD=1.69*



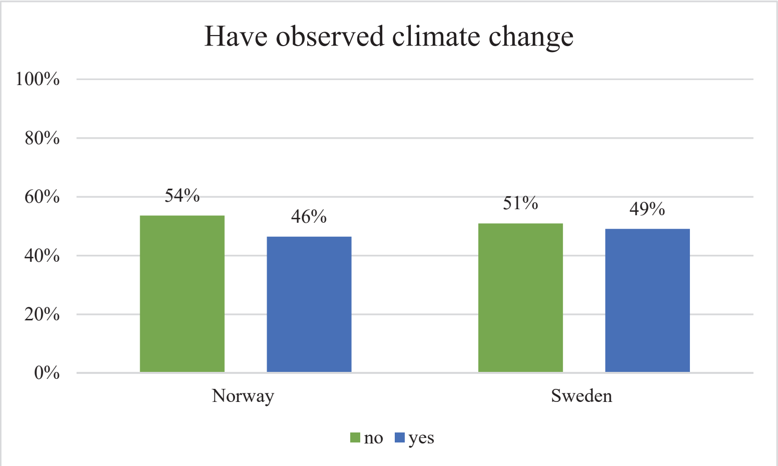

*Low education, small holding: n=314, mean=3.96, SD=1.39*
*Low education, large holding: n=190, mean=3.96, SD=1.54*
*High education, small holding: n=245, mean=4.09, SD=1.26*
*High education, large holding: n=213, mean=4.31, SD=1.44*

*Figure 22 Four groups based on level of education (higher education or not) and holding size (more or less than 100 hectares) replies to the statements: "In order to reduce risks relate to climate change, I will consider …" i. "comprehensive young growth tending as replacement for thinnings", ii. "when conducting thinnings, thin earlier in the iii. "avoid thinnings", iv. "earlier final harvest", v. "other options". The 1st 2nd and 3rd quartile is enclosed in parenthesis in legends."*



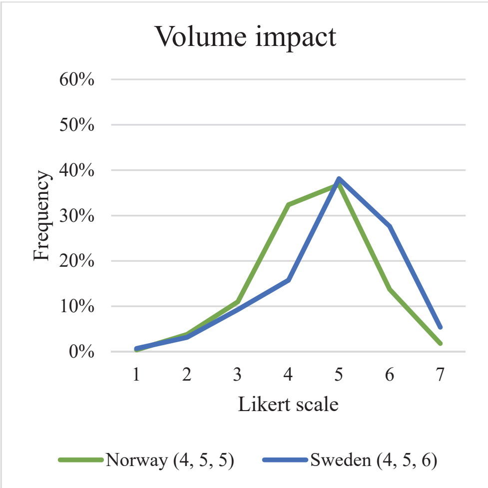

*Low education, small holding: n=233, mean=4.01, SD=0.61,*
*Low education, large holding: n=128, mean=4.07, SD=0.75*
*High education, small holding: n=192, mean=4.04, SD=0.49*
*High education, large holding: n=141, mean=4.02, SD=0.58*

*Figure 23 Four groups based on level of education (higher education or not) and holding size (more or less than 100 hectares) replies to the statements: "In order to reduce risks relate to climate change, I will consider other options". 1st 2nd and 3rd quartiles for each variable is enclosed in parenthesis in legends.*

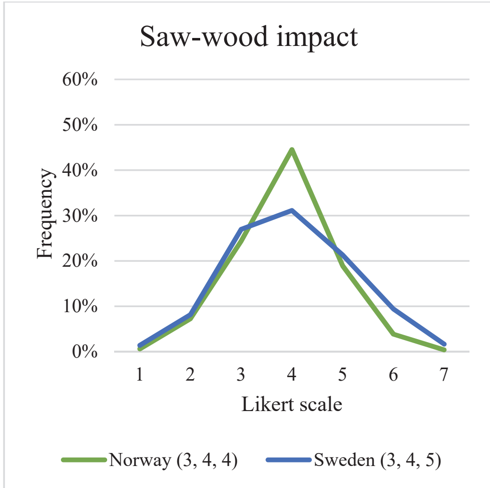



*Norway: n=670, Sweden: n=589.*

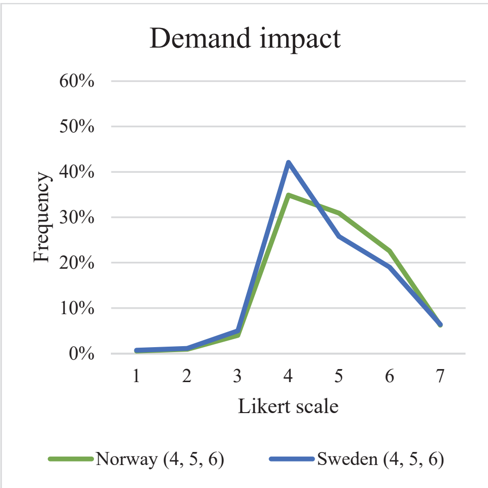
*Figure 24 Proportion of Norwegians and Swedes having observed or experienced climate changing at their holding out of those agreeing that the climate is changing shown in contrast.*



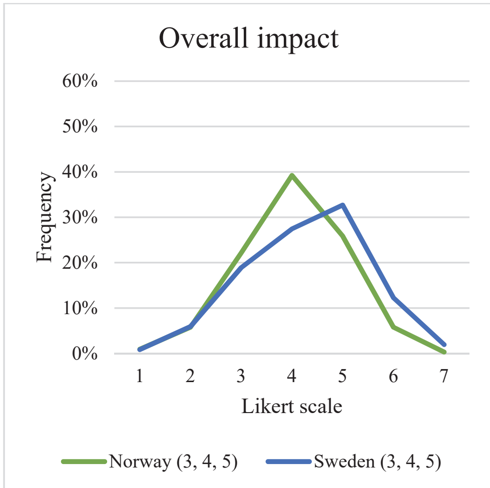

*Norway: n=991, mean=4.49, SD=1.06*
*Sweden: n=724, mean=4.91, SD=1.18*




*Norway: n=988, mean=3.87, SD=0.97*
*Sweden: n=723, mean=3.97, SD=1.20*

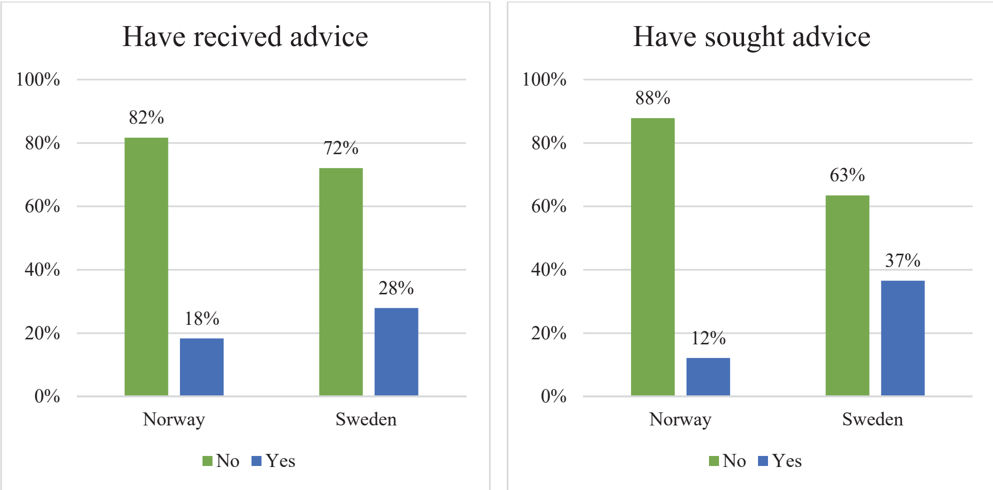



*Norway: n=980, mean=4.87, SD=1.06*
*Sweden: n=722, mean=4.73, SD=1.09*




*Norway: n=1002, mean=4.01, SD=1.02*
*Sweden: n=725, mean=4.29, SD=1.18*

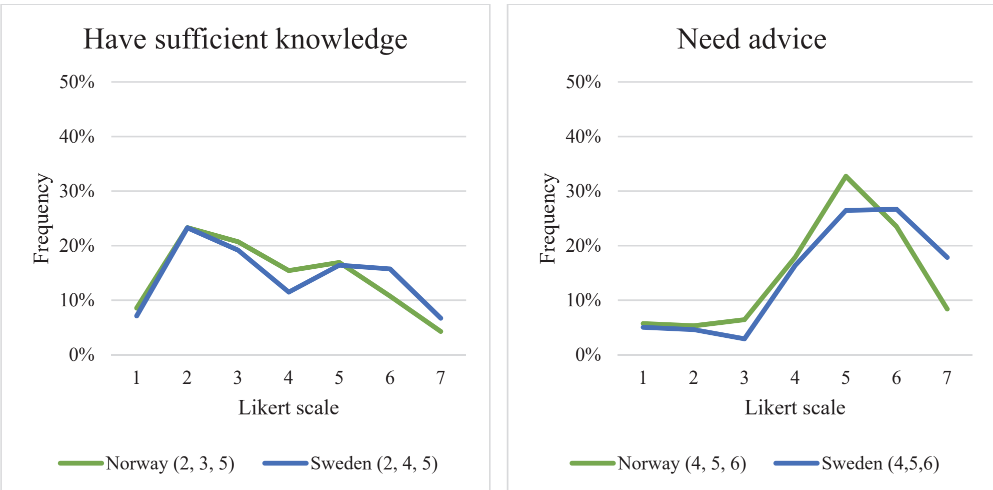
*Figure 25 Norwegian and Swedish respondents' replies to the statements: «I believe the predicted climate changes will influence …" i. "the volume-growth in my forest , ii. "the quality growth in my forest (i.e. the saw log proportion)" iii. "the roundwood demand , and "I believe the predicted climate changes will influence the income-potential and value of my forest holding". The 1st 2nd and 3rd quartiles for each variable is enclosed in parenthesis in legends.*




*Norway: n=1002*
*Sweden: n=728*

*Norway: n=1004*
*Sweden: n=727*

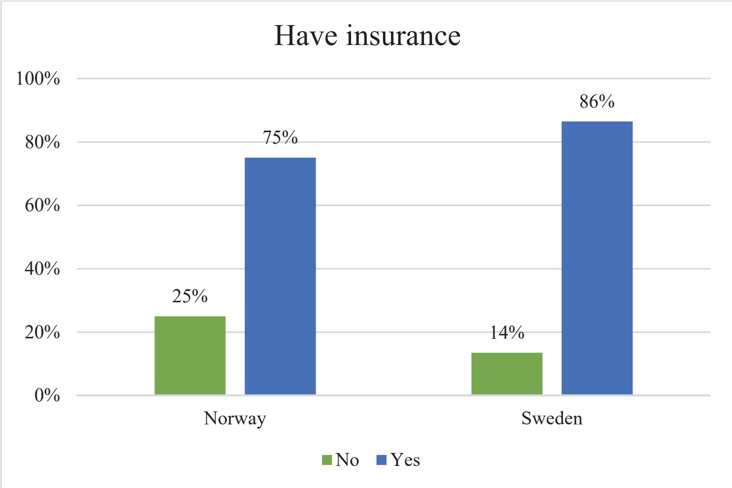
*Figure 26 Proportion of Norwegians and Swedes having sought and received advice about adaptive forest management shown in contrast.*




*Norway: n=1004, mean=3.58, SD=1.65*
*Sweden: n=730, mean=3.81, SD=1.76*

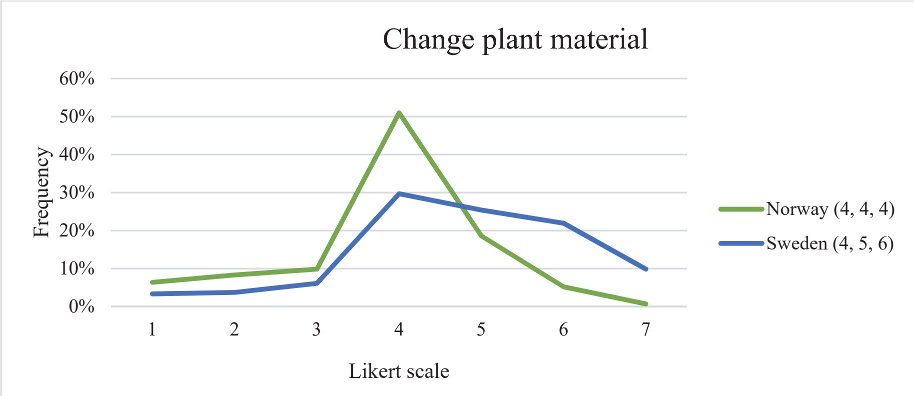
*Norway: n=715, mean=4.70, SD=1.52*
*Sweden: n=464, mean=5.06, SD=1.57*

*Figure 27 Norwegian and Swedish respondents' replies to the statements "I have the knowledge I need about adaptive forestry" and "I need advice and recommendations about adaptive forestry". ". The 1st 2nd and 3rd quartiles for each variable is enclosed in parenthesis in legends.*

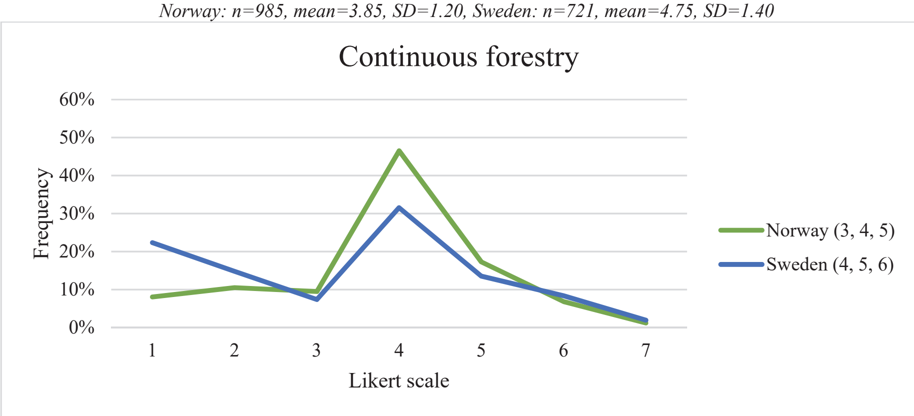



*Norway: n=1005, Sweden: n=725*

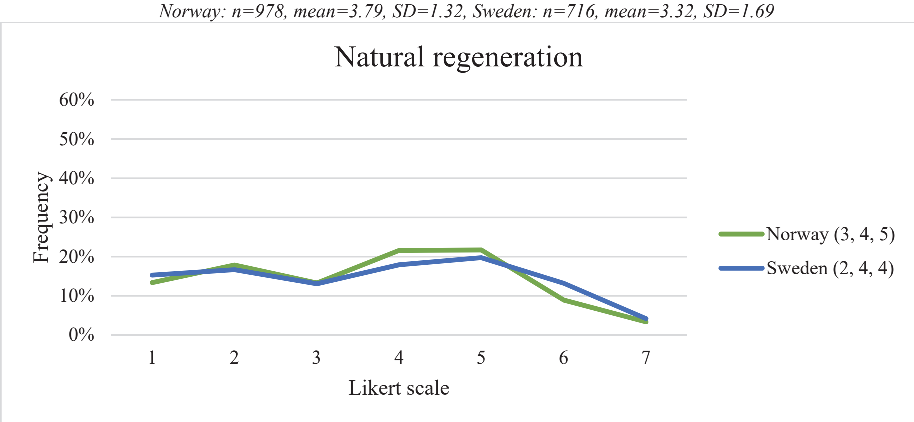
*Figure 28 Proportion of Norwegians and Swedes having taken out insurance shown in contrast.*




*Norway: n=985, mean=3.85, SD=1.20, Sweden: n=721, mean=4.75, SD=1.40*

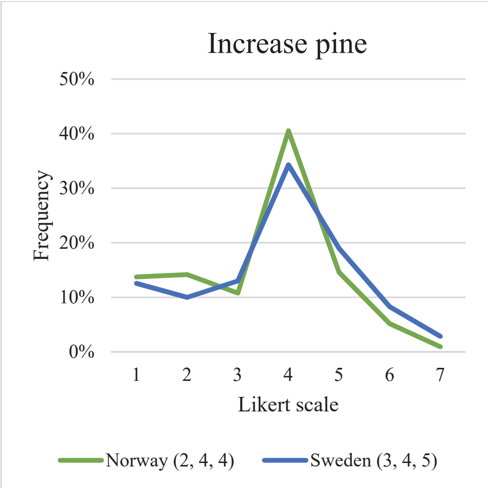



*Norway: n=978, mean=3.79, SD=1.32, Sweden: n=716, mean=3.32, SD=1.69*

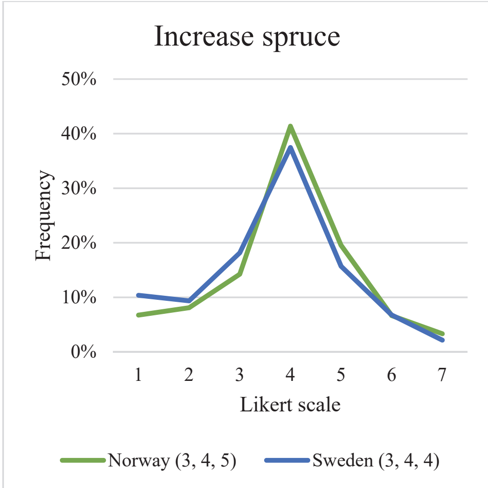



*Norway: n=987, mean=3.605, SD=1.66, Sweden: n=720, mean=3.66, SD=1.77*

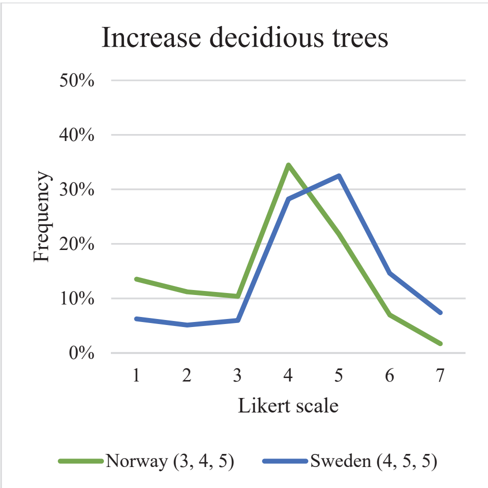
*Figure 29 The Norwegian and Swedish respondents' replies to the statements: "To adapt my forest to climate change I will consider …" i. "choosing plant material from lower provenances", ii. "turn from even-aged stands to continuous cover forestry", iii. "turn from planting to natural regeneration rotation". ". The 1st 2nd and 3rd quartiles for each variable is enclosed in parenthesis in legends.*



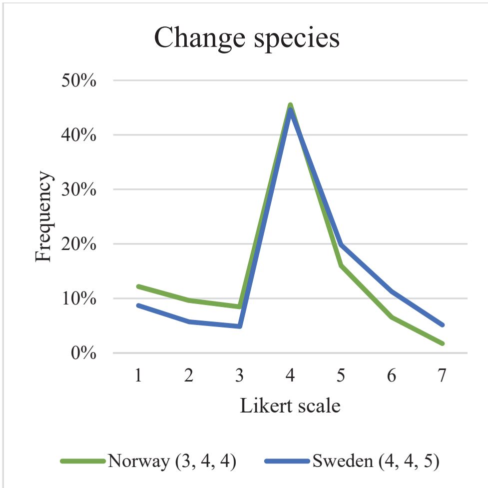

*Norway: n=945, mean=3.47, SD=1.44*
*Sweden: n=700, mean=3.73, SD=1.54*




*Norway: n=962, mean=3.92, SD=1.35*
*Sweden: n=694, mean=3.67, SD=41*

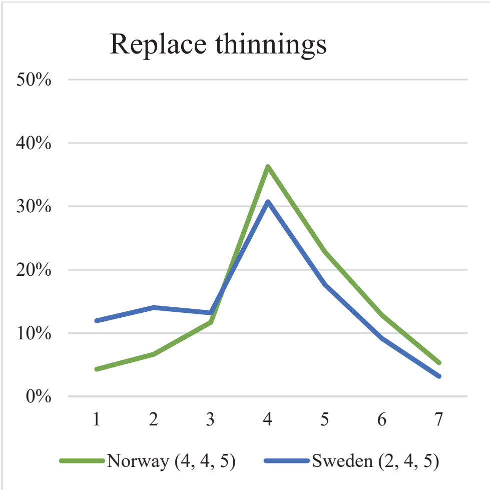



*Norway: n=946, mean=3.67, SD=1.52*
*Sweden: n=705, mean=4.48, SD=1.47*

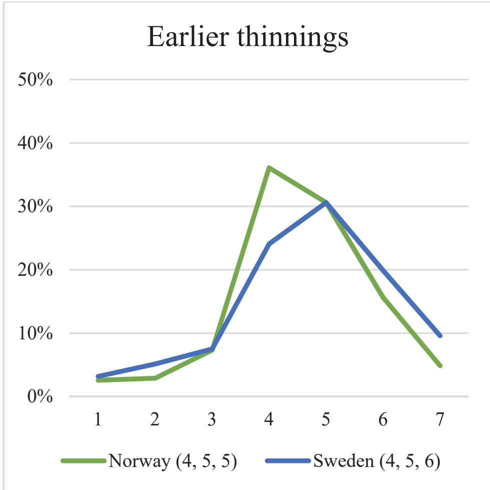



*Norway: n=936, mean=3.7, SD=1.43*
*Sweden: n=702, mean=4.15, SD=1.46*

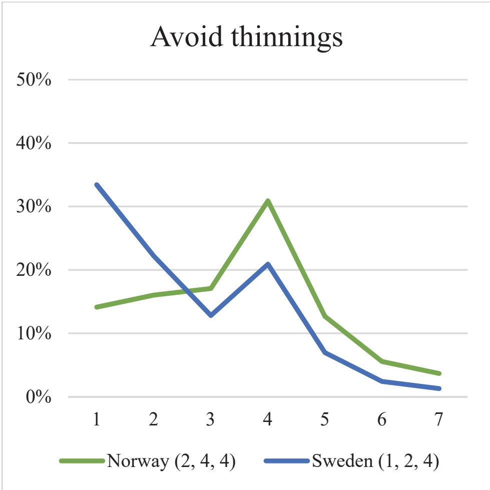
*Figure 30 The Norwegian and Swedish responses to the statements: "In order to adapt my forest to climate change I will consider …" i. "increasing the share of pine", ii. "increasing the share of spruce", iii. "increasing the share of deciduous trees", iv. "change dominating tree species in some stands". ". The 1st 2nd and 3rd quartiles for each variable is enclosed in parenthesis in legends.*



