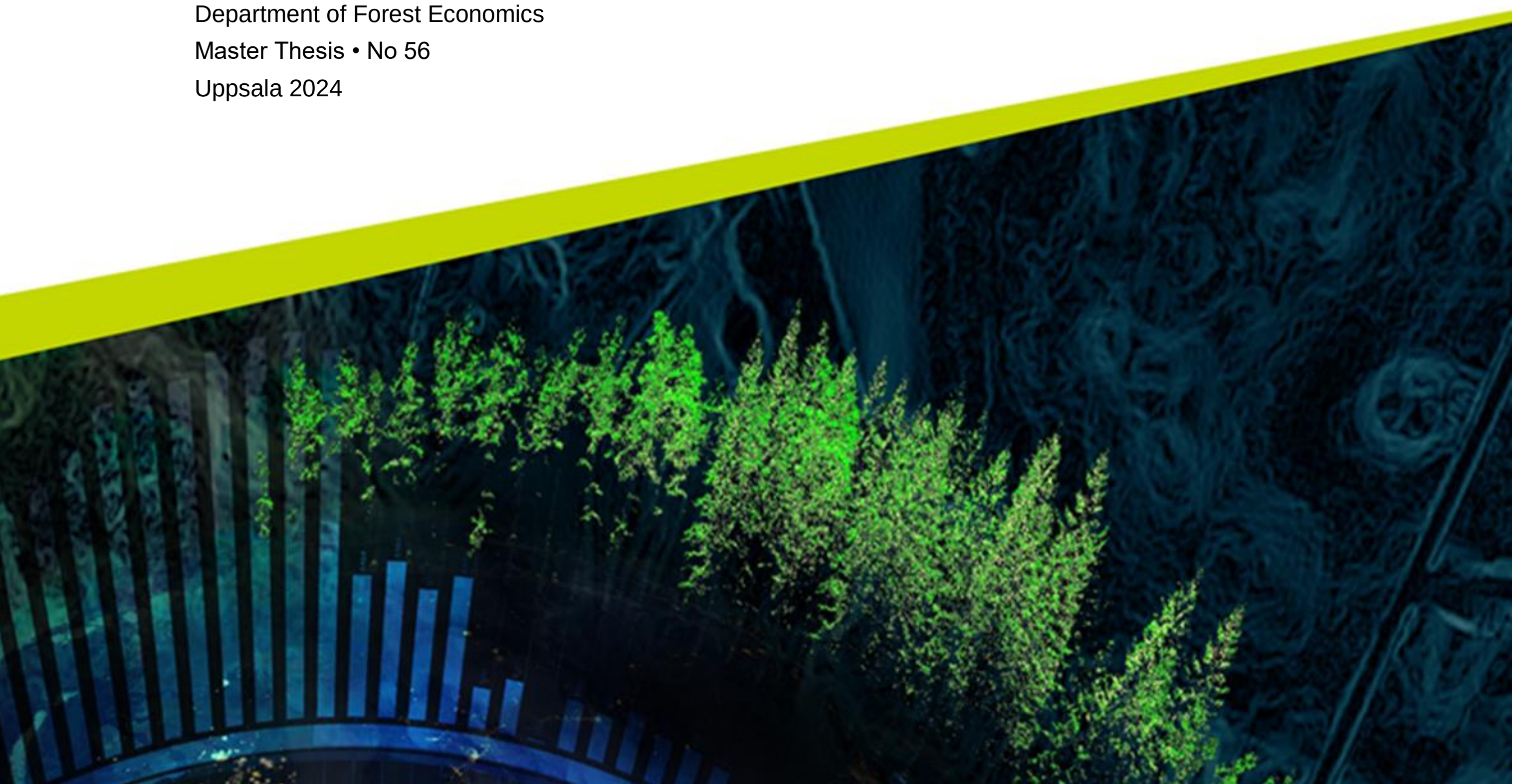
Forest fire insurance decisions

– An exploration from the perspective of individual owners in Sweden

Försäkringsbeslut mot ökad risk för skogsbrand – En undersökning av privata skogsägare i Sverige

Ludvig Andersson

Degree project/Independent project • 30 hp
Swedish University of Agricultural Sciences, SLU
Faculty of Forest Sciences
Department of Forest Economics
Master Thesis • No 56
Uppsala 2024



Forest fire insurance decisions – An exploration from the perspective of individual forest owners in Sweden

Försäkringsbeslut mot ökad risk för skogsbrand – En undersökning av private skogsägare

Ludvig Andersson

Supervisor:	Adan Martinez Cruz, Swedish University of Agricultural Sciences, Department of Forest Economics
Examiner:	Camilla Widmark, Swedish University of Agricultural Sciences, Department of Forest Economics

Credits:	30 hp
Level:	A2E
Course title:	Master thesis in Business Administration
Course code:	EX0976
Programme/education:	Forest Science
Course coordinating dept:	Department of Forest Economics
Place of publication:	Uppsala
Year of publication:	2024
Title of series:	Master Thesis
Part number:	56

Keywords: *Fire, fire risk, forest Insurance, management, net present value*

Swedish University of Agricultural Sciences
Faculty of Forest Sciences
Department of Forest Economics

Summary

Natural disasters are the biggest threat to forests worldwide. Between 2002 and 2013, an estimated 67 million hectares of forest burned annually worldwide. This rise is still evident throughout the first ten years of the twenty-first century. More importantly, these disruptions will most likely cause more harm over the course of the next few decades. Climate change, which influences both the frequency and intensity of disturbances, has been primarily blamed for this increase. One option available to forest owners to mitigate some of the risks associated with a natural hazard is to obtain insurance, which protects them against monetary damages.

The main goal of this study is to examine how forest fire insurance affects the net present value (NPV) of a hectare for private, independent forest owners in Sweden. This is accomplished by developing a private insurance model that takes into account the coverage amount, productive characteristics, and the likelihood of a wildfire occurring. This insurance may cover forest restoration and timber damage entirely or partially. These qualities ought to be included in the insurance policy, either directly or indirectly. In order to examine how this type of insurance influences the economic returns on forests, as measured by the net present value (NPV) of the forests, a number of ideas will be introduced and supported in the theoretical chapter. In this study, the deductive research method is applied. The process of starting with a general concept or hypothesis and working logically down to a specific conclusion is known as deduction. Using a top-down methodology, it starts with a broad theoretical framework and tests it through empirical observation. With this approach, the project hopes to generate theories-based hypotheses that can be investigated through the planning of studies and the collection and assessment of data that either confirms or refutes the theories.

The results show how the fire insurance makes the NPV stay positive due to fire and by the limitations and assumptions due to the project, the results without insurance are highly negative. The key message of this study is that insurance is a good management tool, with in mind the results without insurance.

Keywords: Fire, fire risk, forest Insurance, management, net present value

Sammanfattning

Naturkatastrofer är det största hotet mot skogarna i världen. Mellan 2002 och 2013 brann uppskattningsvis 67 miljoner hektar skog årligen över hela världen. Denna ökning är fortfarande påtaglig under de första tio åren av det tjugonde århundradet. Dessutom, viktigare är att dessa störningar sannolikt kommer att orsaka mer skada under loppet av de närmaste decennierna. Klimatförändringarna, som påverkar både frekvensen och intensiteten av störningar, har framför allt fått skulden för denna ökning. Det finns alternativ för skogsägare för att minska vissa av de risker som är förknippade med en naturkatastrof, det är att skaffa en försäkring som skyddar dem mot ekonomiska skador följt av exempelvis en skogsbrand.

Huvudmålet med denna studie är att undersöka hur skogsbrandsförsäkringen påverkar nuvärdet (NPV) av en hektar för privata skogsägare i Sverige. Detta uppnås genom att utveckla en privat försäkringsmodell som tar hänsyn till värdet som återbetalas, tillväxt faktorer och sannolikheten för att en skogsbrand ska inträffa. Denna försäkring kan täcka skogsrestaurering och virkesskador helt eller delvis. Dessa egenskaper bör ingå i försäkringen, antingen direkt eller indirekt. För att undersöka hur denna typ av försäkring påverkar den ekonomiska avkastningen på skog, undersöks med hjälp av skogens nuvärde (NPV). I detta projekt kommer ett antal idéer att introduceras och stödjas i det teoretiska kapitlet. I denna studie tillämpas den deduktiva forskningsmetoden, där processen börja med ett allmänt koncept eller hypotes och arbetas sedan logiskt ner till en specifik slutsats kallas deduktion. Med hjälp av en top-down metodik börjar den med ett brett teoretiskt ramverk och testar det genom empirisk observation. Med detta tillvägagångssätt hoppas projektet generera teoribaserade hypoteser som kan undersökas genom planering av studier och insamling och bedömning av data som antingen bekräftar eller motbevisar teorierna.

Resultaten visar hur brandförsäkringen får NPV att förbli positiv med försäkring av brand. Givet de avgränsningar och antaganden presenterar även projektet att resultaten utan försäkring är negativa. Slutsatsen i denna studie är att försäkringen är ett bra verktyg, med tanke på resultaten utan försäkring.

Nyckelord: Brand, brandrisk, skogsförsäkring, skötsel, nuvärde

Table of content

List of tables

List of figures

Abbreviations

NIPF	Non-industrial private forest owners
NPV	Net present value
MSB	Swedish Civil Contingencies Agency
SMHI	Swedish Meteorological and Hydrological Institute

1. Introduction

This chapter introduces the phenomena of natural hazards, their effect on the forests, and how insurance could be a useful management tool for a forest owner. This section includes i) Problem background, ii) Problem, iii) Aim and delimitations, and lastly iv) Outline.

1.1. Problem background

Globally, natural hazards pose the greatest threat to forests. An estimated 67 million hectares of forest were burnt annually worldwide between 2002 and 2013, of which 85 million were caused by pests 38 million by extreme weather, and 12.5 million by disease (van Lierop et al., 2015). On a European scale, Schelhaas et al. (2003) showed that disruptions in Europe caused an average of 35 million m3 of damage per year between 1950 and 2000. Of the total damage, 53% was caused by storms, 16% by fire, 3% by snow, and 16% by biotic causes. Furthermore, Schelhaas et al. (2003) demonstrates that during the 50 years, disturbances intensified. In the first ten years of the twenty-first century, this rise is still present (Seidl et al., 2014). More significantly, over the next few decades, the harm from these disruptions is probably going to get worse (Seidl et al., 2014). This increase has been attributed mostly to climate change (Seidl et al., 2011), which affects both the frequency and intensity of disturbances (Van Aalst, 2006).