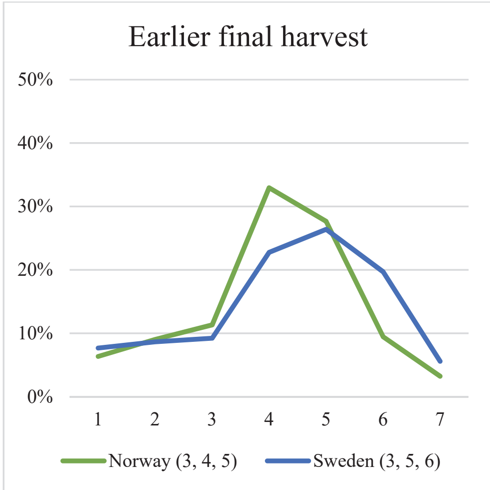

*Norway: n=973, mean=4.26, SD=1.38*
*Sweden: n=719, mean=3.68, SD=1.58*




*Norway: n=967, mean=4.55, SD=1.21*
*Sweden: n=719, mean=4.71, SD=1.42*

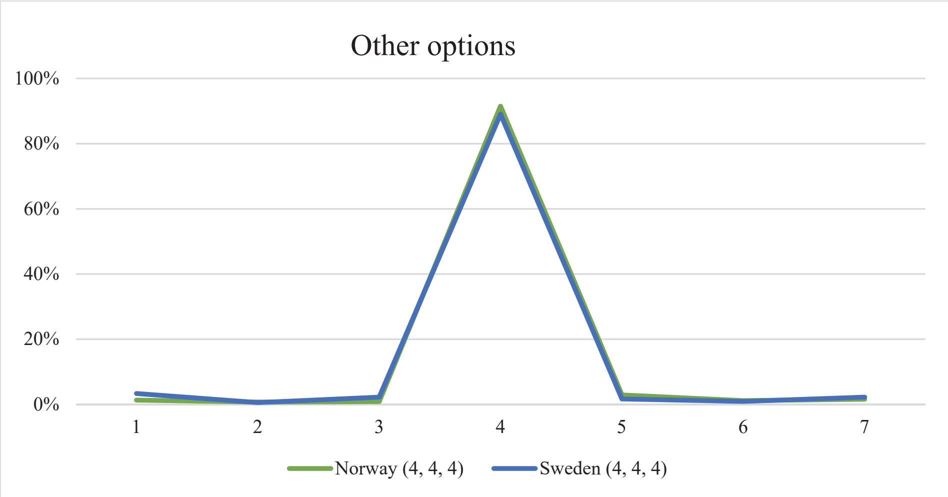



*Norway: n=955, mean=3.43, SD=1.56*
*Sweden: n=703, mean=2.58, SD=1.51*




*Norway: n=962, mean=4.07, SD=1.40*
*Sweden: n=716, mean=4.33, SD=1.60*

*Figure 31 The Norwegian and Swedish responses to the statements: "In order to reduce risks relate to climate change, I will consider …" i. "comprehensive young growth tending as replacement for thinnings", ii. "when conducting thinnings, thin earlier in the iii. "avoid thinnings", iv. "earlier final harvest", v. "other options". The 1st 2nd and 3rd quartile is enclosed in parenthesis in legends."*




*Norway: n=694, mean=4.03, SD=0.60, Sweden: n=540, mean=3.96, SD=0.77*

*Figure 32 The Norwegian and Swedish responses to the statement: "In order to reduce risks relate to climate change, I will consider other options". 1st 2nd and 3rd quartiles for each variable is enclosed in parenthesis in legends.*

# Paper III

# Quantifying the effect of beliefs, observations, risk perceptions and information about climate change adaptation in forestry

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## Abstract

Using a dataset based on 1745 answers to a questionnaire on climate change perceptions and adaptation distributed to members of forest owner associations in Norway and Sweden in 2018, differences between respondents who "completely agreed" that they would consider one or more of 12 adaptive measures and those who did not were explored. Those prone to adapt were significantly more confident that the climate is changing, that forest growth would increase, and that climate change would cause increased damage to their forests or to forest roads; in addition, they had, to a greater extent, received or sought advice and experienced climate change at their holding. Moreover, a larger proportion of those prone to adapt than the other respondents had forestry education and represented a large holding. Generalized linear regression models were formulated, guided by three previously published models, and fitted using half the dataset. The three best models in terms of sensitivity were used for prediction using the other half of the data. Although the models were better than intercept-only models, they did not perform well in predicting those prone to adapt.

*Keywords: Climate change, forestry, climate change adaptation, non-industrial private forest owners, forest owners' perceptions, logistic regression.*

## Introduction

Forests have adapted to changing climatic conditions in the past, but the predicted impacts of climate change on forests are of such velocity and magnitude that the inherited adaptive capacity of species and ecosystems may not be able to respond rapidly enough (GFEP, 2009). According to for example Adger et al. (2007),natural systems (e.g. forests) and human systems must be adapted to mitigate and minimize risks. Thus, those who manage forests must assess whether and how they can adapt their forests to the changing environment. Several publications have been dedicated to reviewing or suggesting proactive adaptive forest management (Millar et al., 2007; Spittlehouse & Stewart, 2004; Ogden & Innes, 2007; Kolström et al., 2011), and in some countries, for example Sweden, official adaptation-related recommendations have already been issued (Skogstyrelsen, 2017).

Questionnaire-based studies of climate change-related adaptive behaviour among forestry decision-makers across Europe show that the proportion of forestry decision-makers who have changed management strategies because of climate change varies between countries. Sousa-Silva et al. (2018)distributed a questionnaire to forestry stakeholders in Romania (2013–2014) and in Belgium, Estonia, France, the Netherlands, Portugal and Slovakia (2015–2016) using social media and forestry networks. The questionnaire was answered by 1131 owners and other stakeholders, and the number of answers ranged from 20 in the Netherlands to 391 in Belgium. The results showed that 40% of the combined sample reported having implemented one or more measures to adapt to climate change. The proportion of "adaptors" varied from 14% in Portugal to nearly 60% in Slovakia. Those who had adapted had most frequently adjusted their regeneration strategy for example by selecting better-adapted tree species and varieties or increased the diversity of species. Another cross-European questionnaire-based study (Blennow et al., 2012) found that close to 20% of the Swedish respondents (n=349), 47% of the German respondents (n=410) and 54% of the Portuguese respondents (n=69) had adapted. Adaptation among Swedish non-industrial private forest owners has been surveyed several times. In Sweden, the proportion of respondents to questionnaires reporting to have adapted increased between 1999 and 2004 (Blennow, 2012), but was approximately the same (≈20%) in 2004 and 2010 when the data for the cross-European study were collected (Blennow et al., 2012). Vulturius et al. (2018) collected data for their study in 2014 but did not survey the proportion who had adapted to climate change, per se. Instead, they asked the respondents whether they had implemented risk-reducing management strategies in the past, and whether they were planning on adapting to climate change in the future. The responses showed that more than 80% of the respondents (n=836) had taken risk-mitigating measures in the past (climate change was however not specified as a motivation for taking action), while close to 40% were planning to adapt to climate change within the next 5 years.

Many researchers have studied climate change adaptation among forest management decision-makers, aiming to identify variables that influence adaptive behaviour (see Vulturius et al.

(2018)for a review of such variables). These influential variables include personal strength of belief in climate change (Blennow & Persson, 2009); strength of belief in climate change science (Vulturius et al., 2018)having seen or experienced climate change (Blennow et al., 2012)and perceiving a high risk of being affected (Blennow, 2012). Some authors have modelled adaptation using logistic regression, with variables indicating (for example) strength of belief and risk perception as independent variables and having adapted or being prone to adapt as the dependent variable (Blennow et al., 2012)). Using data from a questionnaire issued to a sample of forestry decision-makers in Norway and Sweden in the spring of 2018, the first aim of this article is to test for statistical differences between respondents who are prone to adapt and other respondents regarding variables previously shown to impact adaptation. The second aim is to model the probability of respondents' propensity to adapt, drawing on previously-published logistic regression models (Vulturius et al., 2018; Sousa-Silva et al., 2016; Blennow et al., 2012). The final aim of the article is to evaluate the models' ability to predict adaptive behaviour using independent data and to assess this using model sensitivity, Tjur's histograms and Tjur's coefficient of discrimination (Tjur, 2009).

## Materials and methods

*Questionnaire*

The questionnaire was developed using recommendations from Dillman et al. (2009), and comprised 22 standard questions and 10 follow-ups based on previous responses. The majority of "questions" were statements directing the participants to express their level of agreement, disagreement or neutrality by choosing between the alternatives: "completely disagree", "mainly disagree", "somewhat disagree", "no opinion", "somewhat agree", "mainly agree" or "completely agree". These answers thus reflected a seven-point Likert scale, where "4" reflected a neutral middle point. For questions requiring assessments concerning the future, respondents were asked to reflect on the time frame of a normal rotation period (i.e. 60–120 years). In addition to such statements, the questionnaire contained questions with categorical answer alternatives and some open-ended questions. There were no mandatory questions. The topics covered in the questionnaire were:

1. Beliefs, perceptions and experiences with climate change.
2. Expectations about impacts of future climate change on forests and forestry, e.g. increased damage[1], forest growth, demand for forest products, and income-potential and holding value.
3. Assessments as to whether the respondents would consider implementing specified forest management options[2] to adapt to climate change; the options were based on practices recommended bySøgaard et al. (2017), Skogstyrelsen (2017) and Skogbrand (2014), and Skogbrand (2014).
4. Current knowledge and sources of advice related to adaptation.
5. Background variables.

The questionnaire was pre-tested in three pilot studies, first by 12 Norwegian forestry practitioners, followed by 5 forestry scholars from the Norwegian University of Life Sciences' Faculty of Environmental Sciences and Natural Resource Management, and finally by employees from the Norwegian and Swedish forest owner associations. The questionnaire was formulated in Norwegian and translated to Swedish by a native Swedish speaker. The supplementary material

[1] The specified damage consisted of wind, storm, drought, forest fires, pests and disease, root rot, top break or damage to forest roads.
[2] The specified actions were: 1. *species mixture options*: increasing the share of spruce, pine, and/or deciduous trees, or changing dominating tree species; 2. *regeneration options*: turning to natural regeneration, turning to continuous forestry or using better-adapted plant material; 3. *risk-reducing options*: moving final harvest earlier in rotation, avoiding thinnings, replacing commercial with pre-commercial thinnings, thinning earlier when conducting commercial thinnings, and others.

include an English translation of the questionnaire and an information letter. The survey was conducted online, using Questback (Questback, 2017-2018)

*Sampling and distribution*

The sampling of respondents and distribution of invitations to participate was conducted by administrative staff from the Norwegian and Swedish forest owner associations. The size of the gross samples in each association were proportional, giving a total sample of 5000 members in each country, randomly drawn from each association's membership register. The one exception was Norskog, a Norwegian association that organizes many of the owners of the largest non-industrial private forest holdings in Norway (Norskog.no, 2018). To ensure representation of the owners and managers of very large holdings, a relatively larger proportion of Norskog members was included in the gross sample compared with the proportions drawn from the membership bases of the other associations. Table 1 contains an overview of the associations, affiliated forested area, gross sample, net sample and response rates.

The invitations to participate were distributed by emails containing a link to an online-questionnaire form. The time frame of the Norwegian survey was March 19th to April 9th; an email containing a reminder was sent to the entire Norwegian sample 8 to 10 working days after the survey was launched. The Swedish survey took place between April 10th and April 27th, and reminders to participate were sent by Norra and Norrskog. Only participants who agreed to participate by actively choosing to submit their completed questionnaire were registered. Therefore, the data do not contain unsubmitted forms.

*Table 1. Overview of samples and responses.*

| | Association | Region | Coverage in 1000 hectares | Members (N) | Gross sample | Responses, net sample (n) | Responses, net sample (%) |
|---|---|---|---|---|---|---|---|
| Norway | Glommen Skog SA | East | 690 | 3650 | 518 | 117 | ≈ 22.5% |
| | Mjøsen Skog SA | East | 550 | 3700 | 526 | 99 | ≈ 19% |
| | Viken Skog SA | East | 950 | 9400 | 1420 | 211 | ≈ 15% |
| | AT Skog SA | South | 740 | 7300 | 1037 | 250 | ≈ 24% |
| | Vestskog SA | West | 120 | 2750 | 391 | 112 | ≈ 28.5% |
| | ALLSKOG SA | Middle and North | 350 | 7500 | 1065 | 178 | ≈ 17% |
| | Norskog | - | 1300 | 300 | 100 | 45 | 45% |
| | **Total, Norway** | | **4700** | **34600** | **5057** | **1012** | **≈ 20%** |
| Sweden | Södra Skogsägarna | South | 2517 | 51000 | 2406 | 333 | ≈ 13.5% |
| | Skogsägarna Mellanskog | Middle | 1530 | 26000 | 1226 | 158 | ≈ 13% |
| | Norrskog | North | 965 | 12000 | 566 | 98 | ≈ 16.5% |
| | Norra Skogsägarna | Northernmost | 1000 | 17000 | 799 | 149 | ≈ 18.5% |
| | **Total, Sweden** | | **6012** | **89000** | **4997** | **738** | **≈ 14.5%** |
| | **Combined sample** | | **10712** | **116630** | **10054** | **1745** | **≈ 17.5%** |

*Study areas*

The productive forest area of Norway constitutes approximately 86600 km$^2$ (NIBIO, 2018)while the productive forest area in Sweden is close to 280000 km$^2$ (Riksskogstaxeringen, 2017).Non-industrial private forest owners (NIPFs) own approximately 125000[3] of the forest holdings in Norway(Statistics Norway, 2017). Together, these NIPFs own 79% of Norway's forested land, making Norway the country with the largest proportion of privately-owned forest area in Europe (Hirsch & Schmithüsen, 2010). The regulation of forest management is relatively liberal: owners are free to manage their holdings, within legal requirements and voluntary certification schemes to which the owners have committed (PEFC Norway, 2015). In Sweden, non-industrial private forest owners own approximately 50% of the forested land. In total, there are near 330,000 non-industrial private forest owners in the country (Statistics Sweden, 2014). As in Norway, the owners are relatively free to manage their holdings (Lidskog & Löfmarck, 2016) within legal regulations and voluntary certification schemes(PEFC Sweden, 2018; FSC, 2018). The holding structure is similar in the two countries: the majority of NIPFs own small holdings, while a relatively small number of owners own the majority of the forestland (Statistics Sweden, 2014; Statistics Norway, 2017). In Norway, regional forest owner associations, which are members of the Norwegian Forest Owners Federation, handle 84% (Norges Skogeierforbund, 2017)of the roundwood trade, while Norskogs members control 15% of the harvested volume within the country(Norskog.no, 2018). The 4 regional associations in Sweden handle approximately 50% of the roundwood trade originating from NIPF-owned holdings (Mellanskog, 2017; Norra Skogsägarna, 2018; Norrskog, 2017; Södra, 2017).As climate change unfolds, both countries will face rising temperatures, particularly in winter and in the northernmost regions, and increased precipitation (Hanssen-Bauer et al., 2009; SMHI, 2018). Forest productivity, however, is likely to increase in many areas, as long as growth is not restricted by lack of moisture (Bergh et al., 2010; Briceno-Elizondo et al., 2006; Pussinen et al., 2009).

*Data and data analysis*

To survey adaptation, the respondents were asked to respond to the following statement, "In order to reduce risks related to climate change I will consider …", related to 12 adaptive practices. There were four practices focusing on tree-species mixture, three focusing on thinning options, two on regeneration options, one on rotation age, one on continuous-cover forestry. Finally, there was an "other practices" option. To create a binary variable, all those who had answered that they "completely agreed" (n=670) that they would consider implementing one or more of these options were classified as "prone to adapt", and the rest as "others". As Figure 1 shows, most participants "completely agreed" that they would consider only one of the suggested adaptive management actions.

[3] Approximately 4000 of the 12500 belong to an owner that is diseased.

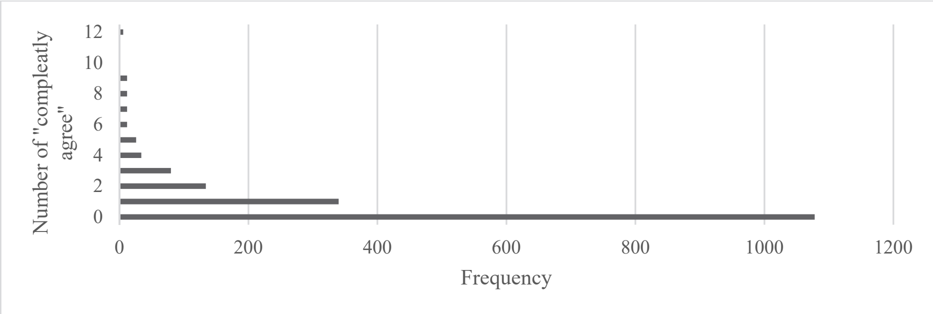



*Figure 1. Number of times the participants in the "prone to adapt" group replied "completely agree" to suggested adaptive options.*

Variables previously shown to influence adaptive behaviour were identified by reviewing studies focusing on forest owners' adaptive behaviour; this review was conducted via Google Scholar using a combination of the search words "climate change", "climate change adaptation", "adaptation", "forest owners' perceptions" and "logistic regression", and by looking up references from articles that had already been reviewed. Table 2 contains the variables identified as being linked to adaptation, their sources and corresponding questions/statements from this study.

*Table 2. Variables previously linked to adaptation, references and corresponding variables or candidates for proxies in the available material.*

| **Variable** | **Reference (e.g.)** | **Candidate variable** |
|---|---|---|
| Personal strength of belief in climate change | (Blennow and Persson, 2009; Blennow et al., 2012) | Strength of belief in climate change at forest holding |
| (Perceived) salience of climate change science | (Vulturius et al., 2018) | Belief in climate change being human-made |
| Having experienced climate change | (Laakkonen et al., 2018; Sousa-Silva et al., 2016) | Having observed or experienced climate change-related changes in forest |
| Education | (Blennow et al., 2012; Blennow et al., 2016) | Level of education |
| Forestry share of household income | (Blennow et al., 2012) | Productive forest area at holding |
| Adaptive capacity, described as knowing how to adapt and believing in positive effect of adapting; Lack of knowledge and information negatively affects adaptation; Knowledge about how to adapt | (Blennow, 2012; Laakkonen et al., 2018; Sousa-Silva et al., 2016; Sousa-Silva et al., 2018; (van Gameren & Zaccai, 2015)) | Has knowledge; Needs knowledge; Has sought advice; Has received advice |
| High risk perception of climate change-related risk factors | (Blennow, 2012; Vulturius et al., 2018) | Expected increase in damages, overall economic impact and forest insurance |
| Personal knowledge of forest management | (van Gameren and Zaccai, 2015) | Forestry education Being a professional forest manager |
| Holding size | (van Gameren and Zaccai, 2015) | Holding size |
| Perceived need to be proactive | (Sousa-Silva et al., 2016; Vulturius et al., 2018) | Having sought advice about adaptive forest management |
| Perceived positive effect of climate change on forest growth | (Sousa-Silva et al., 2016) | Assessment of climate change's impact on growth |

Using the Wilcoxon-Mann-Whitney U rank sum tests for Likert-scale variables and the chi-square-distribution-based proportion test for binary variables, statistically significant differences between those “prone to adapt” and the “others” were identified. The Wilcoxon-Mann-Whitney U rank sum test was chosen because it is considered robust when data are not normally distributed (Crawley, 2012)..

The binary response models published in Vulturius et al. (2018), Sousa-Silva et al. (2016) and Blennow et al. (2012) guided the development of generalized regression models with logit links. The underlying hypothesis was that the factors found in the regression analyses of these studies to have a significant impact on the probability of respondents’ prior adaptation or propensity to adapt would have a significant impact in the present study as well. Blennow et al. (2012) used self-reported adaptation as the dependent variable and included two independent variables: strength of belief in climate change and having experienced climate change. To improve the fit, the authors also added two additional variables: level of education and share of household income from forestry. Vulturius et al. (2018) used stated intention to adapt as their dependent variable, and had a number of independent variables, out of which risk assessment, having implemented risk-mitigating measures in the past, self-efficacy knowledge and (perceived) salience of climate change were found to be statistically significant. The models presented in Sousa-Silva et al. (2016) was based on Blennow et al. (2012), using self-reported adaptation as the dependent variable. They included the following independent variables in their final model: “belief in need to adapt”, “lack of knowledge”, “lack of finances”, “having information”, “having capacity to adapt”, “belief in increased tree (volume) growth”, and binary variables indicating respondents’ uncertainty about whether climate change is happening, or that the respondent did not know how to adapt. If the data did not include a measure of the same variables as those included in the previous models, variables assumed to measure the same underlying factor(s) were used instead: for example, strength of belief in climate change being human-made was used as a proxy for salience of climate change science.

The data were randomly split into a test set and a train set. Using the train set, models mimicking those selected from the literature were formulated and fitted using the generalized linear regression with logit link method. The dependent variable was always the same: the binary variable indicating whether each respondent belonged to the “prone to adapt” group (y=1) or not (y=0). The independent variables were assessed by inspecting z-statistics, and the models assessed by link test for misspecification and tests for multicollinearity. Initially, the variables based on Likert-scale answers were entered as ordered factors. If there were reasons for doing so, for example if all but one of the levels were insignificant according to the z-statistics or there was multicollinearity, the variables and models were simplified by merging levels.

In addition to testing whether the different levels were significantly different from each other, the effect of simplifications was assessed by inspecting goodness of fit measures (i.e. likelihood ratio statistics, Akaikes information criterion (AIC), Pseudo $R^2$, and model sensitivity[4]). The predictive margins and marginal effects of the variables also gave an indication as to whether to keep all levels or simplify. If there were several candidates for proxies, as was the case when the models contained variables indicating (lack of) knowledge, all were tested. The goodness of fit of the final models was compared using likelihood ratio statistics, AIC, pseudo $R^2$, sensitivity, and the Hosmer-Lemeshow $\chi^2$ test. Finally, probabilities for respondents being "prone to adapt" was predicted for the test set, and group belonging was derived from these probabilities using a cut-off between the groups at 0.5. The model's ability to predict group belonging was finally assessed by reviewing the confusion matrix and in particular the sensitivity measure, Tjur's histograms and Tjur's coefficient of discrimination, which is the difference between the mean predicted probability in the prone to adapt and others group (Tjur, 2009). The simple statistical tests were conducted in R (R Core Team, 2018), while Stata was used for modelling (Statacorp, 2015).

[4] Proportion of participants correctly predicted in the "prone to adapt" group, with a cut-off at 0.5.

## Results

*Beliefs and experiences*

There were statistically significant differences between those “prone to adapt” and the “others” for a number of the variables listed in Table 2. First, there was a significant *(n (prone) 632, n (others) 1047, W (U): 377310, p-value 0.000, df=1)* and visible difference in strength of belief in climate change: a larger proportion of the prone to adapt group completely agreed that the climate was changing at their holding (See Figure 2). Only those who (somewhat, mainly or completely) agreed that the climate was changing at their holdings were asked whether they believed that climate change was human-made, which was assumed to be a proxy for trust in climate change science. Still, there was a difference between those “prone to adapt” and the “others”, which was significant at the 10% level (*n (prone) 653, n (others) 1059, W (U): 362460, p-value 0.084, df=1*) The difference between the groups was not as visible, and statistically significant only at the 90% level in the answers to climate change being human-made (Figure 3). Finally, 44% of those “prone to adapt” answered that they had experienced climate change at their holding, while a significantly smaller proportion (28%) *(prop. $\chi^2$: 47.50, p-value 0.000, df=1)* of the “others” reported the same.

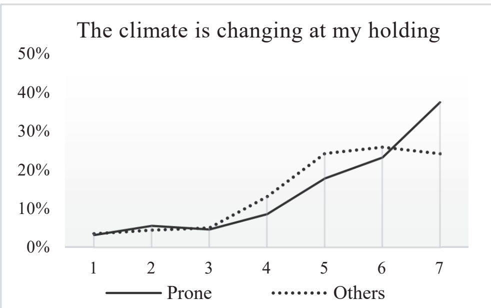



*Figure 1. Answer distribution within the “prone to adapt” and “others” groups for strength of belief in climate change.*
Notes: 1 equals “completely disagree”, 4 equals “no opinion” and 7 equals “completely agree”. The lower and upper quartiles and medians are 5, 7 and 6 and 4, 6 and 5 for the prone to adapt and the others, respectively. The mean response was 5.5 in the prone group and 5.2 in the other group.

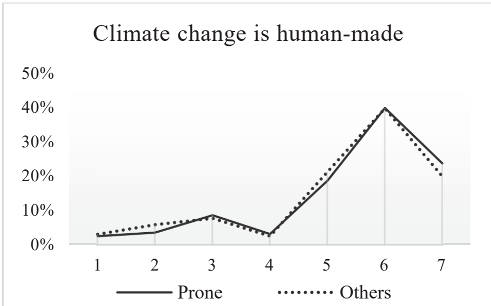



*Figure 3. Answer distribution within the “prone to adapt” and “others” groups for strength of belief in climate change being human-made.*
Notes: 1 equals “completely disagree”, 4 equals “no opinion” and 7 equals “completely agree”. The lower and upper quartiles and medians are 4, 6 and 5 for both groups. The mean response was 3.98 in the prone group and 3.78 in the other group.

*Risk perception measures*

Those prone to adapt were also significantly more confident than the others that damage in their forest from wind, storms, drought, forest fires, pests and disease, root rot, top breakage, and infrastructure would increase (test results are shown in Table 3, numbers 1–8). Figures 1–8 in the supplementary material show the answer distribution for each of these 8 elements. The differences were most visible in the upper part of the distributions for wind, storms, infrastructure and top breakage. The prone to adapt group, however, were also significantly and visibly more confident that forest growth would increase as a result of climate change (Table 2, test 9; supplementary material,

Figure 9). While it is reasonable to assume that if a respondent has taken out forest insurance, he/she has perceived that there is a risk of damage occurring, there were no significant differences between the groups for this variable (Table 4, number 7). The final candidate variable for risk perceptions were the answers to the statement, “Considering all aspects of climate change, I believe that the predicted climate changes will influence the income-potential and value of my forest holding” (Table 3, number 10; supplementary material, Figure 10). For this variable, there was no indication of a statistically significant difference between the groups.

*Table 3. Results of Wilcoxon-Mann-Whitney U tests for variables related to risk perceptions. Degree of freedom is 1 in all tests. Figures 1–10 in the supplementary material show the answer distributions for each group for each variable.*

| Nr | Questionnaire formulation | Variable | Answer alternatives | n | | W (U) | p |
|---|---|---|---|---|---|---|---|
| | | | | Prone | Others | | |
| 1 | I believe the projected climate changes will increase damages in my forest caused by.. | ..wind | Seven-point Likert scale ranging from 1 (i.e. completely disagree) to 7 (i.e. completely agree) | 648 | 1054 | 395170 | 0.000 |
| 2 | | ..storm | | 639 | 1058 | 389110 | 0.000 |
| 3 | | ..drought | | 609 | 1043 | 341820 | 0.008 |
| 4 | | ..forest fires | | 600 | 1044 | 333540 | 0.024 |
| 5 | | ..pests and disease | | 629 | 1057 | 371700 | 0.000 |
| 6 | | ..root rot | | 601 | 1045 | 343060 | 0.001 |
| 7 | | ..top break | | 644 | 1048 | 402470 | 0.000 |
| 8 | | ..infrastructure | | 645 | 1050 | 412120 | 0.000 |
| 9 | I believe the predicted climate changes will influence.. | ..expected volume-growth | Seven-point Likert scale ranging from 1 (i.e. major decrease) to 7 (i.e. major increase) | 652 | 1063 | 382660 | 0.000 |
| 10 | “Considering all aspects, I believe that the predicted climate changes will influence the income-potential and value of my forest holding” | ..expected overall impact | | 663 | 1064 | 347000 | 0.555 |

### *Knowledge about forestry and adaptive forestry*

There were four variables in the material that indicated (lack of) knowledge on climate change adaptation and thus adaptive capacity: 1) have sought advice on adaptive forestry; 2) have received advice on adaptive forestry; 3) perceived level of knowledge about adaptive forestry; and 4) perceived need for advice on adaptive forestry. The variable indicating whether the respondent had sought advice may also indicate whether the respondent had felt a need to be proactive. In addition, there were two variables that indicated personal level of knowledge about forestry (i.e. having had forestry education and being a professional forest manager). Those prone to adapt were statistically significantly less confident that they had sufficient knowledge about adaptive management *(n (prone) 663, n (others) 1071 W(U): 380180, p-value 0.011, df=1)* and perceived that they needed advice on adaptive management *(n (prone) 438, n (others)753 W(U): 178260, p-value 0.016, df=1)*. Figures 4 and 5 show the answer distributions for these two variables. A larger proportion of those “prone to adapt” had, in addition, both sought advice about adaptive forestry and received advice without seeking it out (see test results in Table 4, numbers 1 and 2). A larger proportion of those prone to adapt also had forestry education (Table 4, number 6). Finally, a larger proportion of those prone to adapt were managers (Table 4, number 8); however, as the total number of managers was low (≈ 2% of the combined sample), these results should be considered with caution.

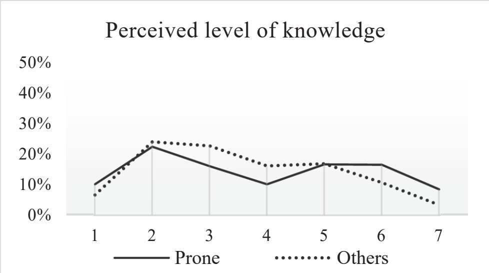



*Figure 4. Answer distribution within the "prone to adapt" and "others" groups for perceived level of sufficiency of own knowledge.*

Notes: 1 equals "completely disagree", 4 equals "no opinion" and 7 equals "completely agree". The lower and upper quartiles and medians are 4, 6 and 5 for both groups. The mean response was 3.83 in the prone group and 3.57 in the other group.

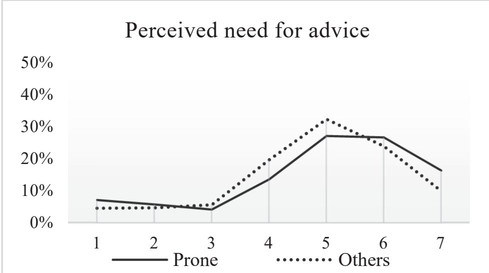



*Figure 5. Answer distribution within the "prone to adapt" and "others" groups for perceived need for advice on adaptive forestry.*

Notes: 1 equals "completely disagree", 4 equals "no opinion" and 7 equals "completely agree". The lower and upper quartiles and medians are 2, 5 and 4 and 2, 5 and 3 for the most prone to adapt and the others, respectively. The mean response was 4.9 in the prone group and 4.8 in the other group.

*Other variables*

The frequency and magnitude of roundwood removals increase with holding size (Central Bureau of Statistics Norway, 2016), which again might indicate that the household dependency on forest-income and level of interest in forestry increases with holding size. In the material, holding size was originally entered as an ordered categorical variable with the same categories as those used by Statistics Norway (cf. Statistics Norway, 2014). Several group divisions were tested before it was decided that two groups, large holdings (≥100 hectares) and small holdings (<100 hectares), were sufficient. A significantly larger proportion of those prone to adapt represented large holdings, but there was no such difference in education (Table 4, numbers 4 and 5).

*Table 1. Positive responses as number (total number of respondents in parentheses) and proportions and statistics from proportion test. Degree of freedom is 1 for all tests. The proportions in calculated using the number of participants in the prone (n=670) and others(n=1078) group respectably.*

| Nr | Variable | n | | Proportion | | $\chi^2$ | p |
|---|---|---|---|---|---|---|---|
| | | Prone | Others | Prone | Others | | |
| 2 | Have received advice = 1 | 177 | 210 | 26.5% | 19.5% | 11.13 | 0.000 |
| 3 | Have sought advice = 1 | 182 | 210 | 27% | 19.5% | 13.58 | 0.000 |
| 4 | Represents a large holding | 294 | 391 | 43% | 36% | 9.72 | 0.001 |
| 5 | Have higher education = 1 | 325 | 489 | 48.5% | 45.5% | 1.51 | 0.217 |
| 6 | Have forestry education = 1 | 218 | 182 | 20% | 11.5% | 56.49 | 0.000 |
| 7 | Have forest insurance = 1 | 521 | 860 | 77% | 79% | 0.89 | 0.344 |
| 8 | Is forest manager = 1 | 25 | 15 | 4 % | 1% | 9.09 | 0.002 |

*Logistic regression*

Model 1, based on Blennow et al. (2012), contains two independent variables: one indicating strength of belief in local climate change effects and one indicating having observed climate change. In this model, as in all the others, the dependent variable was the binary variable indicating whether or not the respondent was “prone to adapt”. Initially, the strength of belief alternative was entered as a categorical variable using the neutral alternative as the reference, merging the three negating categories (i.e. completely, mainly and somewhat disagree) due to the low frequency of negating responses and keeping the three confirming levels separate. However, simplifying the variable to an indicator on whether or not the respondents had completely agreed had little impact on any goodness of fit measure. Both independent variables in the simple model were significant at the 95% level of confidence, and the log-likelihood statistics indicated that the model explained propensity to adapt significantly better than a model containing only the intercept. Table 1 in the supplementary material contains the model, while goodness of fit measures are enclosed in Table 5 Model 1. As in Blennow et al. 2012, two socioeconomic variables were added. Holding size was used as a proxy for income from forestry, while a binary variable indicated whether respondents had attended higher education. Only the holding size variable was significant or improved the fit (see Model 2 in Table 5 and Table 2 in the supplementary material).

*Table 5. Summary of fitted model and model diagnostics.*

| **Nr.** | **Based on** | **n** | **X structure** | **Likelihood** | | | | **AIC** | **Probabilities** | | **Sensitivity (correctly specified)** | **Pseudo $R^2$** | **Hosmer-Lemeshow $p > \chi^2$** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Log (intercept)** | **Log ratio** | **Ratio $\chi^2$** | **$p > \chi^2$** | | **Min** | **Max** | | | |
| 1 | (Blennow et al., 2012) | 873 | Two binary variables | -555.972 (-580.34) | 24.37 | 48.74 | 0.00 | 1119.13 | 0.29 | 0.56 | 27.93% (65.06%) | 0.042 | 0.54 |
| 2 | | 873 | Three binary variables | -553.341 (-580.34) | 26.72 | 53.45 | 0.00 | 1115.26 | 0.26 | 0.61 | 37.84% (64.15%) | 0.046 | 0.43 |
| 3 | (Vulturius et al., 2018) | 855 | Four binary variables | -536.73 (566.33) | 29.6 | 59.19 | 0.00 | 1083.476 | 0.25 | 0.82 | 26.40% (65.06) | 0.052 | 0.83 |
| 4 | (Vulturius et al., 2018 Blennow et al., 2012) | 873 | Five binary variables | -539.63 (-580.34) | 40.52 | 81.42 | 0.00 | 1091.89 | 0.22 | 0.83 | 33.03% (66.67%) | 0.070 | 0.63 |
| 5 | (Sousa-Silva et al., 2016) | 859 | Four binary variables | - 540.02 (-569.73) | 29.71 | 59.41 | 0.00 | 1090.05 | 0.24 | 0.79 | 43.08% (65.66%) | 0.052 | 0.93 |
| 6 | - | 859 | Eight binary variables | -524.36 (-511.65) | 58.1 | 116.2 | 0.00 | 1041.21 | 0.18 | 0.92 | 37.54% (68.10%) | 0.102 | 0.33 |

Model 3, based on the model predicting intention to adapt in Vulturius et al. (2018), was first fitted using eight variables signalling expected increase in damages to forests caused by climate change. In addition, belief in climate change being human-made was entered as a proxy for salience of climate change science, while there was no variable in the dataset that could be assumed to measure the same underlying factor as having implemented risk-mitigating measures in the past. Finally, the four variables "have sufficient knowledge about adaptive forestry" (ordered factor), "perceived need for advice on adaptive forestry (ordered factor), "have sought advice" (binary indicator), and "have received advice" (binary indicator) were tested under the assumption that they would cover the same underlying factor as the self-efficacy knowledge variable in the inspirational model.

There were multicollinearity problems between the risk-assessment candidates. Variables and factor levels were thus excluded using a combination of logic, e.g. risk of damages caused by storms (i.e. to large continuous areas) and damages caused by wind (i.e. to single trees and groups of trees), likely to be related each other, and z-statistics. There was no multicollinearity problem between the knowledge variables, but only "perceived need for advice", "having sought advice", or "having received advice" had significant impact on the dependent variable.

The final version of Model 3 contained four binary variables. The first indicated whether the respondent completely agreed that climate change was human-made. The second indicated whether he/she completely agreed that climate change would increase damages to infrastructure. The third indicated whether he/she completely agreed that storm-related damages would increase, and the final variable indicated whether he/she (completely, mainly or somewhat) disagreed to having sufficient knowledge about adaptive forestry. The final model had a marginally better AIC score, log-ratio statistics and pseudo $R^2$ measures but poorer sensitivity than the model based on Blennow et al. (2012). Model 3's goodness of fit measures are included in Table 5, number 3, while Table 3 in supplementary material contains the full model. Supplementing Model 3 with additional variables indicating whether respondents represented large holdings or had experienced climate change, improved the goodness of fit, while a variable for strength of belief had no impact on these measures. (This model is shown in Table 4 in the supplementary material, while goodness of fit measures are included in Table 5, number 4.)

Model 5, based on Sousa-Silva et al. (2016), was the best model in terms of specificity. (Table 5 in the supplementary material shows the model, while goodness of fit measures are included in Table 5, number 5.) The model has four binary independent variables. The first independent variable indicates whether the respondent completely agreed that the climate is changing, and the second indicates whether the respondent had experienced climate change. The third independent variable indicated whether the respondent disagreed that he or she had sufficient knowledge about adaptive forestry and the final independent variable indicated whether he or she believed that volume-growth would increase considerably because of climate change.

*Table 6. Logistic regression model for being prone to adapt to climate change.*

| | Coef. | Std. Err. | z | p>z | [95% Conf. Int] | | Margin | | dy/ dx |
|---|---|---|---|---|---|---|---|---|---|
| Variable | -0.905 | 0.1918 | -4.72 | 0.000 | -1.281 | -0.529 | | | |
| Have experienced climate change | 0.672 | 0.1616 | 4.16 | 0.000 | 0.356 | 0.989 | 0<br>1 | 0.327<br>0.473 | 0.145 |
| Disagree to having sufficient knowledge on adaptive forestry | -0.166 | 0.1561 | -1.07 | 0.287 | -0.472 | 0.139 | 0<br>1 | 0.392<br>0.358 | -0.033 |
| Completely agree that volume-growth will increase | 0.767 | 0.4551 | 1.69 | 0.092 | -0.124 | 1.659 | 0<br>1 | 0.373<br>0.539 | 0.166 |
| Completely agree that damages to infrastructure will increase | 0.810 | 0.2411 | 3.36 | 0.001 | 0.337 | 1.282 | 0<br>1 | 0.357<br>0.535 | 0.178 |
| Completely agree that damages from storm will increase | 0.657 | 0.2539 | 2.59 | 0.010 | 0.160 | 1.155 | 0<br>1 | 0.363<br>0.506 | 0.142 |
| Represents large holding | 0.269 | 0.1602 | 1.68 | 0.093 | -0.044 | 0.583 | 0<br>1 | 0.355<br>0.411 | 0.055 |
| Have insured forest | -0.385 | 0.1912 | -2.02 | 0.044 | -0.760 | -0.010 | 0<br>1 | 0.442<br>0.362 | -0.080 |
| Have forest education | 0.892 | 0.1770 | 5.04 | 0.000 | 0.545 | 1.239 | 0<br>1 | 0.330<br>0.527 | 0.196 |

Model 6 was the best model in terms of AIC, log likelihood, and Pseudo $R^2$. This model also had the largest spread in predicted probabilities. (Table 6 shows the model, while its goodness of fit measures are included in Table 5, number 6.) In addition to previously discussed variables, having experienced climate change, disagreeing to having sufficient knowledge, completely agreeing that volume-growth will increase, the two risk assessment variables, and a large holding indicator, this final model contained binary variables indicating whether the respondent had insured his/her forest and whether he/she had forestry education. Assessing the predictive margins and marginal effect, all the final variables had a positive impact on the probability of being prone to adapt, apart from having taken out insurance and disagreeing to having sufficient knowledge on adaptive forestry. While the effects of these latter were quite marginal, they still had a significant negative impact on the probability of being prone to adapt. The most influential variables in terms of marginal effects were (in descending order) having had forestry education (or considerable knowledge about forestry), completely agreeing that damages will increase, and completely agreeing that volume-growth will increase.

*Using models for prediction*

Models 2, 5 and 6, the three best models in terms of sensitivity (i.e. the ability to identify those prone to adapt in the train set, with a cut-off at 0.5), were tested as prediction models, using the test dataset. In the test set, there were 337 respondents classified as "prone to adapt" (≈40%), and 538 as "others" (≈60%). Table 7 shows the performance of the models in terms of overall, correct and wrong predictions. The overall proportion correctly predicted was between 60% and 65%, while the proportion correctly classified as "prone to adapt" was between 26% and 35%. The best model, in terms of identifying respondents belonging to the prone to adapt group, was Model 6. Model 5, which had the highest sensitivity rate when using the train set, achieved the poorest sensitivity rate using the test set. The model with the largest proportion of respondents incorrectly predicted as "prone to adapt" was Model 2. The differences between models were rather marginal, however, and considering the relatively small proportion correctly predicted as "prone to adapt", none can be considered particularly useful for separating between these groups.

*Table 7. Diagnostics for prediction of being prone to adapt using generalized regression models with logit link, with a cut-off at 0.5.*

| | **Model 2 n (%)** | **Model 5 n (%)** | **Model 6 n (%)** |
|---|---|---|---|
| **Prone to adapt y=1** | 337 (39%) | 337 (39%) | 337 (39%) |
| **Others y=0** | 538 (61%) | 538 (61%) | 538 (61%) |
| **Predicted y=1** | 217 (25%) | 182 (21%) | 202 (23%) |
| **Predicted y=0** | 658 (75%) | 693 (79%) | 673 (77%) |
| **Sensitivity (correctly predicted) y=1** | 107 (32 %) | 88 (26 %) | 118 (35 %) |
| **False negative (incorrectly predicted) y=0** | 230 (68 %) | 249 (74 %) | 219 (65 %) |
| **Correct negative (correctly predicted) y=0** | 430 (80 %) | 441 (82 %) | 452 (84 %) |
| **False positive (incorrectly predicted) y=1** | 108 (20 %) | 97 (18 %) | 86 (16 %) |
| **Overall proportion correctly specified** | 537 (61 %) | 529 (60 %) | 570 (65 %) |

Figure 6 shows Tjur's overlapping histograms for each of the three models. The histograms show the frequency and proportion of projected probabilities within 10% intervals for respondents classified as "prone to adapt" and the "others" for each of the models. The figure shows how the predicted probabilities of those prone to adapt and the others overlap, visualizing the relatively poor ability of the models to separate between the groups. In the figures on the left-hand side, which depict the distributions in frequency rather than proportions, it is evident that roughly the same number of the others as those prone to adapt were predicted to be prone to adapt. The proportion of respondents predicted to belong to the others group is larger than the proportion predicted to belong to the prone to adapt group, both for those who had signalled through their answers that they were prone to adapt, and for the others. In summary, Figure 6 shows how the models predicted the probability of those classified as "others" to be above 50% nearly as often as they did for those classified as "prone to adapt". However, it is also visible how the shift between the distributions of predicted probabilities is marginally clearer for Model 6 than for Models 2 and 5.