Natural disasters are responsible for multiple sources of potential losses, both to society and the forest owners. The losses linked to the forest owner are the potential losses to the current value of the fallen timber or damages to the standing trees that decrease the value of the timber at the mature stage, (Picard et al., 2002). Moreover, in addition to these economic losses, the occurrence of natural disturbances is associated with great public costs. These public costs followed by fires in the forests, would be human capital such as firefighters and resources that are acquired to fight such events are one example that (Pinheiro & Ribeiro, 2013) have been pointed out. Another example could be losses of carbon sequestration when the forest that are being a carbon sink (Thürig et al., 2005) which from two points of view could be used as more sustainable products. Furthermore, biodiversity in the social aspect, with both habitats for different species and recreational aspects of a forest that are used by humans in other ways than timber.

Global warming as a trigger of frequency and intensity of natural hazards, such as wind, fire, drought, and flooding, in the future will increase the risk that relates to forest management (Spittlehouse & Stewart, 2003; Van Aalst, 2006). However, the impact of climate change is also increasing the terms of biotics such as pests and fungal damages (Williams & Liebhold, 1995). In these terms and an uncertain future, costs will come due to global warming. However, different ways could be done by a forest owner face these changes. All throughout the world, people agree that there is a genuine threat to civilization from climate change. The increase in the frequency and intensity of natural catastrophes like wildfires, hurricanes, and floods during the past 50 years is one sign of climate change in the report from WMO (2021). There is no escaping climate change in Sweden. For example, there has been a rise in forest fires in Sweden (Krikken et al., 2021), with exceptional incidents recorded in the hot summer of 2018 (Granström, 2020).

1.2. Problem

Approximately 23.0 million hectares make up Sweden's total forestland, of which non-industrial private forest owners (NIPF) possess 50%. With 58% of the land notified for regeneration felling in 2008, NIPF owners have a significant role in the supply of round wood to industry (Swedish Forest Agency, 2010). Apart from timber, the non-industrial protected forests (NIPFs) offer diverse benefits to both the owners and the broader community, including recreation, biodiversity, and carbon sequestration. Non-industrial private forestry varies in scope and intensity; some owners may maintain their land with quite different goals in mind, and some holdings may be very tiny. Notably, owning a forest is a significant economic activity in and of itself; the majority of NIPF owners operate as private companies. Decisions on input and harvest can be seen as portfolio management because the forest is a part of the owner's financial portfolio.

Acquiring insurance is one decision that forest owners may take to address some of the risks that come with a natural hazard as insurance helps forest owners against economic losses (Deng et al., 2015). Specifically, insurance contracts are a method used to shift the risk of losses from forest owners to private insurance firms. These companies can then spread the risk by using the reinsurance market. This is the way insurance companies function in general. The insurance provider can compensate those impacted with funds from insurance owners who are not impacted by pooling risk from multiple sources.

Also, it allows for a stabilization of the forest owner’s income (Qin et al., 2016). Therefore, forest insurance can be considered as a risk control strategy for a forest owner to cope with uncertainties associated with hazards (Dai et al., 2015). Typically, hazards like damage from insects in Finland, New Zealand has suffered carbon loss, and fire and storm losses can be insured, for example in France and Germany (Manley & Watt, 2009). Nonetheless, there are noticeable variations between nations when it comes to the uptake of insurance. According to Zhang and Stenger (2014), the northern countries have the highest penetration rate of forest insurance on the market. Approximately 40% of Finland and Norway's private forest area is insured, while 95% of Sweden's is. In other nations, though, things are different. In France, less than 4 percent of private forest land is insured; the same circumstances exist in Germany and Spain (Brunette et al., 2015). An NIPF in Sweden may be insured due to past occurrences and may also have a secured pension in the forestry revenues, according to Kvennefeldt and Lindström (2016). The attitudes to risk are said to be mostly related to the owner’s characteristics which signaling that previous believes that a forest owner is risk averse is not the case (Andersson, 2012). An insurance could be the reason behind this change.

With a focus on forest restoration, the Swedish Strategic Forestry Plan (Sweden´s National Forest program) does not mention the use of forest insurance as a way to manage the risk of losses from wildfires. Because the forest returns to productivity more quickly and offers the community new environmental and ecosystem benefits, this insurance may benefit the landowner as well as society. Therefore, in order to improve forest management, an insurance model that might cover these expenses of forest restoration must be designed. By ensuring that forest profitability is maintained and creating greater incentives to engage in forest production, this kind of coverage may offer more sustainable forest management techniques. Consequently, insurance can ensure that landowners do not lose all their investments while simultaneously aiding in the recovery and restoration of forest regions. It is anticipated that insured woods will recover from burned regions more quickly than uninsured ones thanks to this insurance program.

1.3. Aim and delimitations

This paper's primary objective is to analyze how the NPV of one hectare is affected by forest fire insurance for private independent forest owners in Sweden. To do this, a private insurance model that considers the probability of a wildfire happening, the productive variables, and the coverage amount is created. Timber damage and forest restoration may be fully or not covered by this insurance. The insurance policy should either explicitly or indirectly include these features. In the theoretical chapter, several theories will be presented and supported in this study to analyze how this kind of insurance affects the forest economic returns on forests, as determined by the net present value (NPV) of the forests with the following working hypotheses:

$$NPV_t = \left[PQ(t) - \gamma - C(Q, s, \alpha) - \delta\big(D(Q)\big)\right]e^{-rt} - R \leq 0 \qquad [1]$$

Further investigation of the NPV, is facing the following research question:

How are the increasing cost of insurance premiums affecting the NPV of a forest hectare?

The delimitations of the study are in the context of Sweden and only focus on the individual private forest owners as the unit of analysis in the case of decision-making to acquire forest fire insurance affecting the NPV. However, for this project available secondary data was collected from open sources on public agency’s websites, this data is used to answer the questions set for the project, and not for specific individual person.

1.4. Outline

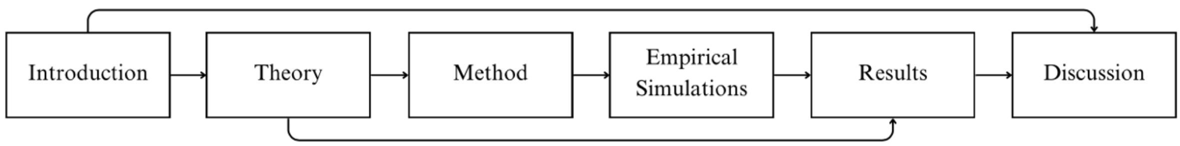


Figure 1: Overview of the thesis structure and how the parts connect.

This study's opening chapter provides a quick overview of the subject (Figure 1). A review of the literature is given in the second chapter. A theoretical framework is presented in the third chapter. The study's selected methodology is presented in the fourth chapter. An empirical basis is provided in the fifth chapter. The outcome along with the interpretation of the empirical findings will be presented in the sixth chapter. The study's result will be presented in the eighth chapter after a discussion in the seventh chapter.

2. Theory

Chapter 2 provides the theoretical model that is used in the thesis, firstly a model of the insurance and a model to calculate the NPV. The chapter is divided into i) forest insurance model ii) the optimal Forest rotation model.

2.1. Forest insurance model

Economic insurance models have been constructed from various angles in a number of previous research papers. For instance, Holecy & Hanewinkel (2006) created an insurance model that estimated the odds of forest destruction and analyzed the gross insurance premium. A further noteworthy study was conducted by (Brunette & Couture, 2008), who provided an insurance model to evaluate the effects of government subsidies following natural disasters. This model explores how a subsidy may affect forest management by considering the desires of the landowner. Thus, the impact of an insurance policy on the landowner's net worth and the influence of this financial resource on forest rotation is not specifically examined in these studies (Barreal et al., 2014).

In order to comprehend the financial effects of forest insurance on forest management during a single forest rotation period, the NPV will be utilized in thesis project (Hanewinkel et al., 2011). Considering earlier contributions, like those made by Amacher et al. (2005) or Martell et al. (1998), the insurance model incorporates the expenses of forest management, which include, among other things, the costs of upkeep and cleaning to stop wildfires. Furthermore, as variables of relevance that alter the NPV calculation, these models used public subsidies for forest management, and the intensity of the wildfire is considered (Barreal et al., 2014). This project will not use the public compensation part and only focus on the NPV calculations with a forest owner acquiring insurance or not.

A landowner's forest wealth must be considered before developing a forest insurance model, as this is what gets damaged (D) in the event of a natural hazard. These losses are tied to the risk of biotic or abiotic hazards and cannot exceed the wealth of the original landowner. The probability of an event not occurring is the remainder $(1-\delta)$, whereas the wildfire risk is defined as δ. As mentioned, the danger of a wildfire is dependent on the forest management (s); therefore, the risk might be reduced by applying preventive measures (González et al., 2005). The forest insurance is impacted by these preventive measures (Ehrlich & Becker, 1972). Therefore, insurance and preventive measures will be complementary if the insurance calls for preventative tactics that enable self-protection activities to lower the likelihood of a disaster. On the other hand, insurance and self-defense will be interchangeable if the insurance price is not based on preventative measures. The risk in this work is inversely correlated with forest management efforts $[\delta'(s) < 0]$; this correlation is concave because more forest management efforts cannot lower the wildfire risk below a certain point $[[\delta''(s) < 0]]$ (Martell et al., 1998; Amacher et al., 2005). Landowners can thereby modify the danger through their activities (Chang, 1983, 1984; Amacher et al., 2009). In Barreal et al., (2014) they stated that the landowners are subject to additional exogenous variables, such as geographic and meteorological conditions, which may have a significant impact on the risk. However, by lack of data to calculate the probability of lowering the fire risk. The risk will be considered as the fire probability. This final set of variables, however, will not be included in the model because no party to the contract can change or modify them. To summarize, the risk of a wildfire is contingent upon the implementation of all preventive measures aimed at lowering the likelihood of a wildfire occurring. It is presumed that the insurer will possess knowledge regarding these preventive measures.

In the case of a forest owner who must bear the cost of forest management; this cost could be mitigated, though, if the government provides public subsidies to split the landowner's part of the management expenses (Lankoande et al., 2005; Yoder, 2008). In the study from Barreal et al., (2014) hey suppose that α defines the landowner's cost rate, and $(1-\alpha)$ represents the amount of public subsidies that go toward forest management. Since this proportion's value is between zero and one, $\alpha \in [0, 1]$ in a mathematical sense (Barreal et al., 2014). However, in this study, the whole cost of forest management is paid by the forest owner.