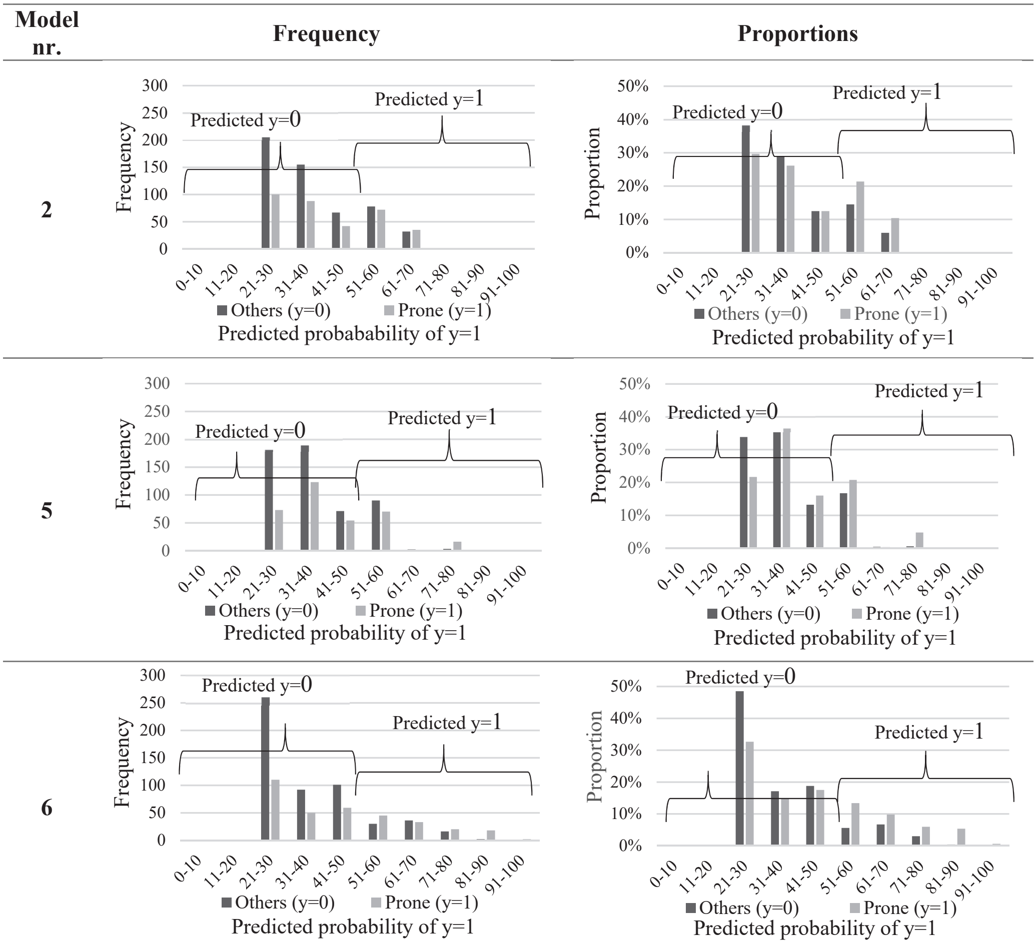



*Figure 6. Tjur's overlapping histograms (Tjur, 2009) for the predicted probabilities.*

Table 8 shows the average predicted probabilities for respondents being "prone to adapt" of those classified as "prone to adapt" and the "others", respectively, and the difference between the group averages, that is, Tjur's coefficient of discrimination. The coefficient is small for all three models, providing a final measure of the three models' relatively poor ability to discriminate between the two groups.

*Table 8. Average predicted probabilities and Tjur's coefficient of discrimination.*

| | **Model 2** | **Model 5** | **Model 6** |
|---|---|---|---|
| **Average predicted probability of y=1 for respondents in the "others" group** | 0.368 | 0.359 | 0.371 |
| **Average predicted probability of y=1 for respondents in the "prone" group** | 0.399 | 0.404 | 0.455 |
| **Tjur's coefficient of discrimination** | 0.031 | 0.045 | 0.084 |

## Discussion

The first aim of this article was to test, using a large dataset collected through a questionnaire distributed in Sweden and Norway in 2018, whether there were statistical differences between respondents who were prone to adapt and other respondents regarding variables that have been shown to impact adaptation among individual decision-makers in forestry. The second aim was to use previously published logistic regression models (Blennow et al., 2012; Sousa-Silva et al., 2016; Vulturius et al., 2018) as the bases for modelling the probability of respondents propensity to adapt. The final aim was to evaluate the models' ability to predict adaptive behaviour using independent data and assess their performance by means of model sensitivity, Tjur's histograms and Tjur's coefficient of discrimination (Tjur, 2009).

There was a significant positive relationship between being prone to adapt and strength of belief in climate change, having observed and experienced climate change, having had forestry education, owning or managing a forest holding larger than 99 hectares, and being confident about one's own knowledge about climate change-related adaptive management. In addition, those "prone to adapt" were more confident that damage to forests and forestry roads would increase because of climate change, and that tree growth would increase. Thus, we identified many of the same differences between those "prone to adapt" and other participants that for example Blennow (2012), Blennow and Persson (2009) and Blennow et al. (2012) found between adaptors and non-adaptors, and Sousa-Silva et al. (2018) and Sousa-Silva et al. (2016) found between forestry decision-makers who were more or less prone to adapt. An additional finding that contrasts with previous studies is the lack of difference between those "prone to adapt" and the others concerning level of education (Blennow et al., 2012). Furthermore, the difference between the groups regarding belief in climate change being human-made, assumed to measure the same underlying variable as (perceived) salience of climate change science (Vulturius et al., 2018), was less evident than expected, as it was significant only at the 90% level of confidence, not at the 95% level.

With regards to the other knowledge- and capacity-related variables, that is "having sought advice", "having received advice" and "having sufficient knowledge", the difference between the two groups was in accordance with findings from previous studies: those "prone to adapt" had sought out advice and could remember having received advice to a greater extent than the others. This latter (remembering having received advice) is particularly interesting with regard to the Norwegian segment of the sample, around 75% of whom had taken out insurance. They had also, some years earlier, received a flyer on how to adapt forests to wind and storms from their insurance company Skogbrand[5], this flyer contained reference to climate change. Thus, a considerably larger share of the

[5] Skogbrand is the only company that offers forest insurance in Norway.

Norwegian sample than the 184 respondents who reported having received advice had actually indeed received it. This suggests that a large share of the Norwegian respondents did not remember having done so. In addition, when asked to give the source from which they had received advice, many mentioned the Norwegian forest magazine entitled “Skog”, which is issued to all members of the associations affiliated with the Norwegian Forest Owners Federation (i.e. all associations but Norskog). All the Norwegians in the sample, except for the 45 respondents from Norskog, had access to articles in this magazine that contained advice. Again, a much larger proportion of the Norwegian sample than the 18% (n=184) who responded that they had received advice on adaptive forestry must in fact have received such advice. The proportion of those prone to adapt in the Norwegian sample who could remember having received advice was 22.5%, while the proportion of the “others” was 14.5%. A likely explanation for this could be that respondents who were already interested in these issues and thus receptive to advice had taken note of and could remember receiving it. This has policy implications concerning communicating adaptive forestry advice to Norwegian forest owners: issuing advice through magazines and/or flyers does not necessarily mean that it will be read or even noted.

The previously published models (Vulturius et al., 2018, Sousa-Silva et al., 2016, Blennow et al., 2012) were used to test significant relationships rather than for prediction; as such, it is challenging to compare the performance of previously published models with those we fitted and adjusted. Another difference between this study and prior questionnaire-based studies is the group division: that is, the dependent variable. While the groups or dependent variables in the other studies were based on a direct question about whether the decision-makers had adapted or intended to adapt to climate change, the dependent variable here was derived from whether the respondent had “completely agreed” that they would consider implementing 12 suggested adaptive practices. To avoid measurement errors in the form of acquiescence or “yes-saying” bias (Ferrando & Lorenzo-Seva, 2010), we used a generic “will you adapt to climate change” question (Dillman et al., 2009), as a more direct question could have made the participants feel that “yes” was the proper, better, preferred or right answer.

Question formulations and response alternatives varies between questionnaires, and some variables included in the previous models had no evident proxy candidates in the available dataset. Still, (proxies for) respondents’ perceived state of and need for knowledge, perceived risk, increased growth, belief and experience, which all were derived from the previously-published models, significantly contributed to explaining respondents’ propensity to adapt. This indicates that these variables are influential, independent of space.

It is worth noting that only the highest level of confidence regarding belief in climate change, belief in climate change being human-made, expected damages to forests, and expected increase in volume-growth turned out to have a significant impact on the probability of a respondent being prone to adapt. This could suggest that considering adaptation is dependent on the forest management decision-makers not only believing, but being convinced beyond doubt that climate change is happening and will affect them.

As for the models ability to predict outcome, none performed particularly well. The mean predicted probabilities for respondents being prone to adapt were below 0.5 in all the models, and the difference in mean predicted probabilities for the two groups was never above 10%. A practical interpretation of this is that, even if the state of the independent variables included in the models are known, this gives only a limited base from which to identify whether individuals in a population are "prone to adapt" their forest management to climate change.

To avoid measurement errors, such as those caused by question formulation, answer formulation, unbalanced questions, layout and order of questions, Dillman et al.'s (2009) recommendations were followed when designing the questionnaire. Wherever possible, an "other" option was provided to avoid forcing respondents to choose an inaccurate alternative answer; a neutral "no opinion" or "no change" alternative was included for the same reason. Moreover, three pilot studies were conducted to ensure that the questionnaire was user-friendly.

Sampling errors and non-response biases can be additional sources of errors in questionnaire data (Dillman et al., 2009). There are no population parameters available for the members of forest owner associations, so conducting a non-response analysis was challenging. However, comparing the net sample with overall population parameters suggested that females were underrepresented, that individuals with university (college) education were overrepresented, and that the average respondent owned or managed a larger holding than the average forest owner in both countries. It has been shown that personal interest in the topic of a questionnaire typically influences the likelihood of a respondent replying (Martin, 1994). Moreover, membership in a forest owner association signals an interest in forests and forestry, being an active forest owner, and being (at least) partially motivated by financial gain, as the associations provides knowledge, information and services, and aims to create monetary value for members through sale of roundwood. When selecting the study population, i.e. forest owner association members in Norway and Sweden, it was therefore assumed that, within this segment of forest owners, we would find the early adapters. Thus, while it is unlikely that the sample is representative of the diversity of the population of forest owners, it is reasonable to assume that the results reflect the behaviours and opinions of those who are most interested in climate change and forestry.

## Concluding remarks

When testing how logistic regressions models with “prone to adapt” as a dependent variable perform with regards to prediction, the result was rather poor. Only 26–36% of those classified as “prone to adapt” were correctly predicted when the models were applied using the test data. Thus, the variables that provide a statistically significant contribution to explaining propensity to adapt may be of little help to policymakers who want to target policy instruments at those decision makers most ready to act and change their management practices to adapt to a changing climate. While this study’s approach to modelling and choice of independent variables were guided by prior research, an alternative approach to analysing propensity to adapt and causal relationships in large datasets would be datamining, using multivariate statistical tools. This might reveal some underlying structure in the data that may offer insight into variables or combinations of variables that impact adaptation.

## Literature


Adger, W. N., Agrawala, S., Mirza, M. M. Q., Conde, C., O'Brien, K., Pulhin, J., Pulwarty, R., Smit, B. & Takahashi, K. (2007). *Assessment of adaptation practices, options, constraints and capacity. In: Climate Change 2007.: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* . In Parry, M., Canziani, O., Palutikof, J., van der Linden, P. & Hanson, C. (eds). Cambridge.

Bergh, J., Nilsson, U., Kjartansson, B. & Karlsson, M. (2010). Impact of climate change on the productivity of silver birch, Norway spruce and Scots pine stands in Sweden and economic implications for timber production. *Ecol Bull*, 53: 185-196.

Blennow, K. & Persson, J. (2009). Climate change: Motivation for taking measure to adapt. *Glob Environ Chang*, 19 (1): 100-104. doi: 10.1016/j.gloenvcha.2008.10.003.

Blennow, K. (2012). Adaptation of forest management to climate change among private individual forest owners in Sweden. *For Policy Econ*, 24: 41-47. doi: https://doi.org/10.1016/j.forpol.2011.04.005.

Blennow, K., Persson, J., Tomé, M. & Hanewinkel, M. (2012). Climate Change: Believing and Seeing Implies Adapting *PLoS ONE* 7 (11): 7. doi: doi.org/10.1371/journal.pone.0050182.

Briceno-Elizondo, E., Garcia-Gonzalo, J., Peltola, H., Matala, J. & Kellomäki, S. (2006). Sensitivity of growth of Scots pine, Norway spruce and silver birch to climate change and forest management in boreal conditions. *For Ecol Manage*, 232 (1-3): 152-167. doi: https://doi.org/10.1016/j.foreco.2006.05.062.

Crawley, M. J. (2012). *The R book*: John Wiley & Sons.

Dillman, D. A., Smyth, J. D. & Christian, L. M. (2009). *Internet, mail, and mixed-mode surveys*. The tailored design method, vol. 3. Hoboken, New Jersey: John Wiley & sons

Ferrando, P. J. & Lorenzo-Seva, U. (2010). Acquiescence as a source of bias and model and person misfit: A theoretical and empirical analysis. *Brit J of Math Stat Psy*, 63 (2): 427-448. doi: https://doi.org/10.1348/000711009X470740.

FSC, F. S. C. (2018). *Om oss [About us]*. Forest Stewardship Council: Forest Stewardship Council. Available at: https://se.fsc.org/se-se (accessed: 16.03 2018).

GFEP, G. F. E. P. o. A. o. F. t. C. C. (2009). *Adaptation of forests and people to climate change – A Global Assessment Report*. World Series vol. 22. Helsinki International Union of Forest Research Organizations (IUFRO).

Hanssen-Bauer, I., Drange, H., Førland, E., Roald, L., Børsheim, K., Hisdal, H., Lawrence, D., Nesje, A., Sandven, S., Sorteberg, A., Sundby, S., Vasskog, K. & Ådlandsvik, B. (2009). *Klima i Norge 2100. Bakgrunnsmateriale til NOU Klimatilplassing [Climate in Norway 2100. Background material for the Official Norwegian report on climate adaptation]*. Oslo: Norsk klimasenter [Norwegian climate center].

Hirsch, F. & Schmithüsen, F. J. (2010). Private forest ownership in Europe. *Geneva timber and forest study papers*, 26.

Kolström, M., Lindner, M., Vilén, T., Maroschek, M., Seidl, R., Lexer, M. J., Netherer, S., Kremer, A., Delzon, S., Barbati, A., Marchetti, M. & Corona, P. (2011). Reviewing the science and implementation of climate change adaptation measures in European forestry. *Forests*, 2 (4): 961-982.

Laakkonen, A., Zimmerer, R., Kähkönen, T., Hujala, T., Takala, T. & Tikkanen, J. (2018). Forest owners' attitudes toward pro-climate and climate-responsive forest management. *For Policy Econ*, 87: 1-10. doi: https://doi.org/10.1016/j.forpol.2017.11.001.

Lidskog, R. & Löfmarck, E. (2016). Fostering a flexible forest: Challenges and strategies in the advisory practice of a deregulated forest management system. *Forest Policy and Economics*, 62: 177-183.

Martin, C. L. (1994). The impact of topic interest on mail survey response behaviour. *J Market Res Soc*, 36 (4): 1-11. doi: https://doi.org/10.1177/147078539403600404.

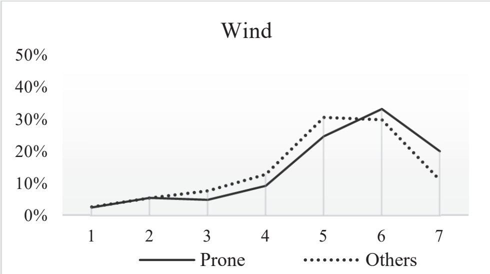
Mellanskog. (2017). *Årsredovisning [Annual report]*. Uppsala: Mellanskog.

Millar, C., Stephenson, N. & Stephens, S. (2007). Climate change and forests of the future: Managing in the face of uncertainty. *Ecol Appl*, 17 (8): 2145-2151.

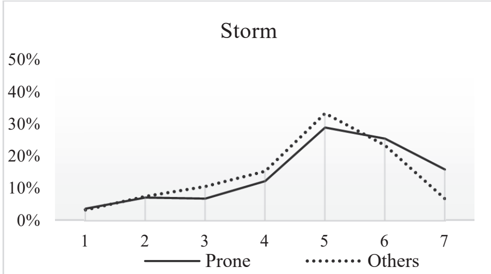
NIBIO, N. I. o. B. R. (2018). *Nøkkeltall om skog [Keynumbers forests]*. nibio.no Norwegian Institute of Bioeconomy Research. Available at: https://nibio.no/tema/skog/skog-og-miljoinformasjon-fra-landsskogtakseringen/nokkeltall (accessed: 16.03. 2018).
Norges Skogeierforbund, N. F. O. F. (2017). *Om oss (about us)*. skogeier.no: Norges Skogeierforbund [Norwegian Forest Owners' Federation],. Available at: http://www.skogeier.no/om-oss/ (accessed: 18.09 2017).
Norra Skogsägarna, N. f. o. (2018). *Om oss [About us]*. www.norraskogvirke.se: Norra Skogsägarna [Norra forest owners]. Available at: https://www.norraskogvirke.se/om-oss (accessed: 02.11 2018).
Norrskog. (2017). *Årsredovisning 2017 [Annual report 2017]*. Kramfors: Norrskog.
Norskog.no. (2018). *Om oss [About us]*. norskog.no: Norskog Available at: http://norskog.no/om-oss/ (accessed: 16.03 2018).
Ogden, A. & Innes, J. (2007). Incorporating climate change adaptation considerations into forest management planning in the boreal forest. *Int For Rev*, 9 (3): 713-733.
PEFC Norway. (2015). *Norwegian PEFC Forest Standard*. PEFC N 02. Oslo: PEFC Norway. p. 31.
PEFC Sweden. (2018). *Om svenska PEFC [About swidish PEFC]*. http://pefc.se/om-svenska-pefc/: Swedish PEFC,. Available at: http://pefc.se/om-svenska-pefc/ (accessed: 16.03 2018).
Pussinen, A., Nabuurs, G.-J., Wieggers, H. J. J., Reinds, G. J., Wamelink, G. W. W., Kros, J., Mol-Dijkstra, J. P. & de Vries, W. (2009). Modelling long-term impacts of environmental change on mid-and high-latitude European forests and options for adaptive forest management. *For Ecol Manage*, 258 (8): 1806-1813. doi: https://doi.org/10.1016/j.foreco.2009.04.007.
Questback. (2017-2018). *Questback* Available at: https://www.questback.com/2017-2018).
Riksskogstaxeringen, S. F. I. (2017). *Forest statistics 2017*. In Fransson, J. (ed.). SKOGSDATA [Forest data]. Umeå: Statistiska centralbyrån/ Riksskogstaxeringen Sveriges Lantbruksuniversitet [Statistics Sweeden/Swedish Forest Inventory Swedish University of Agricultural Sciences].
Skogbrand, S. f. G. S. i. c. (2014). *Skogbehandling før skogen kommer [forest management before the storm]*. Oslo Skogbrand forsikringselskap Gjensidige [Skogbrand insurance company].
Skogstyrelsen, S. F. A. (2017). *Skogsstyrelsens arbete för ökad klimatanpassning inom skogssektorn, Handlingsplan [The Swedish forest Agencys strategy for promotion of increased climate adaptation in the forest sector, Actionplan]*. RAPPORT Jönköping: Skogstyrelsen [Swedish Forets Agency].
SMHI, S. m. o. h. i. S. M. a. H. I. (2018). *Klimaet [Climate]*. smhi.se: Sveriges meterologiske och hydrologiske institut [Swedish Meteorological and Hydrological Institute]. Available at: https://www.smhi.se/klimat (accessed: 10.04. 2018).
Sousa-Silva, R., Ponette, Q., Verheyen, K., Van Herzele, A. & Muys, B. (2016). Adaptation of forest management to climate change as perceived by forest owners and managers in Belgium. *For Ecosyst*, 3 (22): 2-11.
Sousa-Silva, R., Verbist, B., Lomba, Â., Valent, P., Suškevičs, M., Picard, O., Hoogstra-Klein, M., Cosofret, V.-C., Bouriaud, L., Ponette, Q., Verheyen, K. & B, M. (2018). Adapting forest management to climate change in Europe: Linking perceptions to adaptive responses. *For Policy Econ*, 90: 22-30. doi: https://doi.org/10.1016/j.forpol.2018.01.004.
Spittlehouse, D. & Stewart, R. (2004). Adaptation to climate change in forest management. *BC J Ecosyst Manag*, 4 (1): 1-11.
Statacorp. (2015). *Stata Statistical Software: Release 13*. College Station, TX: StataCorp LP.2015).
Statistics Norway. (2017). *Skogeiendommer [Forest holdings]*. In ssb.no (ed.). ssb.no: Central Bureau of Statistics Norway. Available at: https://www.ssb.no/jord-skog-jakt-og-fiskeri/statistikker/stskog (accessed: 16.03 2018).
Statistics Sweden. (2014). *Skogsstatistisk årsbok 2014 [Swedish Statistical Yearbook of Forestry],*. In Christiansen, L. & Skogsstyrelsen [Swedish Forest Agency] (eds). Skogsstatistisk årsbok [Swedish Statistical Yearbook of Forestry]. Jönköping: Skogstyrelsen [Swedish Forest Agency] Official Statistics of Sweden
Södra. (2017). *Årsredovisning och hållbarhetsredovisning 2017 [Annual Report and Sustainability Report]*. Skogsudden, 351 89 Växjö: Södra.

Søgaard, G., Astrup, R., Allen, M., Andreassen, K., Bergseng, E., Fløistad, I., Hanssen, K., Hietala, A., Kvaalen, H. & Solberg, S. (2017). *Skogbehandling for verdiproduksjon i et klima i endring [Forest management for value production in a changing climate]*. NIBIO Rapport, 2464-1162. ÅS: NIBIO.
Tjur, T. (2009). Coefficients of determination in logistic regression models—A new proposal: The coefficient of discrimination. *The American Statistician*, 63 (4): 366-372.
van Gameren, V. & Zaccai, E. (2015). Private forest owners facing climate change in Wallonia: Adaptive capacity and practices. *Environ Sci Policy*, 52: 51-60. doi: https://doi.org/10.1016/j.envsci.2015.05.004.
Vulturius, G., André, K., Swartling, Å. G., Brown, C., Rounsevell, M. D. A., Jönsson, A. M. & Blanco, V. (2018). The relative importance of subjective and structural factors for individual adaptation to climate change by forest owners in Sweden. *Reg Environ Chang*, 18 (5): 1517-1571. doi: https://doi.org/10.1007/s10113-017-1218-1

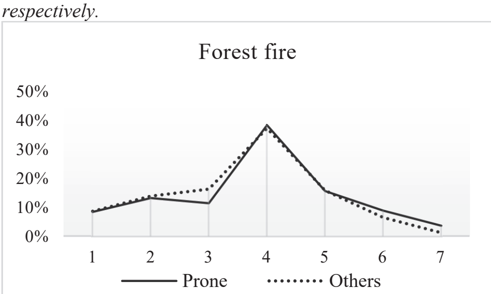
Supplementary material



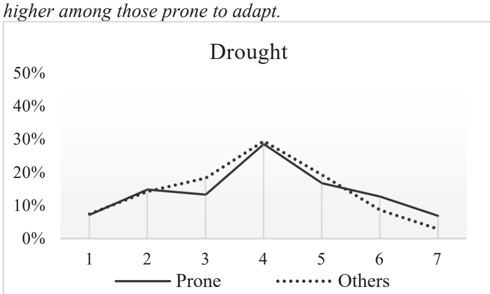

*The lower and upper quartiles and medians are 5, 6 and 6 and 4, 6 and 5 for the most prone to adapt and the others, respectively.*



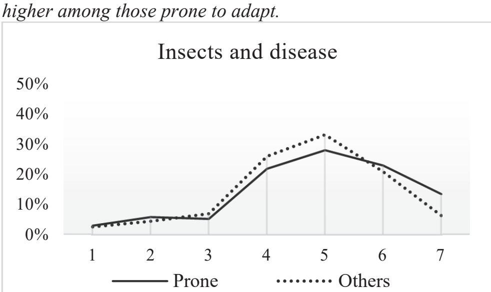

*The lower and upper quartiles and medians are 4, 6 and 5 for both groups. The mean responses was however, 0.34 points higher among those prone to adapt.*



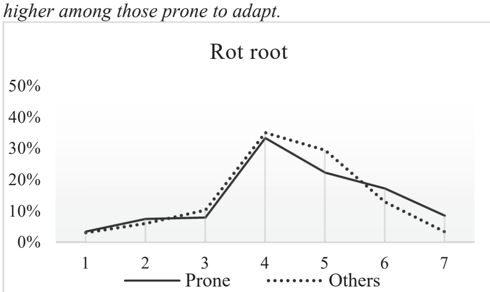

*The lower and upper quartiles and medians are 3, 5 and 4 for both groups. The mean response was, however, 0.18 points higher among those prone to adapt.*



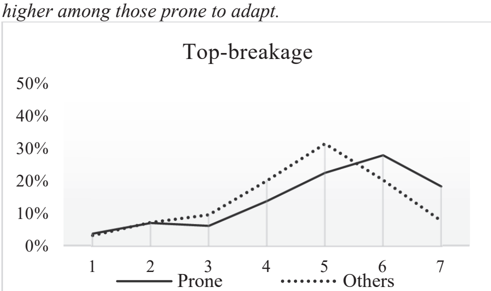

*The lower and upper quartiles and medians are 3, 5 and 4 for both groups. The mean response was, however 0.23 points higher among those prone to adapt.*



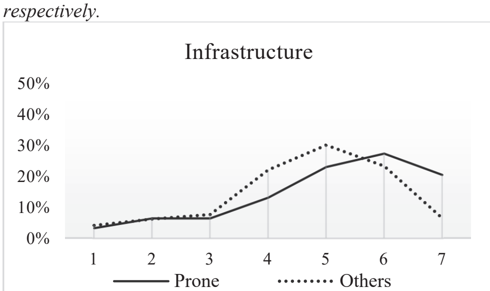

*The lower and upper quartiles and medians are 4, 6 and 5 for both groups. The mean response was, however, 0.23 points higher among those prone to adapt.*




*The lower and upper quartiles and medians are 4, 6 and 6 and 4, 5 and 5 for the most prone to adapt and the others, respectively.*

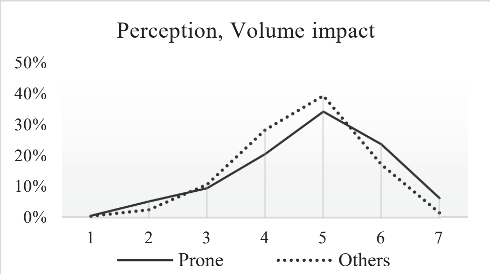



*The lower and upper quartiles and medians are 4, 6 and 5 for both groups. The mean response was, however, 0.43 points higher among those prone to adapt.*



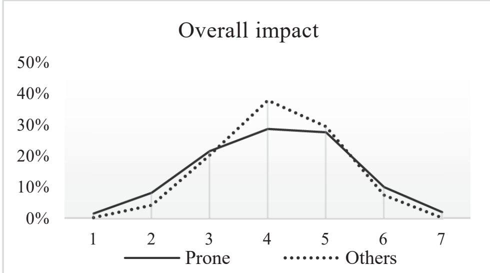

*The lower and upper quartiles and medians are 4, 6 and 5 for both groups. The mean response was, however, 0.49 points higher among those prone to adapt.*

*Supplementary Figures 1–8 show the answer distribution within the "prone to adapt" and "others" groups for 8 risk-perception measures: 1 equals "major decrease", 4 equals "no change" and 7 equals "major decrease".* Notes: 1 equals "major decrease", 4 equals "no change" and 7 equals "major decrease".




*Supplementary Figure 9. Answer distribution within the "prone to adapt" and "others" groups for expected volume-growth impact.*

Notes: 1 equals "major decrease", 4 equals "no change" and 7 equals "major decrease". The lower and upper quartiles and medians are 4, 6 and 5 and 4, 5 and 5 for the most prone to adapt and the others, respectively.




*Supplementary Figure 10. Answer distribution within the "prone to adapt" and "others" groups for expected overall impact of climate change.*

Notes: 1 equals "major decrease", 4 equals "no change" and 7 equals "major decrease". The lower and upper quartiles and medians are 3, 5 and 4 and 3.75, 5 and 4 for the most prone to adapt and the others, respectively.

*Supplementary Table 1. Regression table for Model 1.*

| | Coef. | Std. Err. | z | p>z | [95% Conf. Int] | | Margins | | dy/dx |
|---|---|---|---|---|---|---|---|---|---|
| **Constant** | -0.885 | 0.0951 | -9.31 | 0.000 | -1.072 | -0.699 | | | |
| **Completely agree that climate change is changing as holding = 1** | 0.295 | 0.1701 | 1.74 | 0.083 | -0.038 | 0.629 | 0 | 0.362 | 0.067 |
| | | | | | | | 1 | 0.429 | |
| **Have experienced climate change = 1** | 0.864 | 0.1597 | 5.41 | 0.000 | 0.551 | 1.177 | 0 | 0.309 | 0.205 |
| | | | | | | | 1 | 0.514 | |

*Supplementary Table 2. Regression table for Model 2.*

| | Coef. | Std. Err. | z | p>z | [95% Conf. Int.] | | Margins | | dy/dx |
|---|---|---|---|---|---|---|---|---|---|
| **Constant** | -1.011 | 0.1097 | -9.22 | 0.000 | -1.226 | -0.796 | | | |
| **Completely agree that climate change is changing as holding = 1** | 0.303 | 0.1708 | 1.78 | 0.076 | -0.031 | 0.638 | 0 | 0.361 | 0.069 |
| | | | | | | | 1 | 0.430 | |
| **Have experienced climate change = 1** | 0.806 | 0.1617 | 4.98 | 0.000 | 0.488 | 1.123 | 0 | 0.314 | 0.189 |
| | | | | | | | 1 | 0.504 | |
| **Represents large holding = 1** | 0.357 | 0.1473 | 2.43 | 0.015 | 0.068 | 0.646 | 0 | 0.349 | 0.080 |
| | | | | | | | 1 | 0.429 | |

*Supplementary Table 3. Regression table for Model 3.*

| | Coef. | Std. Err. | z | p>z | [95% Conf. Int.] | | Margins | dy/dx |
|---|---|---|---|---|---|---|---|---|
| **Constant** | -0.633 | 0.1065 | -5.95 | 0.000 | -0.842 | -0.424 | | |
| **Completely agree that damages to infrastructure will increase = 1** | 1.141 | 0.2304 | 4.95 | 0 | 0.689 | 1.593 | 0: 0.344<br>1: 0.615 | 0.270 |
| **Completely agree that damages from storm will increase=1** | 0.771 | 0.2448 | 3.15 | 0.002 | 0.291 | 1.251 | 0: 0.358<br>1: 0.538 | 0.179 |
| **Disagree to having sufficient knowledge on adaptive forestry = 1** | -0.445 | 0.1511 | -2.95 | 0.003 | -0.741 | -0.148 | 0: 0.417<br>1: 0.320 | -0.096 |
| **Completely agree that climate change is human-made = 1** | 0.284 | 0.1612 | 1.77 | 0.077 | -0.031 | 0.600 | 0: 0.358<br>1: 0.421 | 0.063 |

*Supplementary Table 4. Regression table for Model 4.*

| | Coef. | Std. Err. | z | p>z | [95% Conf. Int] | | Margin | dy/dx |
|---|---|---|---|---|---|---|---|---|
| **Constant** | -0.901 | 0.1248 | -7.22 | 0.000 | -1.146 | -0.656 | | |
| **Have experienced climate change = 1** | 0.728 | 0.1556 | 4.68 | 0.000 | 0.423 | 1.033 | 0: 0.323<br>1: 0.489 | 0.165 |
| **Completely agree that damages to infrastructure will increase = 1** | 0.899 | 0.2341 | 3.84 | 0.000 | 0.440 | 1.358 | 0: 0.356<br>1: 0.564 | 0.207 |
| **Completely agree that damages from storm will increase=1** | 0.6118 | 0.2491 | 2.46 | 0.014 | 0.123 | 1.100 | 0: 0.367<br>1: 0.505 | 0.138 |
| **Disagree to having sufficient knowledge on adaptive forestry = 1** | -0.333 | 0.1499 | -2.23 | 0.026 | -0.627 | -0.039 | 0: 0.411<br>1: 0.339 | -0.071 |
| **Represents large holding = 1** | 0.274 | 0.1511 | 1.81 | 0.07 | -0.022 | 0.570 | 0: 0.357<br>1: 0.417 | 0.059 |

*Supplementary Table 5. Regression table for Model 5.*

| | Coef. | Std. Err. | z | p>z | [95% Conf. Int] | | Margins | dy/dx |
|---|---|---|---|---|---|---|---|---|
| **Constant** | -0.795 | 0.1132 | -7.03 | 0.000 | -1.017 | -0.573 | | |
| **Completely agree that climate change is changing as holding =1** | 0.296 | 0.1743 | 1.7 | 0.089 | -0.045 | 0.638 | 0: 0.359<br>1: 0.426 | 0.066 |
| **Have experienced climate change =1** | 0.837 | 0.1629 | 5.14 | 0.000 | 0.517 | 1.156 | 0: 0.310<br>1: 0.505 | 0.195 |
| **Disagree to having sufficient knowledge on adaptive forestry =1** | -0.305 | 0.1495 | -2.04 | 0.041 | -0.598 | -0.012 | 0: 0.406<br>1: 0.339 | -0.066 |
| **Completely agree that volume-growth will increase =1** | 1.024 | 0.4439 | 2.31 | 0.021 | 0.154 | 1.894 | 0: 0.371<br>1: 0.608 | 0.237 |

# Paper IV

# Who and what to trust: Norwegian forestry decision-makers' interpretations of climate change information

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# Who and what to trust: Norwegian forestry decision-makers' interpretations of climate change information

## Abstract

The aim of this study was using the model of private proactive adaptation to climate change as a backdrop and as a mean to structure results for analysing how Norwegian forestry decision makers that partook in focus-group interviews spring and summer 2015 interprets the social discourse on climate change, including a.) What sources of information they trust and distrust, and why it is so b.) Which common strategies they use for contextualising and making sense of the information.
The results showed how most participants had got information about climate change through the media, and through forest media in addition to a number of other sources. Their trust in the mainstream media was very low, and it deed seem that the medias tabloid reporting on climate change negatively affected the participants appraisal of climate change risks. Participants places more trust in the forest media, but admitted and joked that this could be because this media branch fitted their biases. The participants trust in the scientific community varied. Typically, respondents used own experiences and memories to contextualize, interpret, and assess the trustworthiness of information and information sources. Many said that researchers had been wrong about similar situations in the past, often referencing the carbon sequestration debate, and reasoned that they therefore could be wrong again.

# Introduction

Boreal forests are potentially vulnerable to climate change (Adger et al., 2007), and forest scientists have stressed the need for planned adaptation for a decade (Lindner et al., 2014; Schoene & Bernier, 2012; Kolström et al., 2011; Lindner et al., 2010). The forest research communities have invested large efforts in researching various direct and indirect climate change impacts on forests and forestry, and the number of published research articles addressing aspects of climate change and forestry is growing. Scientists have also identified possible climate change adapted forest management strategies (Bolte et al., 2009; Millar et al., 2007; Ogden & Innes, 2007; Spittlehouse & Stewart, 2004) which includes management to create, promote or resist change, management to increase robustness, and passive management were natural adaptive processes deliberately are allowed to unfold without intervention. Another area of interests have been developing tools that may offer support to forestry decision makers who will have to make  management decisions under increasing risk and uncertainty, see for example Yousefpour et al. (2012) for a review. Different adaptive strategies are relevant for different areas and stands, depending on the economic and ecological value of the stand (Bolte et al., 2009) and socio-economic and political context (Keskitalo et al., 2013). According to Moser and Ekstrom (2010), (lack of) information and knowledge may become a barrier at several stages in the process. This is because the decision maker needs information and knowledge to become aware of and concerned about the problem (i.e. climate change impacts on forests), interpret problem-signals (if there are any), understand the problem, and to design and assess options. The interest and focus of the decision maker, his or her prior beliefs that dictates receptiveness to information and willingness to use it, and the (objective and perceived) availability, accessibility, salience, relevance, credibility and trustworthiness of information are thus crucial in the process and may become barriers preventing adaption. Moser and Ekstrom explain how subjective interpretations of a decision maker may be dependent on the society he or she living in, including input and signals from media, politicians, other authorities and more informal connections, e.g. peers, family, friends.

### *A conceptual model of climate change adaptation*

The social discourse on climate change is also among the three external factors assumed to influence individual cognition that again determines whether a private person will take steps to proactively adapt to climate change in the process model of private proactive adaptation to climate change (i.e. MPPACC) (Grothmann & Patt, 2005). The model is shown in Figure 1. The model assumes that two main psychological processes decides whether a private person will take steps to adapt; risk appraisal (i.e. perceived probability of being affected, and perceived severity of being affected), and adaptation appraisal (perceived adaptation efficacy, perceived self-efficacy, and perceived costs).

Risk appraisal is affected by how the individual perceive the social discourse on climate change, adaptation incentives, appraisal of experiences and cognitive biases like the optimism bias (i.e. underestimation of probabilities of being harmed compared to average) or availability heuristics (i.e. estimates of risks based on memory of examples of similar situations). The individuals objective capacity (i.e. time, money, knowledge) are an important factor impacting adaptation appraisal, to what extent they rely on the public to adapt, experiences with similar situations, they are however not the same. Individuals may have relatively high objective capacity, but still perceive that there is little they could do to adapt. The adaptation appraisal process is however also affected by the social discourse on climate change, adaptation incentives, and cognitive biases. The outcome of the model is either an intention to adapt that may or may not lead to the individual actually adapting depending on adaptive capacity, or it can be avoidant maladaptation which is a strategy to avoid stressful emotional consequences of high risk perceptions. The latter is typically the case when an individual perceive risk to be high but have low perceived adaptive capacity.

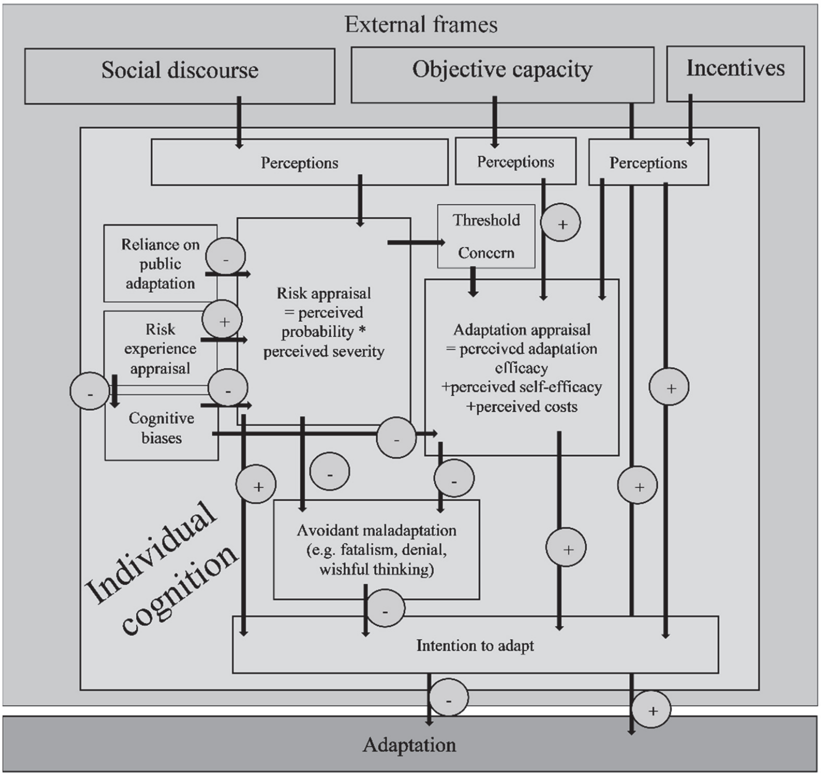


*Figure 1Process model of private proactive adaptation to climate change (MPPACC)*

### *Study aims*

The MPPACC model shows how the intention to adapt is affected by social discourse on climate change and cognitive processes and biases. Using the model as a backdrop and as a mean to structure results, the overall aim of this study is to analyse how Norwegian forestry decision makers that partook in focus-group interviews spring and summer 2015 about climate change and adaptation interprets the social discourse on climate change, including

*a.* What sources of information they trust and distrust, and why it is so

*b.* Which common strategies they use for contextualising and making sense of the information.

### *Literature review*

To the best of my knowledge, there has been no research-based studies focusing on such topics among Norwegian forestry decision makers prior to this project. However, studies who implicitly or explicitly focuses on the subject have been conducted in other countries. A few studies based on analysis of questionnaire-data reports the learning sources or preferred sources of advice of their respondents. Yousefpour and Hanewinkel (2015) for example found that out of the 263 German forestry professionals that responded to this question in their survey, approximately two out of tree answered that they updated their state of knowledge about climate change through “advanced training and information outreach activities”, “media reports, TV, daily and weekly newspapers”, and “forest literature for example forest journals”. In a study based on questionnaire-data from 7 European countries, Sousa-Silva et al. (2018) found that approximately 60% of the managers and owners (n=1131) relied on adaptation advice from forest associations, while public managers primarily relied on policy guidelines and training courses. Few (15%) used scientific literature, while a relatively large proportion (44%) relied on expert opinion of other forest managers (i.e. their peers). Sousa-Silva et al. (2016) studied the climate perception and adaptive actions taken by forestry decision makers in Belgium. They found that a large proportion of their respondents highlighted lack of information and technical knowledge as their main constraint to undertake adaptive actions, and in addition to this “knowledge deficiency” problem, argued that there is a “knowledge transfer problem” since increasing scientific knowledge does not necessarily lead to greater acceptance of climate change or behavioral change. What Sousa-Silva et al. (2016) refer to as “knowledge transfer problem”, is what Kahan et al. (2011) and Kahan et al. (2012) calls the cultural cognition theory. At the core of cultural cognition theory is the assumption that values and beliefs dictates how information about climate change is perceived. Thus, the polarization in belief and concern for climate change will be greatest in the most highly educated part of the populations, as this part of the population possesses the ability to seek out climate change information that supports their pre-existing values. Blennow et al. (2016)

tested this assumption using data from a questionnaire issued among forest owners in Germany and Sweden, but found that high scientific literacy (i.e. higher education) was uncorrelated or positively correlated with climate change concern, while there was no correlation between climate change concern and the respondents' values.  André et al. (2017) studied how knowledge sharing networks affected management decisions and climate change adaptation using questionnaire-data from 930 non-industrial private forest owners in Sweden. They found that the most common sources of information was family and co-owners, neighbors and other owners, forest owner associations, forest companies, and the Swedish Forest Agency. Approximately 50% made decisions alone, one out of three together with a partner and one out of ten with an advisor. Although there was a positive correlation between the owners' climate change perceptions and the size and heterogeneity of the owners' networks, and between climate perceptions and contact with certain "alter groups", the authors conclude that the current function of the owners' network in climate change related knowledge sharing was limited.