In the absence of insurance, the landowner must pay an insurance premium (γ) in exchange for the possibility of receiving compensation (Ω) in the event of a wildfire (Brunette et al., 2013); (Brunette & Couture, 2008). In this scenario, the insurance covers the costs of forest restoration (h), and the coverage may be partial or entire (full coverage). To ascertain the potential costs and the kind of restoration the landowner wants to carry out, this coverage will be connected to the recovery plan. This model will be made simpler by having the insurance policy predetermine the recovery expenses, which are fixed regardless of the intensity of the wildfire. Eq. (1) might therefore be used to calculate compensation, where μ represents the damage rate covered by the insurance policy and $(1-\mu)$ represent the percentage not covered by the insurance program. In the event that $\mu = 1$, full coverage (i.e., all direct damages would be covered by the insurance) would be provided; if $\mu = 0$μ, no insurance would be taken out. However, the insurer only pays up to λ of the estimated restoration costs; the insured landowner is responsible for the remaining amount. Thus, in the event that $\lambda = 1$, the insurer will pay for all forest restoration expenditures; in the event that $\lambda = 0$, these costs will be borne by the insured landowner. Thus, Barreal et al., (2014) defined the compensation as follows:

$$\Omega = \mu D + \lambda h \quad 0 \leq \mu \leq 1, 0 \leq \lambda \leq 1. \qquad [2]$$

In light of the aforementioned factors, landowners who want to be eligible for compensation in the event of a wildfire must purchase insurance. Landowners' wealth will change in accordance with the various payments they receive based on the state of nature (Rees & Wambach, 2008). For the sake of illustration, the net revenues linked to two distinct natural states (x = no fire and y = fire happens) are thus represented by the two subsequent equations:

$$x = PQ(t) - C(Q, s, \alpha) - \gamma(Q, t, s, \mu, \lambda) \qquad [3]$$

$$y = PQ(t) - C(Q, s, \alpha) - D(Q, t, I, \mu) - h(\lambda) - \gamma(Q, t, s, \mu, \lambda). \qquad [4]$$

The first example accounts for wood earnings (PQ), the cost of forest management (C), and the insurance premium (γ). It is therefore assumed that the forest provides a growing stock (Q) that is dependent on the time factor (t) for a certain site productivity. Production and time have a positive and concave connection $[Q'(t) > 0; Q''(t) < 0]$. It is also anticipated that the price of timber (P) will remain constant over time. Additionally, the management cost is influenced by the production of timber (Q), the public subsidy (α), and the effort put forth in forest management (s). Furthermore, the management costs show the following relations with regard to the variables indicated above: $[C'(s) > 0; C'(Q) > 0; C''(s) < 0; C''(Q) < 0]$. They also depend inversely on public subsidies $[C'(\alpha) < 0; C''(\alpha) > 0]$

Although they are not included in the current model, the landowner's views regarding risks are a prerequisite for all prior factors (Brunette & Couture, 2008). The time factor (t), the coverage level $(\mu; \lambda)$, the management effort (s), and the expanding stock (Q) all affect the insurance premium. In the particular scenario when the damages are not covered by wildfire insurance, the forest net revenues are shown in Equation (3). The effort (s)put into forest management and the cost $[h(\lambda)]$ of forest restoration determine these damages (D). Time (t), rising stock (Q), insurance coverage (μ), and wildfire severity (I) all affect damages (Barreal et al., 2014).

2.2. Optimal Forest Rotation Model

Forest wealth is typically valued using methods based on Faustman's rotation model (Faustmann, 1968). These models are meant to compute the optimal rotations period for a forest stand and have been extended and applied by researchers, such as Barreal et al. (2014), Reed (1984), Hartman (1976), and Samuelson (1976). Afforestation expenses (R) and/or timber revenues (PQ), which are financial factors, are included along with the characteristics of the forest. The period (t) that is used as the reference point and the interest rate (r) determine this continuous discount factor. The equation that is presented in Eq. (1), is determining the NPV for one rotation period.

$$NPV_t = PQ(t)e^{rt} - R \qquad [5]$$

The risk and insurance policy will be provided to further clarify the NPV. The NPV is the value of all future cash flows, both positive and negative, discounted to the present throughout an investment's lifetime is known as net present value. A common technique in accounting and finance to ascertain the value of a firm, investment security, capital project, new endeavor, cost-reduction plan, or anything else involving cash flow is NPV analysis. Consequently, the risk of damages determines the new valuation. The extension of the NPV formula is presented in Eq. (2). In this instance, damage risk and the cost of forest management are also considered. The best rotation of forests is determined by considering the risks and costs associated with forest production, which makes forest management a crucial factor in NPV calculations. These impacts, however, are mutually exclusive: while the management effort and associated expenses will rise, the premium to be paid for insurance and the projected damage will drop as the forest management effort grows (Barreal et al., 2014).

The expected damage for a hazardous event is the cross-product of the probability of an event (δ), and damage (D), but also depending on the management efforts made by the forest owner (s), and the possible losses that occur in the stand (Q), and additional cost that's follows with forest restoration (h) (Barreal et al., 2014).

$$NPV_t = [PQ(t) - C(Q, s, \alpha) - \delta(s)(D(Q, t, I) + h)]e^{rt} - R \qquad [6]$$

When a landowner purchases wildfire insurance, the features of the policy ought to be reflected in the earlier formula. Therefore, the insurance premium ought to be considered an extra expense. As a result, the cost of insurance premiums will rise if the coverage level and timber value rise or if the effort put into forest management declines. Furthermore, there is a negative correlation between the damages and the coverage level. As a result, with greater covering levels, there will be less anticipated harm to the timber stand or expense associated with forest restoration. Nonetheless, the damage rises with increasing wildfire severity.

Equation (6), which represents this new modified NPV function, takes into account a landowner's option to purchase insurance or not (Barreal et al., 2014).

$$NPV_t = \left[PQ(t) - \gamma(Q,t,s,\mu,\lambda) - C(Q,s,\alpha) - \delta(s)\big(D(Q,t,I,\mu) + h(\lambda)\big)\right]e^{-rt} - R \qquad [7]$$

3. Method

The following section covers the used method for this project and the prediction of fires in the forest. This chapter is divided into i) Approach ii) Secondary data iii) Predictor of hazards iv) Feeding the optimal rotation model.

3.1. Approach

The deductive research method is used in this project. Deduction refers to the process of initiating with a broad idea or hypothesis and proceeding logically down to a particular conclusion. It employs a top-down approach, beginning with a broad theoretical framework and testing it via actual observation. By using this method, the project aims to develop hypotheses based on accepted theories, which can be tested by designing research and gathering and evaluating evidence to support or contradict. Since it uses statistical analysis and objective measurement to test theories and identify correlations, the deductive method is frequently linked to quantitative research. Deductive research ensures a clear and logical development from hypothesis to conclusion by beginning with a theory and utilizing organized techniques to test it, providing a clear path to judge the validity and dependability of the findings.

3.2. Secondary data

Hakim (2000, p. 24) defined secondary data as "any reanalysis of data collected by another researcher or organization." Because secondary data analysis allows the author to benefit from other people's efforts in data collection, it can be a compelling approach. It also has the benefit of letting the writer focus on interpretation and analysis (Robson & McCartan, 2018). The study's empirical data is limited to publicly available statistics data for the each of the Swedish counties.

3.3. Data collection

To answer the research questions for this project, secondary data were collected. The data used to make the empirical simulations, data has been collected through the open statistical data bases of Statistics Sweden, Swedish Civil Contingencies Agency (MSB), Swedish Meteorological and Hydrological Institute (SMHI) and Swedish Forest Agency.

3.4. Predictors of hazards

Barreal et al. (2012) conducted a study wherein they predicted the probability of wildfires in each administrative demarcation by utilizing socio-economic, topographical, and climate-related data in Spain. This method is used to predict the probability of fires in the counties of Sweden. The data used for the Regression model can be seen in table 1.

Table 1: Data to estimate the fire probability of fire in Sweden from year 2002-2023, divided into variables and descriptions and the source of the data

Variable	Description	Source	Obtained
Fire characteristics			
Affected hectares between forest area	Affected area in hectares in each County (1)	MSB – Swedish Civil Contingencies Agency	OK
Number of fires	Number of fires per year in each district	MSB - Swedish Civil Contingencies Agency	OK
Fictional			
Dummy year t	Represents the year t		
Climate			
Average maximum temperature	Average maximum temperature, in degrees Celsius, for the months of June, July and August for each district	SMHI – Swedish Meteorological and hydrological Institute	OK
Population			
Singular entities	Number of unique entities per district	Swedish Forest Agency	Lack of data
Territorial			
Society value	Average value of rural properties what would correspond to every inhabitant of the district	The Swedish Board of Agriculture	Lack of data
Agro-livestock			
Relative area of tilled land	Proportion of plowed area available to agricultural and livestock farms based on the area of the district	The Swedish Board of Agriculture	Lack of data
Forest cover			
Relative area of transitional shrubland	Proportion of shrub or herbaceous vegetation with scattered trees in the district as a whole	Swedish Forest Agency	Lack of data

To analyze the relationship between the set of exposed variables and the fires in Sweden, a linear regression estimated by the Ordinary Least Squares Method (OLS) is used, controlling the coefficients for the heterogeneity of each district through the Hubert-White correction of the standard errors. Thus, the model will be expressed according to Eq. (8), for which the variables will be arranged in panel data. In this expression the subscripts “j, k, h" refer to the type of variable and "i" to the observation number.

$$Y_i = \beta_0 + \beta_i X_j + \beta_i X_{ki} + \beta_i X_{hi} + \varepsilon_i \qquad [8]$$

With this common specification, both the proportion of hectares burned as a function of the forest area of the district, as well as the number of fires in said territorial demarcation, will be modeled in two independent equations. The independent variables that represent socioeconomic indicators will be represented by the subindex, which will include data on the agricultural livestock, population, territorial and forest cover situation. On the other hand, the climatology will be represented by X_i, which includes the temperature variable. To conclude, the vector X_{hi} is included, which represents the dummy variables that reflect the year to which the data belongs.

3.5. Feeding the optimal forest rotation model

The predicted probability of fire will be used to calculate the benefits for a forest owner to acquire insurance that covers the losses due to fire damage. This variable will determine the losses a forest owner will suffer in the case of a forest fire.