Qualitative studies that touches upon aspects of learning and climate change information includes van Gameren and Zaccai (2015) who found that having high knowledge about forestry, and being part of a formal or informal forestry network, promoted adaptation. Laakkonen et al. (2018), who interviewed Finnish non-industrial private forest owners about changes in their forests while walking through it, found little sense of urgency to modify behaviour among their respondents, but that the respondents had high trust in advice from forest professionals in forest management associations. Lawrence and Marzano (2014) studied forest managers and advisors in the private forest sector in Northern Wales using semi-structured telephone interviews. The main source of information about climate change and forestry was the government-sponsored body "Forestry Commission Wales" (Natural Resources Wales after a merge in 2013) the website of the foresters' professional association, and forest research (through events, and individual key-informants). Some had little time to indulge in updating their knowledge, some also thought the flow of information and experience sharing amongst private owners was poor but also  that there was too much information and emails. Bissonnette et al. (2017) interviewed non-industrial private forest owners in the Quebec region of Canada. Although most participants acknowledge human-made climate change, they perceived it as rather abstract in the forestry context, and some suspected that available mainstream information about climate change was unreliable and they considered climate change at present to be of little consequence to forest management. Grotta et al. (2013) collected their data in focus-group interviews with non-industrial private forest owners in the American Pacific Northwest. The participants had had acquired their knowledge through a wide range of sources. Some had sought information, while most had remained passive and gained knowledge through mass media. The participants doubted the trustworthiness of the information they were exposed to, suspected the dissemination of being biased, and perceived that the presented evidence was ambiguous. Although they in general considered the scientific community as trustworthy, many also suspected scientists of being biased.

Finally, there are a number of relevant qualitative studies from Sweden; Uggla and Lidskog (2016) studied non-industrial private forest owners perceptions of climate change, risk management and forest governance from the perspective of support and barriers towards change embedded in traditions and previous management schemes. They found that "… *the dissemination of knowledge and advice seems to be a rather diffuse process involving various actors, information sources and contexts*". Lidskog and Löfmarck (2016) interviewed forest consultants employed in the agency about the challenges they face and the strategies they apply to operationalize public forest policy (e.g. climate change adaptation) objectives. The Swedish consultants regarded the uncertainties associated with the consequences, rate and magnitude of climate change as a great challenge in their work. They also regarded uncertainty associated which choice and effectiveness of adaptive measures, and the conflict between the long time perceptive of climate change and more short-term operational forest management plans[1] as challenging.. Other challenges included lack of formal tools for reinforcing policy objectives, competing advice from for example forest companies and other consultants within the agency, decreasing social status and thus trust embedded in their profession, and increasing heterogeneity among owners. To cope with uncertainty when advising clients, the agents chose to articulate uncertainty because suppressing it would make them seem untrustworthy, argue for risk diversification, and use the uncertainty as an argument for management that would fulfill national objectives. When giving specific advice the forest consultants used historical references, aiming to communicate the reasons for the current condition in the stand and how the stand or results could have turned out differently if different management had been applied, and contextualize and adapt the advises to suit both the stand and the particular forest owner. Recommendations that originate from the Swedish Forest Agency do however not necessarily change behavior. After the storm Gudrun in 2005, who damaged approximately 2700 $km^2$ hectares of forest, the agency recommended increased planting of deciduous trees and pine, and issued subsidies to promote this. In spite of this recommendation, non-industrial private forest owners having become more aware of wind risk (Ingemarson et al., 2006), and the experience, the majority replanted spruce. Lidskog and Sjödin (2014) studied the owners underlying motivations for effectively recreating vulnerable forests by analysing material from three interview-based studies (Linné, 2011; Sellerberg, 2011; Guldåker, 2009) and the survey of Ingemarson et al. (2006). They found that three main lines of reasoning had guided the owners' choices. First, an understanding or framing of calamites as impossible to mitigate. Second, there was uncertainty associated with alternative regeneration choices and subsequent management, need for changed management and uncertainty regarding the effect of climate change. There was also uncertainty regarding growth, soil and climate requirements of alternative species and finally uncertainty regarding the market for deciduous species. Finally, the forest owners considered

[1] According to the authors, a standard Swedish forest management plan has a time perspective of 10 years.

the short-time economic burden (workload etc.) associated with changing the dominating species as larger than the benefits

"Transformative learning theory" (Mezirow, 2008), assumes that acquiring knowledge and learning experiences may change individuals' beliefs, perceptions and behaviour (Diduck, 2010). Vulturius and Swartling (2015) applied this theory in their analysis of forest professionals learning and perceptions of climate change. The theory consider two types of transformative learning-types: instrumental and communicative. Instrumental learning focuses on solving problems and includes acquiring new knowledge that enables actors adapt to new situations. Communicative learning focuses on increasing actors' ability to understand people's values, beliefs and behaviour. Because deep beliefs and existing frames of references rarely changes, learning is more likely to change the actors' attitudes than their underlying values (Mezirow, 2000). Vulturius and Swartling (2015) utilises data from follow-up interviews with four groups of forestry stakeholders who had participated in a series of group-discussions about climate change and adaptation. In the interviews, nine participants stated that participating had considerably or somewhat influenced their climate change perceptions, ten that effect had been marginal or indirect, and a minority that participating had not influenced their views. Participation had not increased the participants' sense of urgency to adapt, nor did they perceive that the presented science had direct implications for forest management. The authors identified a deviation between science and the participants own experiences as one of the main reasons for this, and stated that the way people consider personal experience when forming opinions about the validity of science is a potential barrier towards climate change adaptation. Another identified barrier was the participants' sense-making concerning scientific uncertainty: many respondents preferred to wait and see. A third barrier was the time horizon, the participants considered the long time between implementing suggested actions and finding out whether the action was effective too long. Trust in climate change science was identified as a key to learning experience and engagement with adaptation, but the respondents expressed that for scientific results to influence their behaviour, it needed to be *"... well founded, tested and generally accepted"*. Finally, the authors found that perceived biases towards environmentalism among scientists, perceived tendency to exaggerate environmental problems for their own benefit, and previous experiences with science, shaped the participants trust in climate change science. An example of such previous experiences was a reference to the acid rain debate, where a participant explained being a sceptic because of nothing that was said back then had been realised.

# Material and Method

***Study area***

This study was conducted among forestry decision makers in the Southeastern Norwegian counties Oslo, Akershus, Østfold, Vestfold, Telemark, Buskerud, Hedmark and Oppland. In total, there is approximately three million hectares productive forestland in the region, consisting mainly of even-aged mixed stands dominated by Norway spruce *(Picea abies (L.) Karst.)* or Scots pine *((Pinus sylvestris L.).* Clear cutting, followed by planting (of spruce) or natural regeneration (if pine) are widely applied, and pre-commercial and commercial thinnings are relatively common in the area (Statistics Norway, 2018). Site quality, property sizes, topography and local climate vary within and between counties, and non-industrial private forest owners (NIPFs) own the majority of forestland (Statistics Norway, 2017).

The forest owner associations Glommen, Viken, Mjøsen and Norskog are the dominant providers of advice to forest owners in the region. Glommen, Viken and Mjøsen are forest owners' cooperatives in the Norwegian Forest Owner's Federation structure. They buy roundwood from their members, which is resold to domestic and international buyers. Often, the associations organise the harvest, the transportation, and other services. Norskog is an independent association who offer advice and political representation to their members. Norskog do not trade roundwood, but their daughter company Nortømmer do (Norskog.no, 2018). All the Norwegian forest owner associations are PEFC members (PEFC Norway, 2015), and are committed to trade roundwood from certified forests only. Apart from having to follow the PEFC standard and national law and regulations, Norwegian forest owners are free to manage their holdings according to their own objectives.

Climate change related forest policy in Norway has focused on promoting mitigation. To increase carbon sequestration, the Norwegian parliament have issued two subsidies. One supports higher planting densities, the other fertilization. The subsidies are granted after application (Stortinget, 2015). In 2016, a public webpage (klimatilpasning.no, 2016) containg information and advice on adaptation was launged. The webpage has a forestry section which contains links to a flyer about forets management for wind resitance (Skogbrand, 2014) issued by the Norewgian forest insurance company Skogbrand, current roadbuilding-standards and the Noregian PEFC standard (PEFC Norway, 2015).

***Focus-groups***

The data for this article was collected through in-person semi-structured group interviews. The qualitative approach allows direct interaction with participants. Such in-person contact between researcher and study-objects (may) allow the researcher to see, understand, and interpret the topic of interest through the eyes of the study objects. A qualitative design also ensures rich and nuanced data, and is therefore useful when researching social phenomena such as perceptions, beliefs and sense-making. Conducting interviews in focus-groups (may) provide an understanding of how individuals through interaction with others construct understanding (i.e. make sense) around topics. The focus-group setting furthermore forces the moderator to relinquish some control over the interview, as the participants will interact with each other and not only with the moderator, a focus-group interview can therefore resemble everyday communication between peers and because of this increase the probability of collecting data that truly represent the thoughts and views of the participants (Bryman, 2001).

### *Design*

To avoid limiting or framing the data-collection process and data-analysis, no theoretical framework hypothesis, theory, coding system or similar was defined prior to the data collection. However, the main topics for the interview-guide was chosen after having reviewed the literature on climate change adaptation in forestry. Thus, earlier empirical results still influenced the process.

i) Climate change related experiences and beliefs (Blennow, 2012; Blennow & Persson, 2009; Weber, 2006)
ii) Knowledge about climate change (Yousefpour & Hanewinkel, 2015; Blennow, 2012)
iii) Adaptation to climate change (Lawrence & Marzano, 2014; Blennow, 2012)
iv) Climate change related risk and uncertainty in forestry

Apart from naming the key topics, the interview guide contained suggestions for questions and keywords to help the moderator along in the interview-process if needed. The supplementary material contain a translated version of the interview guide.

#### *Recruiting respondents*

The focus-groups was recruited using a criterion-based sampling approach. Administrative staff in the Southeastern forest owner associations identified and approached interview candidates among their staff and members. The selection criterions were (i) candidates among forest owners and forest managers should actively be managing a forest holding, and (ii) candidates among staff should hold positions that involved contact with forest owners and forest managers.

#### *Data collection and treatment*

The data-collection consisted of 10 semi-structured focus-group interviews. In total, 15 forest advisors, 26 (previous, current, or coming) NIPFs, and 13 forest managers responsible for the management of a large private or public forest holding participated in the interviews. Except from Group 6, there were one or several participants with forestry related education in all focus groups.

Thirty-four out of 54 participants had some form of forestry education from either University or University College, vocational school, or high school. The most experienced forest advisor had worked in the sector for 38 years, while the least experienced advisor had worked in the sector approximately one year only. The majority of forest managers had been in the forest-based sector for more than 25 years, and only three had less than 11 years of experience. The newest NIPF had owned his holding for 1 year, while the most seasoned NIPF had been 46 years of ownership experience. Group 6 was the only group recruited without assistance of administrative staff in forest owner associations, as this interview initially was intended as a test of the interview-guide. All groups, but Group 4 were pre-existing groups (Bryman, 2001), meaning that the groups met regularly, through forest owner associations or similar. Table 1 gives an overview over the groups.

*Table 1 Group composition*

| ID | Number of group members | Stakeholder characteristic | Group composition and additional information |
|---|---|---|---|
| **1** | 3 | Advisors | The members of these groups were colleagues. Five advisors owned forest holdings. |
| **2** | 5 | | |
| **3** | 4 | | |
| **4** | 3 | Non-industrial private forest owners (NIPFs) | The members of Group 4 and Group 5 owned holdings in the same county, while the members of Group 6 owned holdings in the same community. |
| **5** | 4 | | |
| **6** | 4 | One future and three current NIPFs | |
| **7** | 4 | One future and three current NIPFs | The members of Group 7 were recruited through a local chapter of the Norwegian farmers association, and owned holdings in the same community. We intended this interview to be a pilot, but did not change the interview guide following this interview. We therefore chose to include the data from this interview in the analysis. |
| **8** | 12 | Mixed groups consisting of NIPFs, forest managers and forest advisors | All members of Group 8 either worked or owned forest holdings in the same community. The members of Groups 9 and 10 had no common geographical affiliation. |
| **9** | 8 | | |
| **10** | 7 | | |

The interviews were held between May 30th and September 27th 2016. The groups chose the locations. The moderator started all interview-sessions with information about the research project and data storage after which the participants gave us their socio-demographic and forest property data by filling in a short form. Then, the moderator started the recorder, and introduced the first topic from the interview-guide. After this, the topic order varied between interviews dependent on the course of each group discussion. To avoid (mis-)leading the replies the moderator strived to introduce topics openly, and to let the groups discuss freely without too much moderation. However, when necessary, the moderator would pass the word by glance, hand or words encouraging involvement from all participants. The moderator also intervened asking for clarifications, elaborations and exemplifications, asking follow-up questions, summarizing the discussion on a topic asking the groups to comment and so forth. Each interview lasted between one and two hours. The moderator transcribed the audio-files from the interviews. Our data-analysis was primarily based on these transcripts.

***Analysis***

According to Nilssen (2012), the qualitative analysis start during the data collection and continues through transcription, coding, systemization and summarization etc. Compared to quantitative analysis, qualitative analyses are non-linear as the researcher must interpret the meaning of statements already during the interviews. Inevitably, impressions formed during the first interview will affect the later interviews. Likewise, impressions and ad-hock hypothesis formed when transcribing, reading or coding one interview will influence these processes when working with the other data. The traditional "analysis-stage" of the research process however progressed as follows: first, the transcript were coded "bottom up", marking the statements with short codes marking their meaning using words close to those of the participants using the Nvivo Software (QSR International Pty Ltd, 2015). In this stage, the coding stemmed from the data (Berg, 2001). The initial open coding approach gave a large number of categories, which was grouped into broader themes.

During this process, I found that the data on participants perceptions of the discourses on climate change in society and their descriptions, or rather reasoning, on how this affected their climate change perceptions was so extensive and rich that it would deserve a separate analysis and presentation. Then, a new process started with re-listening to records and re-reading transcripts. Posterior to this, all sections containing such data was extracted, themes and meanings was identified and finally systematized according to the model of Grothmann and Patt (2005). In the process, I emphasized identifying both the typical meanings and perceptions shared by many participants, and the extremes.

# Results

***Assessments of mainstream media, and media reporting impact on risk appraisal.***

Only two sources of information on climate change were discussed in all groups. These two were “the (mainstream) media” and “the forest magazines”. In addition, the weather forecast webpage “yr.no” was mentioned in near all interviews, although when referring to this page it varied whether respondents meant short time forecasts of in-depth articles about climate change showing how some confused climate change with weather. Generally, the respondents had read, heard or watched what was on in the media, and not actively searched out information about climate change themselves. There were some exceptions, including one participants that had looked up information from so-called climate realists. With some exceptions, participants generally mistrusted all climate information they had been exposed to through the media, expressing that the media tended not to base their reporting on facts, but loved putting “monster” in front of everything, i.e. “monster-rain”, “monster-wind” and “monster-weather” and being on the lookout for sensations and big headings. Typically, the participants would explain how this often turned out to be quite ordinary Norwegian “bad weather”. Other descriptions of the medias reporting on climate change was ambiguous, exaggerating, tabloid and contradictory. The quote below is representative:

***[Forest advisor, Group 1]*** *“It is not based on facts what comes out of there. Too many people have too much to say, and then it’s all about who shouts the loudest”.*

A common way of reasoning was that the focus on climate change in all possible channels made it near impossible not pick up some of it:

***[NIPF, Group 4]*** *“Nobody can say that they know enough about this thing, but I read the news and I listen to the radio and I do pay attention to what they are saying”*

Some participants talked about not really being able to assess all the information available out there, while others were convinced that they had common sense or knowledge enough to assess both media reporting and climate change impacts. It was however also common that somebody would express that there too much information and media focus on climate change, and that none of those talking about it seemed to agree on the seriousness of it all. Some handled this with saying that since there was so much disagreement; they choose to believe that it could not be so bad after all to make them sleep at night. It was not clear weather this was an avoidant, so-called maladaptive strategy for avoiding discomfort or based on risk appraisal (i.e. perceived low probability of impact). Others were more clear that the spread in reporting, together with appraisal of experiences with the media and the whether (e.g. comparisons of intimidating forecasts of events with memories of how things had turned out) affected their perception of risk and their level of concern:

***[Forest advisor 2]*** *"… You hear something (in the media), but after a while it turns out it was not so bad after all. The next winter, it is more snow on the North Pole again. Then, summer comes with ultraviolet radiation and I do not know what.  There is a lot of contradictions!."*

Participants also talked about how they assessed climate change information by comparing todays weather with descriptions of the weather from all diaries, weather data-series at their holding, and talking to old people, previous owners and so forth about whether or not there actually had been a change.

***Assessments of the forest media, and forest medias impact on climate change perceptions.***

All participants had access to some forest magazine, and most gave the impression that they read, or rather skimmed, the full volumes. In to reading the Norwegian "Skog[2]" and/or "Norsk Skogbruk[3]", managers and forest advisors sometimes mentioned information about climate change the newsletters from their organization, and the Swedish magazine "Skogen[4]". The participants expressed relatively high trust in the information they got from forestry magazines:

***[NIPF, Group 4]*** *"(I think) what is in the sectorial magazines, it is more based on facts (than what is in the mainstream media). Moreover, it comes from professional communities one can trust more than one can trust those in the press."*

However, after such statement, moderations often accompanied by laughter, were common. Typically, someone word say something in the line of how the information in forestry magazines fitted their beliefs and thus was intuitively easy to place trust in.

The forestry magazines to be particularly trustworthy when it came to a carbon-sequestration debate that had taken place in Norway prior to the interviews. References to this debate (i.e. whether traditional Norwegian forestry with clear-cuts an relatively short rotation ages is the best management for climate change mitigation), was often the first intuitive response of many when the section on information and knowledge on climate change was introduced. This topic furthermore surfaced

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[2] [Forests] Membership magazine for the regional forest owner associations affiliated with the Norwegian Forest Owners Federation.

[3] [Norwegian forestry] A Norwegian forestry magazine that is independent of owner associations, but affiliated with the "Det norske skogselskap [Norwegian forest society]", an NGO who promotes "forests as a valuable source of life quality for all humans". The magazine is available by subscription.

[4] [The forest] Swedish forestry magazine, affiliated with the NGO "Skogen" [The forest], a NGO working to promote use of forests.

several times during the interviews, evoked engagement and temperature, and who for many seemed to overshadow other aspects of climate change (i.e. climate change related risks). The participants were furthermore very much aware of research results from Norway (Holtsmark, 2016) suggesting no (short-term) positive effect of forestry (i.e. when participants talked about forestry, it was clear that their understanding of this term was clear-cuts, short rotation ages, even-aged, mixed species stands dominated by same species stands). The participants dismissed these results:

***[NIPF, Group 4]*** *"I must confess, I read these things and I did fall for it at the time. Then, I read the replies from very competent forestry-people who wrote that actively managing forests contributes positively. That leaves me in a position where I can choose what to believe, and then I choose the side who says that we (forestry) contribute in a positive way".*

A common perception was that stopping harvests and letting  forests grow "wild", would lead to trees dying and $CO_2$ returning to the atmosphere. Traditional forestry could on the other hand maximize the amount of sequestered carbon. Several participants expressed annoyance over the media attention "the other side" received, and perceived Holtsmark to be a spokesperson for those opposing the way of forestry they themselves favoured rather than being objectively presenting research results. Other groups considered this type of research too abstract and unrealistic in its assumptions to regard arguments derived from it relevant. Both NIPFs and forest advisors suggested, or joked, that stakeholders promoting climate mitigation through longer rotations and stopping clear-cuts had hidden motives. They for example suggested that "these people's interests" lay in preserving the forest for sentimental feelings, or promotion of biodiversity because of, according to one advisor in group three: *an exaggerated love for bugs, lichen and moss".* Participants talked about the environmentalist as *"the other side",* and said that their goal was to influence the public and politicians to "turn against" forestry and prevent commercial exploration. One noteworthy element was that while the participants in general had signalled that they had remained passive recipients of climate change information (i.e. randomly read, heard, watched whatever was "on" in media), several talked about how they had searched out information enabling them to argue their case against those advocating views different from their own on carbon-sequestration:

***[Forest advisor, Group 3]*** *"They (the environmentalists) are much better than us at communication. It does not matter which newspaper you open, you will find something from them there. They are extremists in their way. It is important that we find arguments against it".*

All who voiced opinions were convinced about the benefit of modern Norwegian forestry and many said that forestry was "good" in the climate context, for example:

***[Forest advisor, Group 2]*** *"… I have picked up a little (knowledge) here and there, and what I am sure about is that what we are doing (forestry) is a good thing in the climate change context. We are harvesting from nature, when the tree has finished growing and then we plant new trees, so my conscience is clean…"*

Another group member echoed the statement, and explained how his feelings told him that active forestry was beneficial for mitigation:

***[Forest advisor, Group 2]*** *"I will gladly admit my bias – I believe that forestry has a very positive effect…. I am probably a little too caught up in carbon sequestration (….) but my beliefs follow my feelings; forestry is very close to my heart so I am convinced that this is the way to go!"*

These two was not alone in referring to feelings of how forestry was the right thing announcing how they was biased, or. It was relatively common that the participants at some points either joked about this, or simply noted that it was only to expect that their background and education, affiliation or occupation influenced them.

***Science based information and trust in researchers***

Throughout the interviews, participants referred to (knowledge originating from) research in different contexts (e.g. the researcher are saying, if you listen to research, reading research etc.). While this for some participants meant reading actual research papers or research paper abstracts, or popular science, "reading research" could also mean a reference to research in some media, for example:

***[Forest manager, Group 9]*** *"There are articles about climate change in "Norsk Skogbruk" and in our news-letter, and then there is research… and …Swedish forest magazines."*
***[Moderator]*** *"You read research-articles?"*
***[Forest manager, Group 9]*** *… "Well, no, but it [research] is referred to".*

The moderator got the impression that at least some of the participants had a different perception of what "reading research" meant, than what this would mean within the scientific community (e.g. f articles in peer-reviewed journals). Sometimes, participants would also refer to "research says" to substantiate some argument or reasoning, or to defend some perception, stance or assessment. In one case, it turned out that what the participant had meant by reading research was articles about climate change in a national newspapers weekend-magazine. One sole participant referred to the IPCC, and how the organisation presented the work of many research-groups from around the world. He however still expressed some uncertainty regarding the level of scientific consensus, and said he felt overwhelmed by all the amount of available knowledge.