4. Empirical simulations

This chapter covers all the empirical data used in the model for this project and includes a short reminder of the model and covers all the variables used or dropped to determine the NPV.

Wildfires do impact Sweden and seem to be increasing in the future and, the county of Västmanland seems to be the most affected by fires, as seen in Figure 2. Both the quantity of wildfires and the percentage of burned forest land in Sweden are higher in this region. By starting to initially calculate the projected wildfire risk in the counties to simulate the consequences of the earlier theoretical models. Regression models were used to create fire risk prediction indices for each county, and all the districts that correlated with low, medium, and high-risk indices were selected, which covers all the counties.

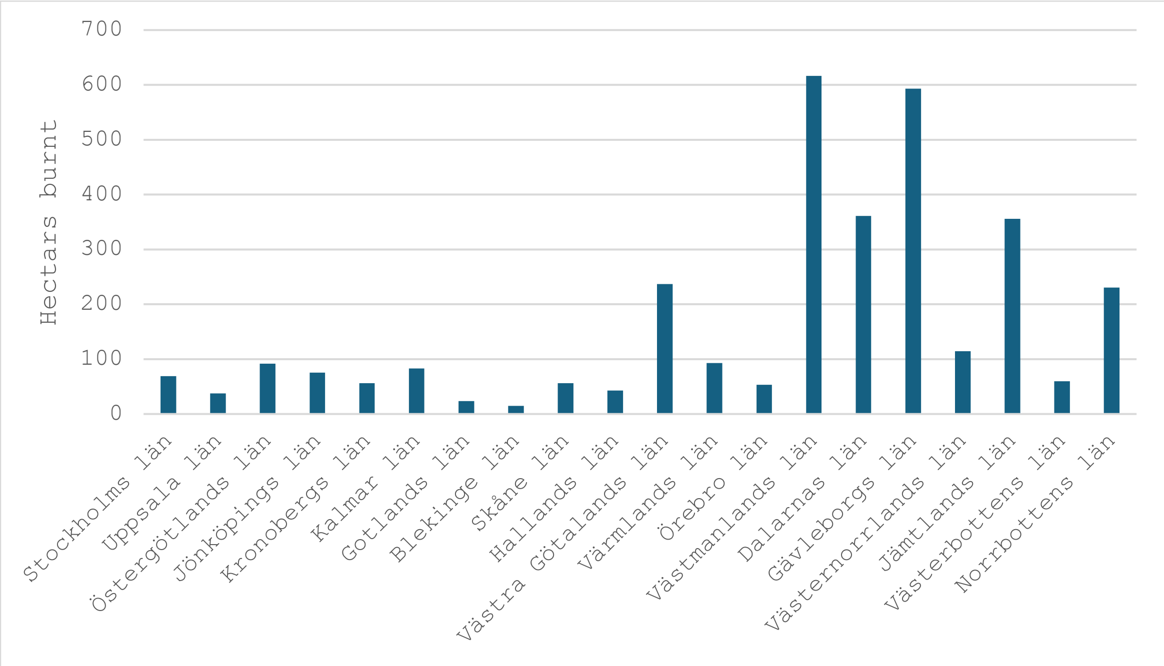


Figure 2: Average brunt hectares in counties in Sweden, reworked data from MSB statistics.

It is posited that there is a constant degree of risk inside every individual county. Another supposition is that all landowners, regardless of the size or management of their properties, have the same risk of wildfires and are eligible to purchase the forest insurance mentioned above. The simulation uses a specified interest rate of 3%, as used by Pasalodos-Tato et al. (2010), to determine the discount factor. The remaining variables are assigned random values because their purposes are limited to simulating the effects of forest insurance and identifying potential effect on the NPV.

Adaptation techniques have been the subject of numerous research as risk-reduction tactics for sustainable forest silviculture (Schoene & Bernier, 2012). There are different options for forest management, for example combination of spatial diversification and forest species that are suggested in local strategies to handle risks that come with climate change (Lindner et al., 2014). However, financial intervention is also one way of risk management in forestry to deal with the risks that are increasing with increasing temperature (Brunette et al., 2015).

In Europe, some governments have implemented financial compensation programs to provide financial support to forest owners affected by natural hazards. In the context of Sweden, after the storm Gudrun in 2005, the Sweden government provided 2 million euros to evaluate the damages and inform both the public and the landowners of the dangers and the recent fires in 2014 and 2018 the Swedish government provided 72 million and 110 respectively (SVT Nyheter, 2018). However, the idea of the negative impact of financial compensation on forest owners to be less likely to acquire forest insurance is stated by (Birot & Gollier, 2001), and (Hanewinkel et al., 2013). However, Brunette and Couture stated (2008) in their article that public post-disaster programs are discouraging individual forest owners from acquiring forest insurance or doing forest management investments that are aimed at protecting their forests from disasters. Also, they find that adopting public financial assistance programs to initiate forest insurance or forest management made forest owners more prone to acquire insurance when they are not contingent on activities that aim for protection.

Consequently, the provided values for damage and restoration coverage are set to $\mu = 100\%$. As a result, there is a deductible, which is equal to a fraction of the expenses and damages that landowners must pay. This means in the the calculation, that also 100% of restoration costs and 100% of timber damage are covered by insurance, based on the prior values. Only commercial values are considered, and the timber damage coverage is set to full coverage.

In this theoretical model an average forest stand in each county is used as an example based on its silvicultural production method to calculate the net present value (NPV) of the forest stand. This type of stand is selected because the values of the average production and standing cubic meter are found by data collected Riksskogsstaxeringen. Among other things, the soil's properties and the climate that affect this species' pace of growth are not able to be found for the average, however, the annual increment of m3sk growth is used. Using 20 years as the reference age to use the same time span as the historical data. Also, the assumption of the stand is having equal part of sawlogs and pulpwood and are paid by quantitative while in reality sawlogs are paid by timber qualitative. The counties vary in average forest productivity, so the current study compares the counties with the different average site indexes to get the differential effect of seeing if any county benefits from acquiring insurance.

A streamlined silvicultural regime is used in this simulation, consisting of a final clear-cut, one thinning throughout the rotation, and the planting and soil scarification cost per hectare. A landowner can accelerate the growth of the surviving trees and, more significantly, the rate at which their value appreciates by providing them with extra growing area. It is also possible to thin out trees that are poorly developed and will not be worth much in the future. The typical tree in the final cut will therefore be smaller and have less commercial value if the landowner does not undertake these intermediate cuts. Therefore, thinning, thinning that are commonly used in the Swedish forestry model will be included in this study to make the comparison more reliable to the collected values.

The prices for the afforestation are used to calculate restoration costs. These expenses, which are capped at 10863 Sek/ha, are the Swedish average price and cover the price of soil scarification, buying saplings, and planting the plants. They also cover the cost of protecting the plants with barriers or other supplies, as well as the planning of wildfire prevention measures.

The potential revenue from the last harvest for each potential rotation is used to determine the worth of the forest stand. The prices for timber and pulpwood are taken from the Swedish statistics (SCB) and shown in Table 2. These figures represent the average mill gate price for the year 2023. Finally, logging expenses and transportation (60 Sek/m3) will be deducted to determine the net revenue of the timber that will be received by the landowner.

The timber stand net value in the preceding equation is determined by the timber stand value as well as the cubic meter per hectare for the corresponding year (k). The timber grade determines this valuation is set to 70% sawlogs and 30% pulpwood. The lumber is categorized as pulpwood, and sawlogs in this model. Table x provides a thorough description of these timber prices in the classification used in the project. The grade of forest production determines the increasing stock per hectare, mill gate price, and harvesting cost per m3fub of timber. Lastly, the transportation cost per m3 to the factory is deducted to find the net worth of the wood stand.

Table 2: Price of sawlogs and pulpwood in Sweden 2023 (SCB, 2024)

Price Sek/m3fuvb	Saw logs	Pulpwood
Northern Norland	541	383
Southern Norrland	550	422
Svealand	564	428
Götaland	776	502

The landowner must pay an insurance premium in accordance with Equation (11) in order to obtain the coverage. This formula is derived from Equation (6). However, previous studies by Andersson & Nilsson (2022) obtained premiums from Länsförsäkringar. These premiums will be used to determine the NPV with eq.6 and are shown in Table 3.

Table 3: Table 3: Forest fire insurance premiums from Länsförsäkringar (Andersson &Nilsson, 2022)

Sek/ha/year	Northern Sweden	Central Sweden	Southern Sweden
Premium fire insurance	15	22,56	72

Consequently, the net present value (NPV) in both natural states should be equal if the landowner has no intention of purchasing insurance.

Remember, eq 6. looks as follows:

$$NPV_t = \left[PQ(t) - \gamma(Q,t,s,\mu,\lambda) - C(Q,s,\alpha) - \delta(s)\big(D(Q,t,I,\mu) + h(\lambda)\big)\right]e^{-rt} - R \quad [6]$$

Where P is the mill prices and Q is the standing volume m3fub by year t. The equation follows with the insurance premium cost (γ) which depends on the standing volume (Q), time (t), and management cost to decrease fire risk (s). The insurance covers the costs of forest restoration (h). where μ represents the damage rate covered by the insurance company and $(1 - \mu)$ the insurer only pays up to λ of the estimated restoration costs; the insured landowner is responsible for the remaining amount. Wildfire risk is defined as δ, wildfire severity (I) all affect damages and interest rate (r). However, in Table 4 an explanation of dropped-out variables is gathered and explained. Eq.1 is the working formula for this project.

$$NPV_t = \left[PQ(t) - \gamma - C(Q,s,\alpha) - \delta\big(D(Q)\big)\right]e^{-rt} - R \quad [1]$$

Table 4: Table of variables in the original eq.6 that are not included in the study. Described both theoretical, empirical and the observations/implications of the variables.

Theoretical	Empirical estimation	Observations/implications
Management to decrease risk of hazard are shown as S	Management due to decrease the damage in the forest stand are not used in the calculations.	No such available data. Less realistic, when different management methods and network of roads could be used to decrease hazard damage.
h is the cover of insurance due to the forest restoration from the public compensation.	It will be dropped out because of the inconsistency about governmental coverage due to damages made by hazards in the forest.	More realism, due to inconsistency of compensation from the public. However, cost is covered by insurance company.
μ represent the rate covered by insurance policy and λ represent the total that the insurance company paid, which means the insured landowner pays the remaining.	Will be dropped out due to no information about the share. Are estimated as fully paid by the landowner.	There is no data of shares for such compensations.
Wildfire severity (I) all affect damages	This variable will not be included due to lack of data.	Less realism, due to using the mean risk probability of fire to both determine the risk and damages.

4.1. Previous studies

Previous studies in the Nordic countries seem not to have been done in any bigger substance of forest insurance. Table 5 contains some of the literature used in the report.

Table 5: Previous studies that are focusing on forest insurance with different approaches.

Author	Aim	Conclusion
Holecy and Hanewinkel (2006)	The purpose of the study was to present a general model for forest destruction insurance that can be used to determine risk premiums for insurance against the possibility of forest destruction caused by individual or combined harmful factors.	Insurance boosts forest financial stability, contingent on fair premiums and large-scale coverage. Current limited interest stems from state subsidies. Private risk precaution gains importance amid public financial challenges. Forest owners aim to cut premiums via risk-reduction measures.
Brunette & Couture, (2008)	Aims to answer, (i) How do public reimbursement for disaster damages affect the risk management decisions made by forest owners to invest in risk-reducing forest management initiatives or buy insurance? (ii) Are public compensation programs an alternative to forest management or insurance? (iii) How do public post-disaster compensations affect forest owners' decisions about risk management differently? (iv) How might government action motivate owners of private forests to implement risk management strategies? This paper's goal is to examine these hitherto unconsidered topics.	Public post-disaster assistance discourages private forest owners from purchasing insurance or investing in protective forest management. Aligning public assistance with insurance coverage or protection activities makes these options more appealing. Further analysis, considering joint insurance and risk-reducing practices, and additional data on forest owners' decisions, is recommended for a more accurate understanding of the impact of public assistance on insurance and forest management.
Andersson & Nilsson, (2022)	The purpose of this study is to investigate if purchasing forest fire insurance passes a cost-benefit analysis when viewed from the standpoint of a single forest owner who considers the likelihood of a fire. We do a cost-benefit analysis under two different probability scenarios: (i) as if the probability represents historical fire probabilities; and (ii) as if the probability reflects updated expectations that account for the expected rise in future fire probabilities brought on by climate change.	The study addresses the profitability of acquiring forest fire insurance for individual owners in Sweden based on historical fire data. Despite considering different scenarios, including varying probabilities of fire and the influence of climate change, the research suggests that, overall, acquiring such insurance is not financially beneficial for private forest owners. The model identifies tipping point probabilities for different regions in Sweden, highlighting varying thresholds for profitability. However, the study acknowledges several limitations, such as loose assumptions, simplified variable considerations, and the assumption that estates represent entire regions. The model does not fully account for local differences in infrastructure, climate, and forest characteristics. Additionally, the decision-making process for forest owners may involve factors beyond monetary costs, such as non-timber values or estate characteristics. The study also points out data limitations and uncertainties related to the government's role in forest fire insurance, suggesting the need for further discussion on subsidies for fire preventative silviculture and compensation for non-timber values lost in fires.

Holecy & Hanewinkel (2006) aim to provide a general model for forest insurance that could be used to calculate risk premiums for policies covering the potential for single or many detrimental elements to cause forest loss. Their finding where that under the condition of reasonable premiums and broad coverage, insurance increases the financial stability of forests. State subsidies are the source of the current low interest. Amidst governmental financial crises, the significance of private risk protection increases. The goal of forest owners' risk-reduction strategies is to lower premiums. Following, Brunette and Couture, (2008) emetized the similar conclusion that private forest owners are deterred from engaging in protective forest management or buying insurance by public post-disaster aid. These possibilities become more attractive when public aid is coordinated with insurance coverage or protective initiatives. For a more accurate understanding of the impact of public support on insurance and forest management, more research is advised, taking into account joint insurance and risk-reducing strategies as well as additional data on the decisions made by forest owners.

However, in the Nordic countries, the insurance uptake seems to be high, and was shown in different studies that Andersson & Nilsson (2022) that the insurance uptake is high in Sweden. They also aimed to see if there was a beneficial investment to acquire fire insurance which in their study was not beneficial. However, their study stated that it had many limitations and that data collection for this kind of study is challenging.

Previous studies mostly aimed to calculate the impact of the government and policymaking on forest insurance. However, this study contained good mathematical methods to calculate and derive a good method for this study.

5. Results

The following chapter presents the results of the project and describes the outcome of the analysis. This section contains i) Fire risk in the counties of Sweden ii) the NPV of forest investment on fire insurance iii) The effect of insurance premiums on the NPV.

5.1. Fire risk in the counties of Sweden

From the model used to calculate the probability of fire risk, the following figure shows the mean probability of fire risk in each county in Sweden. This was made by running an ordinary OLS shown in section 3.4. The original idea was to use all data collected, unfortunately lack of data missing for the period on most of the variables the regression was made on the temperature and on the highest temperature during the summer month.

The highest probability is determined in Stockholm at 0.063 and the lowest in Jämtland at 0.38. The range between the lowest and the highest probability is 0.25 which also shows the spread of risk in the other counties and can be seen in Figure 3.

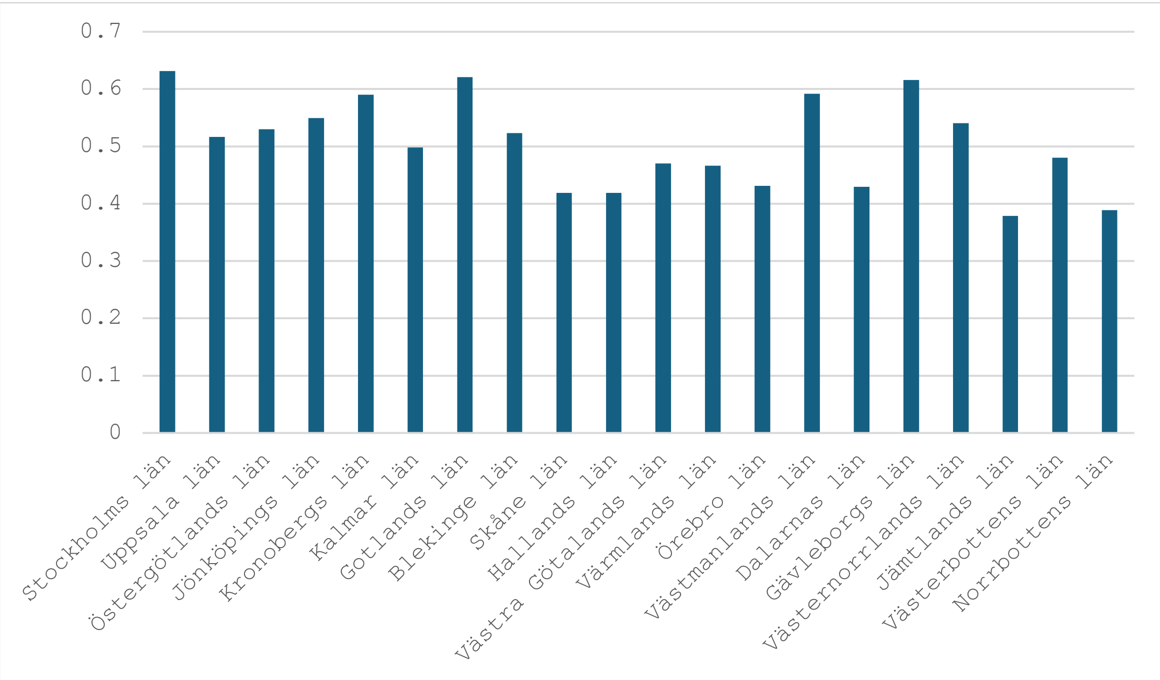


Figure 3: Mean probability in each county in Sweden, own elaboration of regression. (Source: MSB 2023, SCB 2023). Data can be found in Table 4.

5.2. NPV of forest investment on fire insurance

The following figures show the NPV values for each county in Sweden when the forest owner has acquired forest fire insurance or is not under a certain risk in their county. Due to the data and the results from Eq. (6) in all counties the forest fire risk is reducing the NPV shown in figure 4. When a forest owner acquires fire insurance it increases the NPV with in mind the computed risk. In Figure 4 the NPVs that have been determined for the counties in Sweden have a positive value when acquiring insurance, except for Stockholm where the NPV with insurance is negative 35350.41 SEK. The county of Dalarna in the central part of Sweden is the county that has the highest NPV of 189669.74 Sek with insurance and has an NPV similar to the southern located regions.

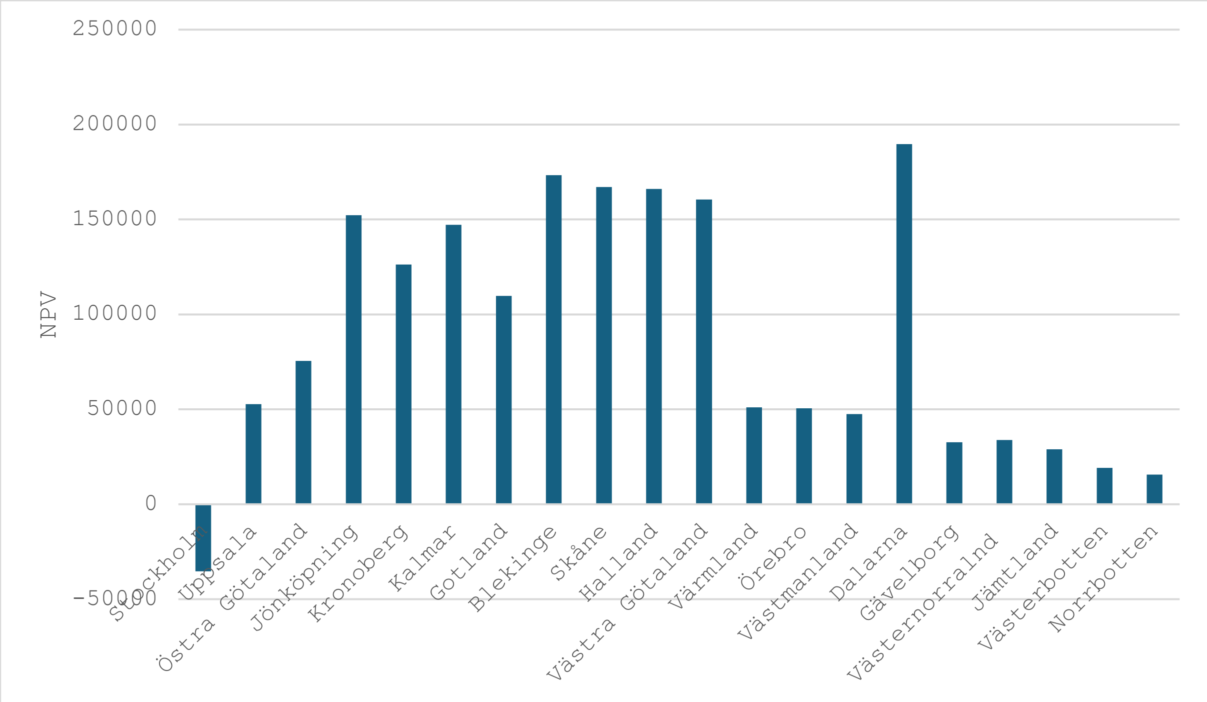


Figure 4: NPV of a forest hectare in each county with fire insurance, Results from displayed from the hypothetical working equation used in section 4.