The Norwegian meteorologists were perceived as more trustworthy than other scientists, even though a reappearing joke was something in the line of meteorologists seemingly being unable to produce reliable weather forecasts for one day ahead, and that it thus was rather remarkable that they could forecast climate change for the next century. Still, the participants considered the meteorologists the most trust-worthy research-community. The participants' thoughts on the trustworthiness of researchers can best be described as diverse. Many perceived the research-community to be in disagreement about either the cause, the scope, or the consequences of climate change, alternatively about all. The underlying reasoning then being, that for some researchers to be right, others had to be wrong:

***[NIPF, Group 4]*** *"I find it alarming that so-called experts draw the complete opposite conclusions. What are we supposed to think? Especially when these researchers should have the exact same background and basis for assessment and they still conclude quite contradictory".*

A quite usual stance was that if a participant perceived that a researcher admitted there were limits to his or her knowledge, this inspired trust:

***[Forest advisor, Group 1]*** *"I trust those who aren't controversial, those who aren't so extreme, and admit that they don't know everything. And, you have to remember, they all have their background and their motives".*

The latter part of the above statement, hinting that all researchers have biases, was often repeated. Both the researchers' personal values, their background, and financial gain was among the suggested motivations for research results, for example:

***[NIPF, Group 8]*** *"We joke a lot about it, when they say new American research show… and then it all depends who funded the study".*

Opinions varied when it came to forest researchers. One forest advisor dryly implied that forest research were irrelevant to practitioners:

***[Forest advisor, Group 1]*** *"...during my time at Ås (the Norwegian University of Life Sciences), we (forestry students) read a lot of research articles. I have to say, it's not like they always had anything to do with actual forestry…"*

The advisors in Group 2 made sure to ad that if researchers were to contribute with anything of value, they had to make clear recommendations, implying that (they perceived) researchers sometimes to be too vague to offer real guidance:

***[Forest advisor, Group 3]*** *".... and then, we do not want a bunch of factors and numbers and graphs on the table, accompanied by: you choose".*

Others thought forest researchers were more trustworthy than most:

***[NIPF, Group 6]*** *"It is very hard, assessing this, but I think I trust those who study forestry at little distance. So my answer will be that I trust forest researchers".*

In addition to the reasons listed above for remaining sceptical towards researchers and research results, were remembrance of researchers being wrong about risk in the past. A typical example mentioned by several In the 80ties and 90ties, a large coalition of researchers both within and outside Norway, politicians, NGO's and worried citizens agreed that large areas of Norwegian forests were dying due to acid rain, while Norwegian forest researchers claimed that there were no empirical evidence supporting such a suspicion. The debate was heated and received massive press-attention. The aftermath showed that the national forest researchers had been right (Wigen, 2016). During the interviews, it did not appear that the forestry decision makers necessarily divided between different groups of researchers in the debate: they foremost remember how scientists with confidence had predicted forest die-back and destruction and that this turned out quite differently. Another example of old "wrongs" the participants joked about devaluating researchers, was the advice of a former forestry professor who up through the years had advocated risk spreading by promotion of deciduous trees. The attitude of the participants quite clearly showed that they thought history and market development had proven the professor wrong. The ozone layer scare was also mentioned, and closely related to this, the participants tended to balance and compare research based knowledge about climate change to own experiences and fragments of knowledge from history, geology and similar. Several for example said that there might be critically warm in a short perspective, but the real problem could be that earth were heading towards a new ice age. Reasoning such as this, often to explain why one should not panic over the climate changing, was rather common among both NIPFs, managers and advisors:

***[Forest manager, Group 9]*** *"... It seems that the masses only recently have become aware of the carbon cycle, and they are exaggerating. There have always been climate change, there has been* *forests on the Hardanger plateau, large oak forests in eastern Norway and in the eighteen century the climate got worse because of a volcano outburst in the Canary Islands"*

***How the actions of politicians impacted trust.***

Both national and international politicians were described as unreliable and unpredictable. Several used the now elected American president as an example. A common suggestion or joke with undertones was that the Norwegian politicians exploited climate change as an excuse to increase public income.

***[Forest manager, Group 3]*** *"To me it seems like it (climate change) primarily have become an argument for increasing taxes and fees".*

In one group, politicians lack of action to mitigate or slow down climate change was even mentioned as a reason for not being alarmed, since politicians for sure would have acted if there was real danger of being severely affected by climate change.

Most participants regarded policy changes and politicians a greater risk to forestry than climate change, and substantiated this view by contrasting the government's strategy for increasing carbon sequestration with that of conserving 10 percent of Norwegian forests. Others pointed out how an abrupt change in regulations stopped production of bio-based fuels some years ago, which they considered a non-science based political horse-trade. The newly implemented forestry and climate change policy of subsidies for higher plant density were according to the participants yet another strange example of unpredictable policy. None could understand what mitigation-effect this policy would have, since the extra seedlings would typically end up be removed during pre-commercial thinning:

***[Forest manager, Group 9]*** *"That subsidy for increased plant density, it is close to ridiculous if the point is carbon sequestration, the recommendation is pre-commercial thinnings and then you will cut back more than the extra plants, no, I don't understand!".*

## Discussion

The aim of this article was to analyse how Norwegian forestry decision makers that partook in focus-group interviews spring and summer 2015 about climate change and adaptation interprets the social discourse on climate change, including

a. What sources of information they trust and distrust, and why it is so
b. How they contextualise and make sense of the information, and how it impacts their climate change perceptions.

We found that the two most common sources of climate change information was the media and the forest media, and that the participants in general put very little trust in information originating from the former. In the model of Grothmann and Patt (2005), social discourse including information from the media, cognitive biases and appraisal of experiences are factors assumed to affect risk perceptions. From the results, it seems that the media reporting on climate change in Norway as perceived by the participants affected their appraisal of risk negatively, although some of the participants could also be interpreted as maladaptive when they for talked about choosing what to believe to make them sleep at night. The respondents perception of media-reporting on climate change is in line with research results: a study of Norwegian media's coverage of climate change published in 2006 (Ryghaug) showed that the coverage of climate change up to that point had been characterized by dramaturgy, and that journalistic narratives had emphasized scientific controversy. In the study, the authors also identified a tendency to balance the views of climate scientists with those of sceptics in the dissemination. Such balanced reporting of the climate change debate (Antilla, 2005), have also been found in other countries (Carvalho, 2007; Carvalho, 2005; Dispensa & Brulle, 2003). The participants' examples of media reporting, for example the use of exaggerated expressions like "monster-"weather, and their notion of (presumed) climate experts being in disagreement, are furthermore consistent with the perceptions of Norwegian citizens without affiliation with forestry (Ryghaug et al., 2011). Thus, evidence suggests that at least parts of the media reporting on climate change in Norway are in fact in-consistent and tabloid, and that the public are aware of this and interprets media-reports accordingly. The underlying perception that journalists frame news to scare, sell, and create online clicks may furthermore have diluted the message about the severity of climate change. The Norwegians are not unique in having public media among their main source of climate change information, nor are they unique in not trusting the media. Other examples of studies reporting public media being either the main, or one of the main, sources of information is Grotta et al. (2013) and Yousefpour and Hanewinkel (2015). The description of the lack of trustworthiness of climate change related news in the mass-media that are known to dramatize to create scandal and scare, is similar to that reported by Grotta et al. (2013), and lack of trust in mainstream information was mentioned also by the respondents of Bissonnette et al. (2017).

Another important source of information were the forest magazines. Generally, participants placed more trust in these than in the mainstream media, although admitting that this might be because the forest magazines echoed their biases. This was particularly the case for the carbon-sequestration debate, which was the first issue many associated with climate change suggesting that at least until the point of the focus group interviews, this debate had caught more interest and focus than other aspects of climate change. The focus on this part of the social discourse of climate change may have lead participants to not thinking about physical risks associated with climate change, but rather on the risk of their autonomy being limited through policy influenced by those promoting longer rotations and stop in harvest for mitigation. The According to Moser and Ekstrom (2010) framework, the lack of interest and focus of decision makers may become a barrier preventing them to move forward towards adaptation, and considering the respondents engagement with the carbon sequestration debate, is not unlikely that this could be the case in Norway. Another potential barrier could be the participants' tendency to undermine, distrust and reject the information contradicting their views, beliefs, frames, or sometimes feelings, assuming that this may transfer to other parts of climate change information than information concerning carbon-sequestration. The participants' attitude towards "new" forestry practices could indicate that this is the case: although the participants in general said that they did trust forest scientists, several considered forest science (or forest scientists' dissemination) too abstract to have any practical relevance

To make sense of, assess, and contextualize information, those who participated in this study described drawing on their own experiences, personal sources of information like diaries containing descriptions of the weather and "old" debates that shared similarities with the climate change debate. According to Grothmann and Patt (2005) such biases typically influences risk perceptions, but there, it seemed that they also influenced the assessment of the discourse on climate change, including that originating from science.

High trust in climate change science and strength of belief in climate change has repeatedly been identified as one of the key variables that promotes climate change adaptation in forestry (Vulturius et al., 2018; Blennow et al., 2012). Lack of trust, salience and clarity of information may on the other side prevent people from engaging in adaptation (Moser & Ekstrom, 2010). However, it is reasonable to assume that the respondents' constant exposure to a mixture of opinions and more or less research-based information through the media also affected the assessed trustworthiness of information sources underlying the media reports, and influenced the participants assessment of for example climate change science.  Except for most respondents agreeing that the Norwegian meteorologists were trustworthy (but even this was joked about), there were in fact no source of information, research institution or authority the respondents fully trusted without reservations. The respondents did not express distrust in science and scientists *per se*, but assessed what they perceived as scientific information with the same scepticism as they assessed other sources of information, for example suggesting that also researchers have beliefs and biases, may have alternative motives or are dependent on founding. The discourse concerning scientists and science is similar to what Grotta et al. (2013) found among forest owners in the Pacific North West. References to how researchers have been wrong before (e.g. the predicted forest die-back from acid rain) were also used by some Swedish forest stakeholders when explaining to Vulturius and Swartling (2015) why they did not trust scientists without reservations after a learning experiment. However, while Vulturius and Swartling (2015) stated that this applied only to a minority of their respondents, this line of reasoning was quite common among those we interviewed. This underlying doubt and scepticism about the (in-) ability of researchers to predict the future may become a barrier to engaging forestry decision makers in pro-active adaptation, if this should become a policy-objective. Norwegian forestry decision makers have experienced that researchers can be very confident and outspoken about predictions that turned out fundamentally wrong. In this context, a "*wait and see*" attitude seems a quite natural stance, but the attitude is by definition a barrier towards implementing planned adaptation in the present. There were other similarities between the respondents Vulturius and Swartling (2015) interviewed and those in this study as well: for example the perceived biases towards environmentalism among scientists. The Norwegians does however seem to be unique in their large focus and engagement with the carbon sequestration-debate, although Lawrence and Marzano (2014) mentioned that some of their respondents expressed that they think climate change adaptation is associated with change of energy-consumption rather than growing of trees by owners.

This article is based on data collected through a series of semi-structured group interviews among forestry decision makers with an interest in, and opinions about, climate change and forestry. The participants were recruited with the help of the forest owner associations in Southeastern Norway. Thus, a non-random sampling approach was applied. Thus, the findings cannot without reservation be assumed to reflect the opinions and perceptions on these matters in the population of forestry decision makers in Norway. It can however be assumed that the findings reflect perceptions that exists also outside our sample, although their proportion in the population remains unknown.

The group setting, designed to mimic everyday life, may allow dominating participants to dictate the conversation so that other views than their own are suppressed, creating an impression of false consensus within the group and thus undermine the internal validity. Some participants may likewise have avoided voicing their opinions out of fear, embarrassment or because they were unconformable with the setting and our results may thus lack important perspectives (Bryman, 2001). To prevent this, the moderator strived to challenge and include all participants and to create an open atmosphere, but this effort does not guarantee that participants with other views, contradicting views, or other perspectives actually voiced these. There are furthermore both advantages and potential risks associated with using pre-existing groups, mutual familiarity and trust within a pre-existing group may for example increase the probability of genuine replies and open dialogue, but established communication patterns, roles and dynamics can limit and steer the responses of each group member (Bryman, 2001). Even though the moderator strived to counteract potential risks of using pre-existing groups, it cannot be excluded that such factors influenced the data. Also the introduction of the topics, the order of the topics, the framing and formulation of questions, the moderators choice of words and body language, perceptions among the participants regarding what the moderator wanted them to reply and so forth may have affected the discussion (Bryman, 2001). To decrease the probability of such issues influencing the conversations, the moderator tried to avoid influencing the discussions more than necessary, and strived to formulate questions openly and in a balanced manner. Regarding the order of the topics, this varied between the interviews following the course of each group discussion. All the interviews however started with some general questions regarding either beliefs or experiences related to climate change (section 1), which might have framed the subsequent discussion. Assessing this in retrospect, it could have been beneficial to also vary the start topic between interviews. Uncertainties such as these associated with the methodological approach, might however somewhat be balanced by a larger number of interviews. The data-basis for this study is 10 focus-group interviews, involving altogether 54 participants of varying stakeholder category, holding size, experience, age, education and so forth. This strengthens the validity of the findings, as it reduces the chance of them being influenced too much by one single interview, group, participant, or the methodological approach (Carlsen & Glenton, 2011).

## Concluding remarks

This paper analysed how Norwegian forestry decision makers have learned and made sense of climate change information using data from 10 focus group interviews with altogether 54 participants. The results showed that the forestry decision makers had learned about climate change from a number of sources, and interpreted and contextualized this information using own experiences and old knowledge. The results also shows that the forestry decision makers do not trust any source of information, including scientists, without reservations. If adaptation of Norwegian forest and forestry to climate change should become a policy objective, or if changing forestry and forests should become an objective for some other reason than climate change, the findings of these thesis may be relevant for identifying effective policy tools (or rather, implicate which policy tools that might not be effective) to motivate change. Firstly, the results suggests that communication policy objectives and simply encourage change are likely to fail, as many participants distrust both politicians. Neither advice coming from experts will necessarily be effective, since the decision makers do not trust scientists or forest scientists without reservations. Thus, tools that reinforces policy will be necessary. Eventual subsidies should however be designed with great care to insure that they will promote the intended behaviour, or forestry decision makers might find ways to exploit the subsidies fulfilling their own objectives rather than the policy objectives as was the case with the subsidy for higher plant density.

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## Literature


Adger, W. N., Agrawala, S., Mirza, M. M. Q., Conde, C., O'Brien, K., Pulhin, J., Pulwarty, R., Smit, B. & Takahashi, K. (2007). *Assessment of adaptation practices, options, constraints and capacity. In: Climate Change 2007.: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* . In Parry, M., Canziani, O., Palutikof, J., van der Linden, P. & Hanson, C. (eds). Cambridge.

André, K., Baird, J., Swartling, Å. G., Vulturius, G. & Plummer, R. (2017). Analysis of Swedish forest owners' information and knowledge-sharing networks for decision-making: insights for climate change communication and adaptation. *Environ Manage*, 59 (6): 885-897.

Antilla, L. (2005). Climate of scepticism: US newspaper coverage of the science of climate change. *Glo Environ Change*, 15 (4): 338-352. doi: https://doi.org/10.1016/j.gloenvcha.2005.08.003.

Berg, B. L. (2001). *Qualitative reserch methods for the social sciences* 4ed. Needham Heights, MA USA Allyn & Bacon.

Bissonnette, J.-F., Dupras, J., Doyon, F., Chion, C. & Tardif, J. (2017). Perceptions of small private forest owner's vulnerability and adaptive capacity to environmental disturbances and climate change: Views from a heterogeneous population in Southern Quebec, Canada. *Small-scale for*, 16 (3): 367-393.

Blennow, K. & Persson, J. (2009). Climate change: Motivation for taking measure to adapt. *Glob Environ Chang*, 19 (1): 100-104. doi: 10.1016/j.gloenvcha.2008.10.003.

Blennow, K. (2012). Adaptation of forest management to climate change among private individual forest owners in Sweden. *For Policy Econ*, 24: 41-47. doi: https://doi.org/10.1016/j.forpol.2011.04.005.

Blennow, K., Persson, J., Tomé, M. & Hanewinkel, M. (2012). Climate Change: Believing and Seeing Implies Adapting *PLoS ONE* 7 (11): 7. doi: doi.org/10.1371/journal.pone.0050182.

Blennow, K., Persson, J., Persson, E. & Hanewinkel, M. (2016). Forest Owners' Response to Climate Change: University Education Trumps Value Profile. *PloS one*, 11 (5): e0155137. doi: doi:10.1371/journal.pone.0155137.

Bolte, A., Ammer, C., Löf, M., Madsen, P., Nabuurs, G.-J., Schall, P., Spathelf, P. & Rock, J. (2009). Adaptive forest management in central Europe: climate change impacts, strategies and integrative concept. *Scand J For Res*, 24 (6): 473-482. doi: 10.1080/02827580903418224.

Bryman, A. (2001). *Social Research  Methods* 1 ed. Oxford, Greate Britain Oxford University press

Carlsen, B. & Glenton, C. (2011). What about N? A methodological study of sample-size reporting in focus group studies. *BMC Med Res Methodology*, 11 (26).

Carvalho, A. (2005). Representing the politics of the greenhouse effect: Discursive strategies in the British media. *Cri Discourse Stud*, 2 (1): 1-29. doi: doi.org/10.1080/17405900500052143.

Carvalho, A. (2007). Ideological cultures and media discourses on scientific knowledge: re-reading news on climate change. *Public Underst Sci*, 16 (2): 223-243.

Diduck, A. (2010). The Learning Dimension of Adaptive Capacity: Untangling the Multi-level Connections. *Adaptive Capacity and Environmental Governance*: 199-221.

Dispensa, J. M. & Brulle, R. J. (2003). Media's social construction of environmental issues: focus on global warming – a comparative study. *Int J Sociol Soc Pol*, 23 (10).

Grothmann, T. & Patt, A. (2005). Adaptive capacity and human cognition: the process of individual adaptation to climate change. *Glo Environ Change*, 15 (3): 199-213. doi: https://doi.org/10.1016/j.gloenvcha.2005.01.002.

Grotta, A. T., Creighton, J. H., Schnepf, C. & Kantor, S. (2013). Family forest owners and climate change: Understanding, attitudes, and educational needs. *J of For*, 111 (2): 87-93. doi: https://doi.org/10.5849/jof.12-052.

Guldåker, N. (2009). *Krishantering, hushåll och stormen Gudrun. Att analysera hushålls krishanteringsförmåga och sårbarheter* Lund, Sweden Lund University

Holtsmark, B. (2016). *Seven essays on policies and international cooperation to abate emissions of greenhouse gases*: Universitetet i Oslo

Ingemarson, F., Jansson, V., Malmhäll, J., Merkell, B., Nasic, S. & Svensson, S. A. (2006). *Hur drabbades enskilda skogsägare av stormen Gudrun? Resultat av en enkätundersökning*. Jönköping, Sweden Skogsstyrelsen
Kahan, D., Peters, E., Wittlin, M., Slovic, P., Ouellette, L., Braman, D. & Mandel, G. (2012). The polarizing impact of science literacy and numeracy on perceived climate change risks. *Nat Clim Change*, 2 (10): 732-735.
Kahan, D. M., Jenkins-Smith, H. & Braman, D. (2011). Cultural cognition of scientific consensus. *J Risk Res*, 14 (2): 147-174. doi: https://doi.org/10.1080/13669877.2010.511246.
Keskitalo, E. C. H., Nocentini, S. & Bottalico, F. (2013). Adaptation to climate change in forest management: what role does national context and forest management tradition play? In: Forest management of Mediterranean forest under the new context of climate change In Lucas-Borja, M. E. (ed.) *Forest management of Mediterranean forest under the new context of climate change*, pp. 149-161. New York: Nova Science Publishers, Inc.
klimatilpasning.no, T. N. C. C. A. P. (2016). *Skogbruk [Forestry]* Offical Webpage klimatilpasning.no: Norwegian Environmental Agency Available at: http://www.klimatilpasning.no/sektorer/landbruk/oppgaver/skogbruk/ (accessed: 10.04 2018).
Kolström, M., Lindner, M., Vilén, T., Maroschek, M., Seidl, R., Lexer, M. J., Netherer, S., Kremer, A., Delzon, S., Barbati, A., Marchetti, M. & Corona, P. (2011). Reviewing the science and implementation of climate change adaptation measures in European forestry. *Forests*, 2 (4): 961-982.
Laakkonen, A., Zimmerer, R., Kähkönen, T., Hujala, T., Takala, T. & Tikkanen, J. (2018). Forest owners' attitudes toward pro-climate and climate-responsive forest management. *For Policy Econ*, 87: 1-10. doi: https://doi.org/10.1016/j.forpol.2017.11.001.
Lawrence, A. & Marzano, M. (2014). Is the private forest sector adapting to climate change? A study of forest managers in north Wales. *Ann For Sci*, 71 (2): 291-300. doi: 10.1007/s13595-013-0326-4.
Lidskog, R. & Sjödin, D. (2014). Why do forest owners fail to heed warnings? Conflicting risk evaluations made by the Swedish forest agency and forest owners. *Scand J For Res*, 29 (3): 275-282. doi: https://doi.org/10.1080/02827581.2014.910268.
Lidskog, R. & Löfmarck, E. (2016). Fostering a flexible forest: Challenges and strategies in the advisory practice of a deregulated forest management system. *Forest Policy and Economics*, 62: 177-183.
Lindner, M., Maroschek, M., Netherer, S., Kremer, A., Barbati, A., Garcia-Gonzalo, J., Seidl, R., Delzon, S., Corona, P., Kolström, M., Lexer, M. J. & Marchetti, M. (2010). Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. *For Ecol Manage*, 259 (4): 698-709. doi: https://doi.org/10.1016/j.foreco.2009.09.023.
Lindner, M., Fitzgerald, J., Zimmermann, N., Reyer, C., Delzon, S., van der Maaten, E., Schelhaas, M.-J., Lasch, P., Eggers, J., van der Maaten-Theunissen, M., Suckow, F., Psomas, A., Poulter, B. & Hanewinkel, M. (2014). Climate change and European forests: What do we know, what are the uncertainties, and what are the implications for forest management? *J Environ Manage*, 146: 69-83.
Linné, T. (2011). *Skogens framtid. En sociologisk undersökning av skogsägares uppfattningar.* Lund University Publications Lund, Sweden Media and Communication Studies Lund University
Mezirow, J. (2008). *An overview on transformative learning." Lifelong learning*: Routledge.
Mezirow, J. e. (2000). *Learning as Transformation: Critical Perspectives on a Theory in Progress. The Jossey-Bass Higher and Adult Education Series*. San Francisco: Jossey-Bass Publishers.
Millar, C., Stephenson, N. & Stephens, S. (2007). Climate change and forests of the future: Managing in the face of uncertainty. *Ecol Appl*, 17 (8): 2145-2151.
Moser, S. C. & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *P Natl Acad Sci USA* 107 (51): 22026-22031. doi: 10.1073/pnas.1007887107.
Nilssen, V. (2012). *Analyse i kvalitative studier, den skrivende forskeren [Analysing qualitative studies, the writing scientists]*. 1 ed.: Universitetsforlaget
Norskog.no. (2018). *Om oss [About us]*. norskog.no: Norskog Available at: http://norskog.no/om-oss/ (accessed: 16.03 2018).