In Figure 5, the NPV value for a forest owner who has not acquired insurance against fire has a negative NPV. The values are determined with eq.6 without the insurance cost and the losses due to fire damages. From previous Figure 4 the results in Figure 5, NPV without fire insurance is that the numbers are all negative. This is the result of losing all the potential income from that forest stand and the investments of different silvicultural efforts don't pay out. Also, the regeneration cost occur when it needs to be replanted.

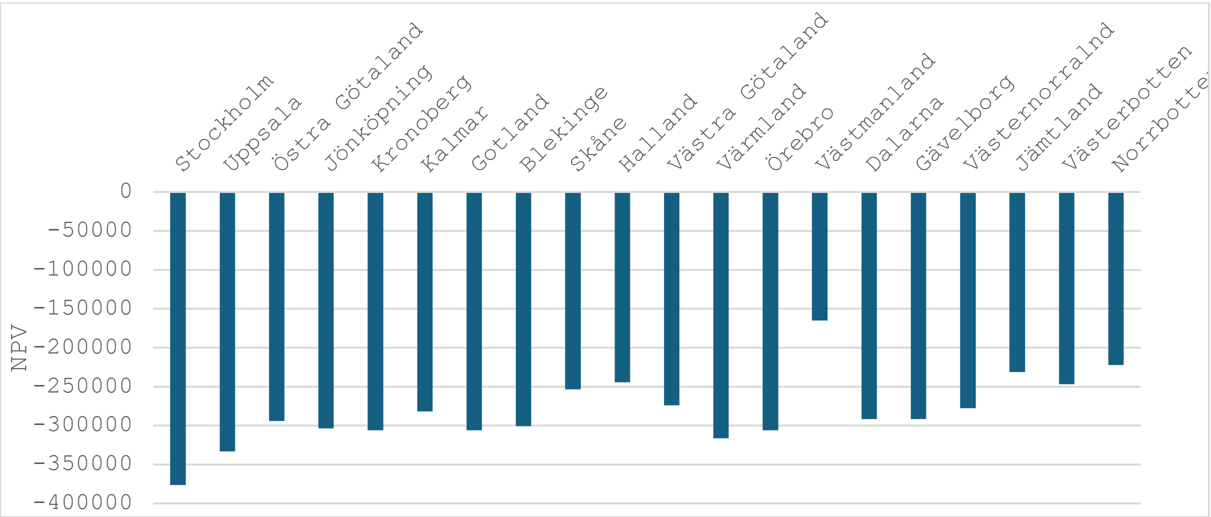


Figure 5: NPV of a forest hectare in each county without fire insurance.

5.3. The effect of insurance premiums on the NPV

By changing the insurance premium, the NPV was decreased according to Table 6. However, the NPV only decreases with the premium cost due to fire insurance, the premiums can be seen in Table 3. The effect of the insurance premium was obtained through eq.6 where only the percentage of the premium where changed. The greatest changes can be seen in the southern regions in Östergötland, Jönköping, Kronoberg, Kalmar, Gotland, Blekinge, Skåne, Västra Götaland, which have the highest premium costs.

Table 6: NPV-change with higher cost when increasing premiums, with a base value calculated with today's premiums, increased cost from 50% up to 700%

Premium Change	Base	50%	100%	200%	700%
Stockholms län	-35350,41	-35382,61	-35414,81	-35479,20	-35801,18
Uppsala län	52720,94	52688,74	52656,55	52592,15	52270,17
Östergötlands län	75565,73	75462,97	75360,21	75154,70	74127,11
Jönköpings län	152205,77	152103,01	152000,25	151794,73	150767,15
Kronobergs län	126331,63	126228,87	126126,11	125920,60	124893,01
Kalmar län	147186,91	147084,15	146981,39	146775,87	145748,29
Gotlands län	109792,48	109689,72	109586,96	109381,44	108353,86
Blekinge län	173362,22	173259,46	173156,71	172951,19	171923,60
Skåne län	167131,13	167028,37	166925,61	166720,10	165692,51
Hallands län	166095,99	166069,32	166042,65	165989,31	165722,62
Västra Götalands län	160498,48	160395,72	160292,96	160087,44	159059,85
Värmlands län	51134,72	51102,52	51070,33	51005,93	50683,95
Örebro län	50537,79	50505,59	50473,40	50409,00	50087,02
Västmanlands län	47449,42	47417,22	47385,03	47320,63	46998,65
Dalarnas län	189669,74	189637,54	189605,34	189540,94	189218,97
Gävleborgs län	32607,47	32586,06	32564,65	32521,84	32307,76
Västernorrlands län	33819,45	33798,05	33776,64	33733,82	33519,74
Jämtlands län	29002,91	28981,51	28960,10	28917,28	28703,20
Västerbottens län	19199,26	19177,83	19156,44	19113,62	18899,54
Norrbottens län	15685,53	15664,12	15642,71	15599,89	15385,81

6. Discussions

This chapter covers the interpretation and analysis of the results of the project and the limitations interpretation of the result. The following sections include i) Interpretation and analysis of the results ii) Limitations.

6.1. Interpretation and analysis of the results

6.1.1. Fire probability and risk

The results from the regression are based on the correlation between the number of fires and max temperature, which should be interpreted as the risk of a fire starting during the day with the highest temperature. The data used are based on the model described in 3.4. Due to a lack of data for the model, those where variables were used to run the regression.

In Table 7, the following probabilities were used in the optimal forest model to calculate the NPV of acquiring fire insurance. However, it’s also important to keep in mind that the damages caused by fire are based on this number which would be based on the prediction of the fire severity. With the time frame of this project, the model only uses the mean fire probability.

Table 7: The mean fire probability during the June, July, and August between 2022-2023

County	Mean fire probability
Stockholms län	0.6311507
Uppsala län	0.5164884
Östergötlands län	0.5298296
Jönköpings län	0.5493596
Kronobergs län	0.5902597
Kalmar län	0.4979397
Gotlands län	0.6209415
Blekinge län	0.523335
Skåne län	0.4190702
Hallands län	0.4190702
Västra Götalands län	0.4700396
Värmlands län	0.4661136
Örebro län	0.431208
Västmanlands län	0.5915616
Dalarnas län	0.4293053
Gävleborgs län	0.61566
Västernorrlands län	0.540678
Jämtlands län	0.3787879
Västerbottens län	0.4800885
Norrbottens län	0.3888326

6.1.2. NPV with or without fire insurance

The NPV for all the counties was positive with insurance against fire besides the county of Stockholm. This is not what was expected due to the number of fire ignitions in that area, this can be the result of not including hectares burnt that are getting affected by fire in the regression to calculate the fire probability. In the case of the set variables and the data used in the calculations, fire insurance would increase the NPV. This includes that the insurer is fully compensating the forest owner in the event of a fire. As mentioned before, public subsidies or public compensation are not made daily in the event of fires in Sweden. Therefore, connected to the theory, this part is not included in the calculations.

In the case of not being insured, the outcome was a negative NPV. However, this could be expected when the fire risk decreased the NPV for each county. The calculations were also done by mirroring the time frame for the collected data, which would have a great impact by using average data. The results should not be used to decide whether to acquire insurance or not in the specific case of a forest owner.

6.1.3. NPV with increasing premium

When rising voices about insurance premiums, due to the rising voices of worries about increasing insurance premiums. The project also wanted to investigate how the cost of the insurance is influencing the NPV. In this case, is the NPV highly connected to the total cost and will be discounted with the costs. In this case and data, the cost seems to not influence the NPV more than the actual cost. This means that the model does not cover the actual price other than the set boundaries of repaying the losses with insurance. The impact of the insurance coverage likely makes the NPV less volatile because the risk is transferred to the insurer who will pay the losses due to fire.

6.2. Limitations

6.2.1. Limitations of the probability of fire

Due to the timeframe of this project a list of limitations where necessary to outrun the analysis. Firstly, the variable of fire risk that were calculated by the model by Barreal et al. (2012) included several data inputs shown in table 1. However, the regression model could only be done with the number of fires and temperature during the summer months of June, July, and August. This was because of the lack of data for the other variables. The variable from the regression, later used in the NPV formula, should be interpreted as the chance of getting the ignition in the forest during the hottest day. Because of time and lack of data, this variable was used both as, the chance of getting a fire and the percentage of damaged wood.

The regression model would be useful, and this type of analysis would benefit from a rigid way of calculating risk due to hazards.

6.2.2. Limitations of the Optimal Forest Rotation Model

The analysis is made on the average standing volume in the whole county and does not consider the differentiation of standing volume, site indexes, soil properties, etc. on each forest stand or property, which gives less realism in the specific case of a forest owner. The cost of pre-commercial thinning would give a more realistic comparison to the real mainstream silviculture system used in Sweden when pre-commercial thinning usually is done when a forest stand reaches 10-15 meters of height.

Important to remember is that the system of forest silviculture is timing of the different managements used in Sweden differs along the country, because of the rotation period. Practically this means, that depending on the site's productivity your rotation period would be different and should be considered when comparing the results that use the same rotation period.

Limitations due to coverage and public compensations were also not included in the analysis. However, due to greater hazards, the government has paid out money with the help of MSB or the Forest Agency and could be interesting to understand the change in fire insurance uptake if public compensation were an ordinary practice.

The analysis was made by using average data for a forest stand in each county which made the optimal rotation period for the calculations hard to decide. The average forest stand in Sweden is said to be between 80-100 years depending on where you are in the country, from shorter in the southern parts and longer in the northern areas. The rotation period where therefore decided to be the same time interval as the collected data of 21 years.

The premium is used from a recent study made by Andersson & Nilsson (2022) Where they collected data for the three regions divided as Northern, middle, and southern Sweden, which was based as an average by Länsförsäkringar. This study would benefit from having collected data from each local insurance company in each county to have a more precise insurance premium against fire. However, the time constraint allowed to use of existing data already collected.

7. Conclusions

This chapter will address the conclusions and findings of the project and connect to the aim of this thesis, this section includes i) The contribution of the aim ii) Future research iii) critics of the model.

7.1. Concluding discussion

This project aimed to analyze how the NPV of a forest would change by acquiring fire insurance. Additionally, a further investigation was done by changing the insurance premiums and increasing the fire probability. To do so, the NPV was calculated to see the effect of acquiring fire insurance to cover the losses due to fire damage. Furthermore, by changing the premium the project aimed to see how the model used to calculate the NPV would change the results of it being beneficial to still invest in a more costly insurance.

The study showed that in all counties in Sweden, fire insurance would increase the NPV and benefit the forest owner. However, in the county of Stockholm, the NPV of fire insurance showed a negative NPV.

A previous study from Andersson & Nilsson (2021), showed that the NPV value becomes negative while acquiring a fire insurance. This is important to have in mind when making decisions on insurance or not. However, this study is prolonging their study and is using more data and making more statistical methods to decide the fire risk. This project also used exciting models to decide how to make an insurance model and would hopefully contribute to a better way to calculate the premiums and the effect of insurance as an investment on the NPV.

Unfortunately, there is not much research done on this area in Scandinavia, which would be beneficial when the uptake of insurance is high.

7.2. Future research

With an increasingly unknown future of different hazards and their severity, more pressure will be put on the insurers and society. When the risks become higher, and the damage caused by these hazards the insurance premiums are likely to become more costly more precise insurance models might be needed to make the forest owner make different ways of decreasing risk and making better premiums depending on local risk, risk management, and social uses.

- Examine the relationship between forest management practices and the likelihood of forest fires with regard to infrastructure, the distribution of tree species, and fire-prevention silviculture, among other things.
- Examine the decision-making processes a forest owner must handle, such as timing and type of insurance.
- Calculating each estate's specific needs based on forest management plans.
- Provide a tool that uses the model to help each owner make decisions and supports them in doing so. The forest management plan for each individual forest owner may

serve as the basis for this. To implement the paradigm, the tool would also require a function that converts the various property stands into monetary terms.
- The government's responsibility to provide funding for the risks a forest owner faces should be computed and incorporated into the model in order to reduce losses from fire. This would allow for the inclusion of a parameter that benefits society as a whole.

7.3. Critics of the model

The model includes the effect of management methods to decrease the effect of fire damage or the possibility of ignition. To do so, more data or methods to evaluate these kinds of efforts need to be able to do so. No such data were found for this project to be able to use those assumptions in the calculation.

The model should be made to make fast calculations for a single forest stand in the context of a forest owner. However, the models made today are mostly concerning public compensation. The model does also not include the different forest attributions such as soil wetness or species’ different resistance against fire when connecting to the premiums for a forest owner. This would be beneficial to calculate the premiums from a single forest stand.

Acknowledgments

I would like to especially thank my supervisor, Adan Martinez Cruz for all the support and inspiring words during the time of this project. One person that also important for the sake of getting this project done and supporting throughout the course is Cecilia Mark-Herbert. Thank you both! Lastly, I would like to thank my beloved girlfriend that have been unbelievably supportive during all the ups and downs.

References

Amacher, G. S., Malik, A. S., & Haight, R. G. (2005). Not getting burned: the importance of fire prevention in forest management. *Land Economics*, *81*(2), 284-302.

Amacher, G. S., Ollikainen, M., & Koskela, E. (2009). *Economics of forest resources*. Mit Press Cambridge.

Barreal, J., Loureiro, M. L., & Picos, J. (2014). On insurance as a tool for securing forest restoration after wildfires. *Forest Policy and Economics*, *42*, 15-23.

Birot, Y., & Gollier, C. (2001). Risk assessment, management and sharing in forestry, with special emphasis on wind storms. *papier présenté lors de la*, *14*.

Brunette, M., Cabantous, L., Couture, S., & Stenger, A. (2013). The impact of governmental assistance on insurance demand under ambiguity: a theoretical model and an experimental test. *Theory and decision*, *75*, 153-174.

Brunette, M., & Couture, S. (2008). Public compensation for windstorm damage reduces incentives for risk management investments. *Forest Policy and Economics*, *10*(7-8), 491-499.

Brunette, M., Holecy, J., Sedliak, M., Tucek, J., & Hanewinkel, M. (2015). An actuarial model of forest insurance against multiple natural hazards in fir (Abies Alba Mill.) stands in Slovakia. *Forest Policy and Economics*, *55*, 46-57.

Chang, S. J. (1983). Rotation age, management intensity, and the economic factors of timber production: Do changes in stumpage price, interest rate, regeneration cost, and forest taxation matter? *Forest science*, *29*(2), 267-277.

Chang, S. J. (1984). Determination of the optimal rotation age: a theoretical analysis. *Forest Ecology and Management*, *8*(2), 137-147.

Dai, Y., Chang, H.-H., & Liu, W. (2015). Do forest producers benefit from the forest disaster insurance program? Empirical evidence in Fujian Province of China. *Forest Policy and Economics*, *50*, 127-133.

Deng, Y., Munn, I. A., Coble, K., & Yao, H. (2015). Willingness to pay for potential standing timber insurance. *Journal of Agricultural and Applied Economics*, *47*(4), 510-538.

Ehrlich, I., & Becker, G. S. (1972). Market insurance, self-insurance, and self-protection. *Journal of political Economy*, *80*(4), 623-648.

Faustmann, M. (1968). Calculation of the value which forest land and immature stands possess for forestry. In *Economics of Forestry* (pp. 1-40). Routledge.

González, J. R., Pukkala, T., & Palahí, M. (2005). Optimising the management of Pinus sylvestris L. stand under risk of fire in Catalonia (north-east of Spain). *Annals of Forest Science*, *62*(6), 493-501.

Hanewinkel, M., Cullmann, D. A., Schelhaas, M.-J., Nabuurs, G.-J., & Zimmermann, N. E. (2013). Climate change may cause severe loss in the economic value of European forest land. *Nature climate change, 3*(3), 203-207.

Hanewinkel, M., Hummel, S., & Albrecht, A. (2011). Assessing natural hazards in forestry for risk management: a review. *European Journal of Forest Research, 130,* 329-351.

Hartman, R. (1976). The harvesting decision when a standing forest has value. In *Economics of Forestry* (pp. 295-302). Routledge.

Holecy, J., & Hanewinkel, M. (2006). A forest management risk insurance model and its application to coniferous stands in southwest Germany. *Forest Policy and Economics, 8*(2), 161-174.

Lankoande, M., Yoder, J., & Wandschneider, P. (2005). *Optimal wildfire insurance in the wildland-urban interface in the presence of a government subsidy for fire risk mitigation*.

Lindner, M., Fitzgerald, J. B., Zimmermann, N. E., 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? *Journal of environmental management, 146,* 69-83.

Mats Andersson (2012), "Assessing non-industrial private forest owners’ attitudes to risk: Do owner and property characteristics matter?", Journal of Forest Economics: Vol. 18: No. 1, pp 3-13. http://dx.doi.org/10.1016/j.jfe.2011.05.001

Martell, D. L., Gunn, E. A., & Weintraub, A. (1998). Forest management challenges for operational researchers. *European journal of operational research*, *104*(1), 1-17.

Kvennefeldt, E. and Lindström, L. (2016). *Riskbeteende hos skogsägare - en studie om faktorer som påverkar skogsägares beslut att försäkra sin skog*. Sveriges Lantbruksuniversitet, instutitiionen för skogens biomaterial och teknologi. https://stud.epsilon.slu.se/9435/1/kvennefeldt_e_lindstrom_l_160812.pdf.

Picard, O., Robert, N., & Toppan, E. (2002). Les systèmes d’assurance en forêt et les progrès possibles. *Fédération Nationale des Syndicats de Propriétaires Forestiers Sylviculteurs*.

Pinheiro, A. C., & Ribeiro, N. d. A. (2013). Forest property insurance: an application to Portuguese woodlands. *International Journal of Sustainable Society*, *5*(3), 284-295.

Qin, T., Gu, X., Tian, Z., Pan, H., Deng, J., & Wan, L. (2016). An empirical analysis of the factors influencing farmer demand for forest insurance: Based on surveys from Lin’an County in Zhejiang Province of China. *Journal of Forest Economics*, *24*, 37-51.

Reed, W. J. (1984). The effects of the risk of fire on the optimal rotation of a forest. *Journal of environmental economics and management*, *11*(2), 180-190.

Rees, R., & Wambach, A. (2008). The microeconomics of insurance. *Foundations and Trends® in Microeconomics*, *4*(1–2), 1-163.

Samuelson, P. A. (1976). Economics of Forestry in an Evolving Society∗. In *Classic Papers in Natural Resource Economics Revisited* (pp. 355-378). Routledge.

Schelhaas, M. J., Nabuurs, G. J., & Schuck, A. (2003). Natural disturbances in the European forests in the 19th and 20th centuries. *Global Change Biology*, *9*(11), 1620-1633.

Schoene, D. H., & Bernier, P. Y. (2012). Adapting forestry and forests to climate change: a challenge to change the paradigm. *Forest Policy and Economics*, *24*, 12-19.

Seidl, R., Schelhaas, M.-J., Rammer, W., & Verkerk, P. J. (2014). Increasing forest disturbances in Europe and their impact on carbon storage. *Nature climate change*, *4*(9), 806-810.

Seidl, R., SCHELHAAS, M. J., & Lexer, M. J. (2011). Unraveling the drivers of intensifying forest disturbance regimes in Europe. *Global Change Biology*, *17*(9), 2842-2852.

Spittlehouse, D. L., & Stewart, R. B. (2003). Adaptation to climate change in forest management.

Thürig, E., Palosuo, T., Bucher, J., & Kaufmann, E. (2005). The impact of windthrow on carbon sequestration in Switzerland: a model-based assessment. *Forest Ecology and Management*, *210*(1-3), 337-350.