Ogden, A. & Innes, J. (2007). Incorporating climate change adaptation considerations into forest management planning in the boreal forest. *Int For Rev*, 9 (3): 713-733.
PEFC Norway. (2015). *Norwegian PEFC Forest Standard*. PEFC N 02. Oslo: PEFC Norway. p. 31.
QSR International Pty Ltd. (2015). *NVivo qualitative data analysis Software for WINDOWS*. qsrinternational.com: QSR International Pty Ltd2015).
Ryghaug, M., Holtan Sørensen, K. & Næss, R. (2011). Making sense of global warming: Norwegians appropriating knowledge of anthropogenic climate change. *Pub Underst Sci* (20 ): 778-795.
Schoene, D. & Bernier, P. (2012). Adapting forestry and forests to climate change: A challenge to change the paradigm. *For Policy Econ*, 24 (SI): 12-19.
Sellerberg, A. M. (2011). *Efter stormen. En sociologisk undersökning av skogsägarfamiljer [After the storm. A sociological analysis of families owning forest properties.]*. Lund University Publications Lund, Sweden Sociology of Everyday Life-lup-obsolete (research group) Lund University
Skogbrand, S. f. G. S. i. c. (2014). *Skogbehandling før skogen kommer [forest management before the storm]*. Oslo Skogbrand forsikringselskap Gjensidige [Skogbrand insurance company].
Sousa-Silva, R., Ponette, Q., Verheyen, K., Van Herzele, A. & Muys, B. (2016). Adaptation of forest management to climate change as perceived by forest owners and managers in Belgium. *For Ecosyst*, 3 (22): 2-11.
Sousa-Silva, R., Verbist, B., Lomba, Â., Valent, P., Suškevičs, M., Picard, O., Hoogstra-Klein, M., Cosofret, V.-C., Bouriaud, L., Ponette, Q., Verheyen, K. & B, M. (2018). Adapting forest management to climate change in Europe: Linking perceptions to adaptive responses. *For Policy Econ*, 90: 22-30. doi: https://doi.org/10.1016/j.forpol.2018.01.004.
Spittlehouse, D. & Stewart, R. (2004). Adaptation to climate change in forest management. *BC J Ecosyst Manag*, 4 (1): 1-11.
Statistics Norway. (2017). *Skogeiendommer [Forest holdings]*. In ssb.no (ed.). ssb.no: Central Bureau of Statistics Norway. Available at: https://www.ssb.no/jord-skog-jakt-og-fiskeri/statistikker/stskog (accessed: 16.03 2018).
Statistics Norway. (2018). *The National Forest Inventory*. Growing stock and annual increment. Volume inside bark. ssb.no: Statistics Norway Available at: https://www.ssb.no/en/lst (accessed: 14.05 2018).
Stortinget, T. N. P. (2015). *Statsbudsjettet 2016 [State budget 2016]*. Stortingets administrasjon, K. a. P. a., Constitutional Department]. Oslo: Stortingets administrasjon, Konstitusjonell avdeling [Parliament administration, Constitutional Department].
Uggla, Y. & Lidskog, R. (2016). Climate risks and forest practices: forest owners' acceptance of advice concerning climate change. *Scand J For Res*, 31 (6): 618-625. doi: https://doi.org/10.1080/02827581.2015.1134648.
van Gameren, V. & Zaccai, E. (2015). Private forest owners facing climate change in Wallonia: Adaptive capacity and practices. *Environ Sci Policy*, 52: 51-60. doi: https://doi.org/10.1016/j.envsci.2015.05.004.
Vulturius, G. & Swartling, Å. G. (2015). Overcoming social barriers to learning and engagement with climate change adaptation: experiences with Swedish forestry stakeholders. *Scand J For Res*, 30 (3): 217-225. doi: https://doi.org/10.1080/02827581.2014.1002218.
Vulturius, G., André, K., Swartling, Å. G., Brown, C., Rounsevell, M. D. A., Jönsson, A. M. & Blanco, V. (2018). The relative importance of subjective and structural factors for individual adaptation to climate change by forest owners in Sweden. *Reg Environ Chang*, 18 (5): 1517-1571. doi: https://doi.org/10.1007/s10113-017-1218-1
Weber, E. U. (2006). Experience-based and description-based perceptions of long-term risk: Why global warming does not scare us (yet). *Clim Chang*, 77 (1-2): 103-120.
Yousefpour, R., Jacobsen, J. B., Thorsen, B. J., Meilby, H., Hanewinkel, M. & Oehler, K. (2012). A review of decision-making approaches to handle uncertainty and risk in adaptive forest management under climate change. *Annals of forest science*, 69 (1): 1-15.
Yousefpour, R. & Hanewinkel, M. (2015). Forestry professionals' perceptions of climate change, impacts and adaptation strategies for forests in south-west Germany. *Clim Chang*, 130 (2): 273-286. doi: 10.1007/s10584-015-1330-5.

# Appendices

# Appendix I,

# Interview guide (translated)

| Subject | Possible Formulations | Keywords (if necessary) | Notes and supplements |
|---|---|---|---|
| Climate change, beliefs and experiences | Do the group believe that we (Earth) are in the beginning of period with substantial climate change?<br><br>Have group members experienced or observed changes in/on forest ecosystems/forestry/forest infrastructure/operational conditions that they attribute to climate change?<br><br>Do you think climate change will impact forest ecosystems<br>If yes, how?<br><br>Will forestry change because of climate change?<br><br>Which climate related events do you believe we will experience more often?<br><br>Which climate related effects do the group think will have most impact on forest ecosystems and forestry? | Human made/natural variability<br><br>Impact and consequence,<br><br>World and Norway<br><br>Evolution/Shock<br><br>Own holding<br><br>All forest<br><br>Local/Norway<br><br>Evolution/shock<br><br>Time perspectives: 5 years, 20 years, towards 2100<br><br>Positive/Negative<br><br>Economically/ecologically | Describe and explain<br>If needed:<br><br>Wind, water, snow, invading species, drought, fire, insects, fungus, growth<br><br>Possibility: other groups believe in climate change? |
| Knowledge | How do you assess your knowledge about climate change/climate change in a forest/forestry perspective?<br><br>What is the origin of the knowledge the group possess?<br><br>How do the group assess the different providers of knowledge about climate change?<br><br>Is there any need for/demand for silvicultural advice in a climate change context among the participants? | Compared to the "average Norwegian"<br><br>Radio/TV/Newspapers (which kinds?)<br><br>Forest media/research publications/official information/internet/friends and family/education/colleagues/conferences<br><br>Media, scientists, forest organizations and associations<br><br>Whom do they trust?<br><br>What kind of demand? | Active pursuit of knowledge? |

| Subject | Possible Formulations | Keywords (if necessary) | Notes and supplements |
|---|---|---|---|
| Adaptation to climate change | Do any of the group members make other assessments/make other decisions when making management decisions because of climate change?<br><br>How can forest management be adapted to reduce climate change risk and uncertainty?<br><br>Have the group members assessed implementing such measures?<br><br>Have they implemented such measures?<br><br>How do the group assess their own knowledge about adaption of silviculture with respect to climate change?<br><br>Have any of the group members been recommended/recommended others to change their forest management with respect to climate change?<br><br>Has any of the group members assessed change of main production species? | Regeneration, Silviculture, old growth, Etc.Invest less/Risk diversification trough changed forest composition/Changed silviculture?<br>Why/why not?<br>Do they know how to adapt?<br>Who recommended the adjustment?<br>Spruce – vulnerable? | |
| Risk and uncertainty | How do the group perceive the degree of risk and uncertainty in forest management/forestry?<br><br>Is the degree of risk and or uncertainty changing?<br><br>What is the origin of risk and uncertainty?<br><br>What is the perceived as the major and the minor risks and sources of uncertainty?<br><br>Is the forest based sector perceived to be a sector with much risk and uncertainty? | Marked, technical, politicians, physical (weather and climate)<br><br>Increasing/Decreasing<br><br>Why? | |
| | Is this (climate change and forestry) considered an important subject? | Is this something the participants talk about with other FDMs?<br><br>Is climate change/climate change adaptation a focus in the associations?<br><br>Is climate change a focus among the advisors that the NIPFs are in contact with?<br><br>Is it a focus in the forest- media? | |
| | Is there anything else the participants want to ad? | | |

# Appendix II

## Information letter (translated)

**Forest owners' perceptions about climate change, climate adaptive forest management, and advice about climate change adaption in forestry.**

This survey is a part of a master thesis in forestry at the Norwegian University of Life Sciences (NMBU) in Ås. The survey is a cooperation with the forest owners associations in Norway and Sweden, and the insurance company Skogbrand forsikringsselskap Gjensidig. You receive this invitation to participate as a member of [forest owners association].

**Objectives**

The objectives of the survey is to map forest owners perceptions about:

- Climate change
- Climate change impacts on forestry and climate adaptive forest management
- The need for - and access to, advice and insurance

**Background**

The intergovernmental panel on climate change (IPCC) agrees that the Earth has entered a period of substantial changes in climate. The climate impacts forests and forestry both directly and indirectly. Temperature and access to water limit growth, strong winds may cause substantial damages. The carrying capacity of both forest roads and forest ground is also affected by temperature and water in addition to soil properties.

**Anonymity and handling of data.**

When you reply to the questionnaire, you remain anonymous. Thus, your replies cannot be linked to your identity. We will treat the data confidentially, they will be stored at NMBU, and they will be used as primary data for a master thesis and for research at the University. Participation is voluntary, and you give your consent to participate by answering the questionnaire. The study has been approved by «Personvernombudet for forskning» ( http://www.nsd.uib.no/) [Norwegian Centre for Research Data].

Completing the questionnaire will take about 15 minutes. We hope you will prioritize answering our questions and thus contribute to give the survey the best possible representativeness. Deadline for participation is about 14 days from the distribution of this email.

**Contact**

If you have questions, reactions or similar, we would like to hear from you. Please contact master-student in forestry [Name – number – email] or Professor [name – number – email]

**Best regards**

**Master-student [Name] (NMBU)**

**Professor [Name] (NMBU)**

**[Forest owners association]**

**[Association logo]**

# Appendix III

## Questionnaire (translated)

Section one contains questions about climate change.

In some of these questions, we will ask you to assess ahead in time. In these questions, please consider a time horizon equaling a rotation (from 60 to 120 years).

Question 1

**Give your opinion on the following statement: The climate is changing**

| | *Completely disagree* | *Mainly disagree* | *Somewhat disagree* | *No opinion* | *Somewhat agree* | *Mainly agree* | *Completely agree* |
|---|---|---|---|---|---|---|---|
| Globally | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| In Nordic countries | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| At my forest holding | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

For Question 2 to be visible for a respondent, the respondent's response to Question 1 a) or b) or c) had to equal

- Somewhat agree, or
- Mainly agree, or
- Completely agree.

Question 2

**I believe that climate change is fully or mainly human-made**

| *Completely disagree* | *Mainly disagree* | *Somewhat disagree* | *No opinion* | *Somewhat agree* | *Mainly agree* | *Completely agree* |
|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

For Question 3 to be visible for a respondent, the respondents' response to Question 1 c) ("at my forest holding") had to equal

- Somewhat agree, or
- Mainly agree, or
- Completely agree.

Question 3

**Have you, during the past five years, observed or experienced changes in your forest caused by climate change?**

Yes ☐
No ☐
I do not know ☐

For Question 4 to be visible for a respondent, the respondents' response to Question 3 had to equal

- Yes

Question 4

**What changes have you experienced? (Multiple options possible)**

| | |
|---|---|
| Increased growth | ☐ |
| Challenging conditions for forest operations during spring or autumn* | ☐ |
| Increase in climate related damages to forest-roads | ☐ |
| Shorter periods feasible for harvest operations during the winter season | ☐ |
| Increase in climate-related damages to the forest | ☐ |
| Increased competition in the regeneration phase (from *Sambucus racemosa*, *Reynoutria sachaliensis*, grasses or similar)* | ☐ |
| Changed forest appearance** | ☐ |
| Others | ☐ |

*Only in the Norwegian questionnaire
**Only in the Swedish questionnaire

Question 5

**I believe the projected climate changes will increase damages in my forest caused by**

| | *Completely disagree* | *Mainly disagree* | *Somewhat disagree* | *No opinion* | *Somewhat agree* | *Mainly agree* | *Completely agree* |
|---|---|---|---|---|---|---|---|
| Storm (large contiguous areas) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Wind (single-trees or groups of trees) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Drought | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Forest fire | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Insect attacks or forest diseases | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Rot infection | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Top breakage caused by wet and heavy snow | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Damages to forest roads and other infrastructure | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Question 6

**I believe the predicted climate changes will influence…**

| | *Major decrease* | *Moderate decrease* | *Minor decrease* | *No change* | *Minor increase* | *Moderate increase* | *Major increase* |
|---|---|---|---|---|---|---|---|
| The volume-growth in my forest | □ | □ | □ | □ | □ | □ | □ |
| The quality-growth in my forest (saw-log proportion) | □ | □ | □ | □ | □ | □ | □ |
| Roundwood demand | □ | □ | □ | □ | □ | □ | □ |

Question 7

**Considering all aspects of climate change, I believe that the predicted climate changes will influence the income potential and value of my forest holding.**

| *Major decrease* | *Moderate decrease* | *Minor decrease* | *No change* | *Minor increase* | *Moderate increase* | *Major increase* |
|---|---|---|---|---|---|---|
| □ | □ | □ | □ | □ | □ | □ |

With operations during winter season, we mean harvests conducted during winter in areas that in the first place have low carrying capacity, but gets sufficient carrying capacity due to frost and snow

Question 8

**I think the predicted changes in climate will …**

| | *Completely disagree* | *Mainly disagree* | *Somewhat disagree* | *No opinion* | *Somewhat agree* | *Mainly agree* | *Completely agree* |
|---|---|---|---|---|---|---|---|
| Reduce the possibility to conduct harvest operations during winter season | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Make harvest operations during winter season impossible | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Question 9

**In what proportion of your forest holding do you depend on forest operations during winter season in order to harvest roundwood?**

| | |
|---|---|
| *I am not dependent on operations during winter season at my holding* | ☐ |
| *In 1 to 25 % of the holding* | ☐ |
| *In 26 and 50 % of the holding* | ☐ |
| *In 51 and 75 % of the holding* | ☐ |
| *In 76 and 99 % of the holding* | ☐ |
| *In all stands on my holding* | ☐ |
| *I do not know.* | ☐ |

Question 10)

**To adapt my forest to climate change, I will consider …**

| | *Completely disagree* | *Mainly disagree* | *Somewhat disagree* | *No opinion* | *Somewhat agree* | *Mainly agree* | *Completely agree* |
|---|---|---|---|---|---|---|---|
| Choosing plant material from lower provenances*/ Choosing better adapted seedlings** | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Turn from even-aged stands to continuous forest cover forestry. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Turn from planting to natural regeneration | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

*Norwegian questionnaire
**Swedish questionnaire

Question 11

**Which of the alternatives below best describes the species-composition on your forest holding today?**

| | |
|---|---|
| Spruce dominated | ☐ |
| Pine dominated | ☐ |
| Deciduous tree dominated | ☐ |
| Mixed forest | ☐ |
| Other | Open ended |
| I do not know | ☐ |

Question 12

**In order to adapt my forest to climate change, I will consider**

| | *Completely disagree* | *Mainly disagree* | *Somewhat disagree* | *No opinion* | *Somewhat agree* | *Mainly agree* | *Completely agree* |
|---|---|---|---|---|---|---|---|
| Increasing the share of spruce | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Increasing the share of pine | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Increasing the share of deciduous trees | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Change dominating tree-species in some stands | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Question 13

**In order to reduce risks related to climate change, I will consider**

| | *Completely disagree* | *Mainly disagree* | *Somewhat disagree* | *No opinion* | *Somewhat agree* | *Mainly agree* | *Completely agree* |
|---|---|---|---|---|---|---|---|
| Pre-commercial thinnings as replacement for thinnings | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| When conducting thinnings, thin earlier in the rotation | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Avoid thinnings | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Earlier final harvest | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Others | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Question 14

**Do you have forest insurance?**

| | |
|---|---|
| Yes | ☐ |
| No | ☐ |
| I do not know | ☐ |

For Question 15 to be visible for a respondent, the respondents' response to Question 14 had to equal

- Yes

Question 15

**What type of forest-insurance do you have?**

| | |
|---|---|
| Fire | ☐ |
| Storm | ☐ |
| I do not know | ☐ |

For Question 16 to be visible for a respondent, the respondents' response to Question 14 had to equal

- Yes

Question 16

**If offered, I would consider taking out insurance against …**

| | Yes | No |
|---|---|---|
| Bark-beetle attach | ☐ | ☐ |
| Pine weevil attach | ☐ | ☐ |
| Climate damages in the regeneration phase | ☐ | ☐ |
| Damages caused by moose-browsing | ☐ | ☐ |
| Damages to roads and other infrastructure | ☐ | ☐ |
| Other | ☐ | ☐ |

This part of the questionnaire consists of questions about need of knowledge and advice.

Question 17

**I possess the knowledge I need about climate adaptive forestry.**

| *Completely disagree* | *Mainly disagree* | *Somewhat disagree* | *No opinion* | *Somewhat agree* | *Mainly agree* | *Completely agree* |
|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Question 18

**I have received advice about climate adaptive forestry (during the last five years)**

| | |
|---|---|
| Yes | ☐ |
| No | ☐ |
| I do not know | ☐ |

For Question 19 to be visible for a respondent, the respondents' response to Question 18 had to equal

- No

Question 19

**I need advice and recommendations about climate adaptive forestry.**

| *Completely disagree* | *Mainly disagree* | *Somewhat disagree* | *No opinion* | *Somewhat agree* | *Mainly agree* | *Completely agree* |
|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Question 20

**I have sought out advice about climate adaptive forestry (during the last five years)**

| | |
|---|---|
| Yes | ☐ |
| No | ☐ |
| I do not know | ☐ |

For Question 21 to be visible for a respondent, the respondents' response to Question 20 had to equal

- Yes

Question 21

**We would appreciate if you write from whom/where you sought out advice.**

*Open ended*

For Question 22 to be visible for a respondent, the respondents' response to Question 18 had to equal

- Yes

Question 22

**Have you received any of the following recommendations? (Multiple options possible)**

| | |
|---|---|
| Choose plant material from lower provenances*/ Choose better adapted seedlings** | ☐ |
| Conduct young growth tending before the stand reaches 4 meters of height | ☐ |
| Replace thinning with comprehensive young growth tending, | ☐ |
| Conduct early thinnings | ☐ |
| Avoid late and comprehensive thinnings | ☐ |
| Increase the planting density, | ☐ |
| Harvest earlier in risk-exposed stands | ☐ |

* Norwegian questionnaire
** Swedish questionnaire

For Question 23 to be visible for a respondent, the respondents' response to Question 18 had to equal

- Yes

Question 23

**From whom did you receive advice about climate-adapted forest management?**

| | |
|---|---|
| Through information distributed by the forest owners association | ☐ |
| From the forest owners association representative in my area | ☐ |
| Through forestry magazines | ☐ |
| From courses, conferences etc. | ☐ |
| From the government (municipality officials, county officials, Ministry officials etc.) | ☐ |
| From other forest owners | ☐ |
| From Skogbrand insurance company* | ☐ |
| From others | ☐ |

*Only in the Norwegian questionnaire

In this part of the questionnaire, we want you to answer some questions about background variables. The purpose of asking these questions is to identify eventual systematic differences and similarities between forest owners.

Question 24

**I am**

Male ☐
Female ☐
I do not want to specify ☐

Question 25

**I am**

Non-industrial private forest owner ☐
Forest manager ☐

Question 26

**Please enter your year of birth**

*Open ended*

Question 27

**What is your highest completed education?**

*Comprehensive school* ☐
*High school or similar* ☐
*Vocational school* ☐
*University or University College* ☐

Question 28

**Have you completed any formal forestry education?**

Yes ☐
No ☐

| |
|---|
| For Question 29 to be visible for a respondent, the respondents’ response to Question 28 had to equal<br>o Yes |

Question 29

**What is the highest level of forestry education you have completed?**

| | |
|---|---|
| Agricultural school | ☐ |
| Vocational school | ☐ |
| Degree in forestry at University or University College | ☐ |
| Single classes in University or University College | ☐ |
| Others | ☐ |

Question 30

**Where is your forest holding(s) located? (Multiple answers possible).**

*List of Swedish and Norwegian counties, respectively.*

Question 31

**How many decares*/hectares** does your holding consist of?**

*Groups according to the subdivision applied by Statistics Norway.*

* Norwegian questionnaire
** Swedish questionnaire

Question 32

**I am a member of (Multiple options possible)**

*List of Swedish and Norwegian forest owners associations, in addition to “others”.*

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