Van Aalst, M. K. (2006). The impacts of climate change on the risk of natural disasters. *Disasters*, *30*(1), 5-18.

van Lierop, P., Lindquist, E., Sathyapala, S., & Franceschini, G. (2015). Global forest area disturbance from fire, insect pests, diseases and severe weather events. *Forest Ecology and Management*, *352*, 78-88.

Williams, D. W., & Liebhold, A. M. (1995). Herbivorous insects and global change: potential changes in the spatial distribution of forest defoliator outbreaks. *Journal of Biogeography*, 665-671.

Yoder, J. (2008). Liability, regulation, and endogenous risk: the incidence and severity of escaped prescribed fires in the United States. *The Journal of Law and Economics*, *51*(2), 297-325.

Previous reports in this series

1. Lindström, H. 2019. Local Food Markets - consumer perspectives and values

2. Wessmark, N. 2019. Bortsättning av skotningsavstånd på ett svenskt skogsbolag - en granskning av hur väl metodstandarden för bortsättningsarbetet följts

3. Wictorin, P. 2019. Skogsvårdsstöd - växande eller igenväxande skogar?

4. Sjölund, J. 2019. Leveransservice från sågverk till bygghandel

5. Grafström, E. 2019. CSR för delade värderingar - En fallstudie av kundperspektiv hos skogs- och lantbrukskunder inom banksektorn

6. Skärberg, E. 2019. Outsourcing spare part inventory management in the paper industry - A case study on Edet paper mill

7. Bwimba, E. 2019. Multi-stakeholder collaboration in wind power planning. Intressentsamråd vid vindkraftsetablering

8. Andersson, S. 2019. Kalkylmodell för produkter inom korslimmat trä - Fallstudie inom ett träindustriellt företag. Calculation model for products within cross-laminated timber - A case study within a wood industrial company

9. Berg Rustas, C. & Nagy, E. 2019. Forest-based bioeconomy - to be or not to be? - a socio-technical transition. Skogsbaserad bioekonomi - att vara eller inte vara? - En socio-teknisk övergång

10. Eimannsberger, M. 2019. Transition to a circular economy - the intersection of business and user enablement. Producenters och konsumenters samverkan för cirkulär ekonomi

11. Bernö, H. 2019. Educating for a sustainable future? - Perceptions of bioeconomy among forestry students in Sweden. Utbildning för en hållbar framtid? - Svenska skogsstudenters uppfattningar av bioekonomi

12. Aronsson, A. & Kjellander, P. 2019. Futureshandel av rundvirke - Möjligheter och hinder för en futureshandel av rundvirke. A futures contract on roundwood - Opportunities and barriers for a futures trade on roundwood

13. Winter, S. 2019. Customers' perceptions of self-service quality - A qualitative case study in the Swedish banking sector. Kundernas uppfattning om självbetjäningskvalitet

14. Magnusson, K. 2020. Riskanalys av hybridlärk (Larix X marschlinsii) - Möjligheter och problem. Risk analysis of hybrid larch (Larix X marchlinsii) - Opportunities and problems

15. Gyllengahm, K. 2020. Omsättningslager för förädlade träprodukter - en avvägning mellan lagerföring - och orderkostnad. Levels of cycle inventory for processed wood products - a trade-off between inventory - and order cost

16. Olovsson, K. 2020.Ledtider i sågverksindustrin – en analys av flöden och processer. Lead times in the sawmill industry – an analysis of flows and processes

17. Holfve, V. 2020. Hållbart byggande – Kommuners arbete för flerbostadshus i trä. Building in a sustainable way –Municipalities' work for wooden multistory constructions

18. Essebro, L. 2020. Ensuring legitimacy trough CSR communications in the biobased sector. Att säkerställa legitimitet genom CSR kommunikation i den biobaserade sektorn

19. Gyllengahm, K. 2020. Making material management more efficient – reduction of non-value-adding activities at a wood products company. Effektivisering av materialflödet – reducering av icke värdeadderande aktiviteter på ett trävaruföretag

20. Berg, E. 2020. Customer perceptions of equipment rental – Services for a circular economy. Kunders uppfattning av maskinuthyrning – Serviceutbud och cirkulär ekonomi

21. Emerson, O. 2020. Impacts of environmental regulations on firm performance – the development of a new perspective. Påverkan av miljökrav på företags prestanda – utvecklingen av ett nytt perspektiv

22. Essebro, L. 2020. Communicating a climate friendly business model. Att kommunicera en klimatvänlig företagsmodell

23. Halldén, A. 2020. Skogens roll i klimatfrågan – En medieanalys av Dagens Nyheter 2010–2019. The role of forests in the climate discourse – a media analysis of Dagens Nyheter 2010-2019

24. Gebre-Medhin, A. 2020. Swedish FES-related policy: Integration of national objectives and factors affecting local actors' policy respons

25. Tanse, K. 2020. The Swedish policy framework for Forest Ecosystem Service. A study of integration of objectives, policy instruments and local actor's knowledge about policies and policy objectives

26. Braunstein, G. 2020. Promoting sustainable market development – A case study of wooden multi-story buildings. Att främja en hållbar marknadsutveckling – En fallstudie om flervåningsbyggande i trä

27. Saati, N. 2021. Corporate social responsibility communication in apparel retail industry. Företagens sociala ansvars kommunikation i textila detaljhandeln

28. Fakhro, I. 2021. Leadership Contribution to Organizations During Pandemic Disruption – A case Study of Private Swedish Organizations. Ledarskapsbidrag till organisationer under pandemisk störning - en fallstudie av privata svenska organisationer

29. von Heideken, F. 2021. Municipal Construction Strategies – The promotion of wooden multi-storey construction. Kommunala byggstrategier – Främjandet av flervåningshus i trä

30. Tiwari, V. 2021. The Challenges in Public Private Partnerships and Sustainable Development. Utmaningar i hållbara utvecklingsprojekt mellan privata och publika aktörer – ej publicerad

31. Söderlund, M. 2021. Att skapa mervärde i en produktlinjeutvidgning. To create added value in a product line extension

32. Eriksson, P. 2021. Wood procurement using harvest measurement. For improved management of forest operations. Virkesanskaffning med hjälp av skördarmätning – För en förbättrad verksamhetsstyrning

33. Olsson, M. & Sparrevik, G. 2021. Commercial forestland investments. A comparative analysis of ownership objectives. Kommersiella skogsmarksinvesteringar -En jämförande studie av ägarmål

34. Dahl, P. 2021. Improving sawmill scheduling through Industry 4.0 A CASE study at VIDA AB. Förbättring av sågverksplanering genom Industry 4.0 – En fallstudie på VIDA AB

35. Leijonhufvud, E. 2022. Råvaruförsörjning av grot - Försörjningskedjan vid Södra Skog Raw material supply of logging residues -The Supply Chain at Södra Skog

36. Nytell, A. 2022. Young Consumer perceptions of Wooden Multistorey Construction Unga konsumenters uppfattningar om flervåningshus i trä

37. Ljudén, A. & Nyström, A. 2022. Digitaliserings potential Kartläggning och analys av arbetsprocesser. The potential of digitalization – Mapping and analysis of business processes

38. Rubensson, N. 2022. Processeffektivisering vid hyvling - En analys av operatörernas förutsättningar. Process streaming in planning- An analysis of the operations conditions

39. Eriksson, P. 2022. The Forest Sector's Adaptation. Taxonomy and Emerging Carbon Markets. Skogssektorns hållbarhetsanpassning – Taxonomin och kolmarknader

40. Olander, C. 2022. I'll have what he's having - Can a bank increase financial equality? Jag tar det han får – Kan en bank öka finansiell jämställdhet?

41. Färnström, I. 2022. Market development for multi-story wood construction – Views of architects and structural engineers. Marknadsutveckling för träbygge i flervåningshus. Arkitekter och byggnadsingenjörers perspektiv

42. Andersson, S. 2023. Hållbarhetscertifiering – Effekter på värdekedjan av byggmaterial. Green certificate – A case study on effects in the value chain of building materials

43. Sköld, C. 2023. Lönsamhet i skogsmarksgödsling för privata markägare i norra Sverige. En jämförelse av lönsamheten i två olika gödslingsstrategier. Profitability in forest fertilization for forest owners in Sweden. A comparison of two different forest fertilization regimes

44. Sjölund, A. 2023. Bankens roll vid generationsskifte av skogsfastigheter – En studie av intressenters tjänstebehov. The role of the bank in the succession of forest properties – A study of stakeholders´ service needs

45. Hurtig, A. & Häggberg, E. 2023. Ökad kolsänka i den svenska skogen – Ett intressentperspektiv. Increased carbon sink in the Swedish forest- A stakeholder perspective

46. Berrebaane, D. A. 2023. "No pay, no care?" – Insights from a preliminary review of payment for ecosystem services payment suspensions

47. Lundberg, E. 2023. Private label effect on small producer business development A multiple-case study from a producer perspective. Handelns egna märkesvarors inverkan på små producenters affärsutveckling – En fallstudie från ett producentperspektiv

48. Mattsson, J. 2023. Local food networks – value creation and the role of the producer. Lokala livsmedelsnätverk – värdeskapande och producentroll

49. Grele, E. 2023. Skogssektorns anpassning till EU taxonomin – Redovisning av hållbarhetsinformation. The forest sector´s adaptation to EU taxonomy – Reporting of sustainability information

50. Rudolph, A-C., 2023. Marketing of meat alternatives - A comparison between Germany and Sweden. Marknadsföring av köttalternativ - En jämförelse mellan Tyskland och Sverige

51. Nazarali, A. & Stefanov, N. 2024. Aquaculture in Northern Sweden – Exploring conditions for sustainable aquaculture. Vattenbruk i norra Sverige – Undersökning om förutsättningar för hållbart vattenbruk

52. Persson, E. 2024. Communication Responsible Forestry – Companies in forest supply chains. Kommunikation ansvarsfullt skogsbruk – Företag i skogliga försörjningskedjor

53. Hernblom, C. 2024. Towards Biodiversity Credits A qualitative case study in Yayasan Sabah Forest Management Area Borneo Malaysia. Mot krediter för biologisk mångfald - En kvalitativ fallstudie i Yayasan Sabah Forest Management Area, Borneo Malaysia

54. Johannesson, K. & Näslund, R. 2024. Smart specialisering för regional tillväxt- Skoglig bioekonomi i Värmland. Smart specialization for regional growth – forest bioeconomy in Värmland

55. Lindqvist, A. 2024. Investing in refined birch – Perceptions and attitudes behind the choice. Att investera I förädlad björk – Uppfattningar och attityder bakom valet