# Fire insurance in Sweden from an individual owner's perspective

- a cost benefit analysis

*Brandförsäkring utifrån en enkild privat skogsägares prespektiv*
*- en kostnads-nyttoanalys*

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Bachelor thesis project· 15 hp
Swedish University of Argicultural Science, SLU
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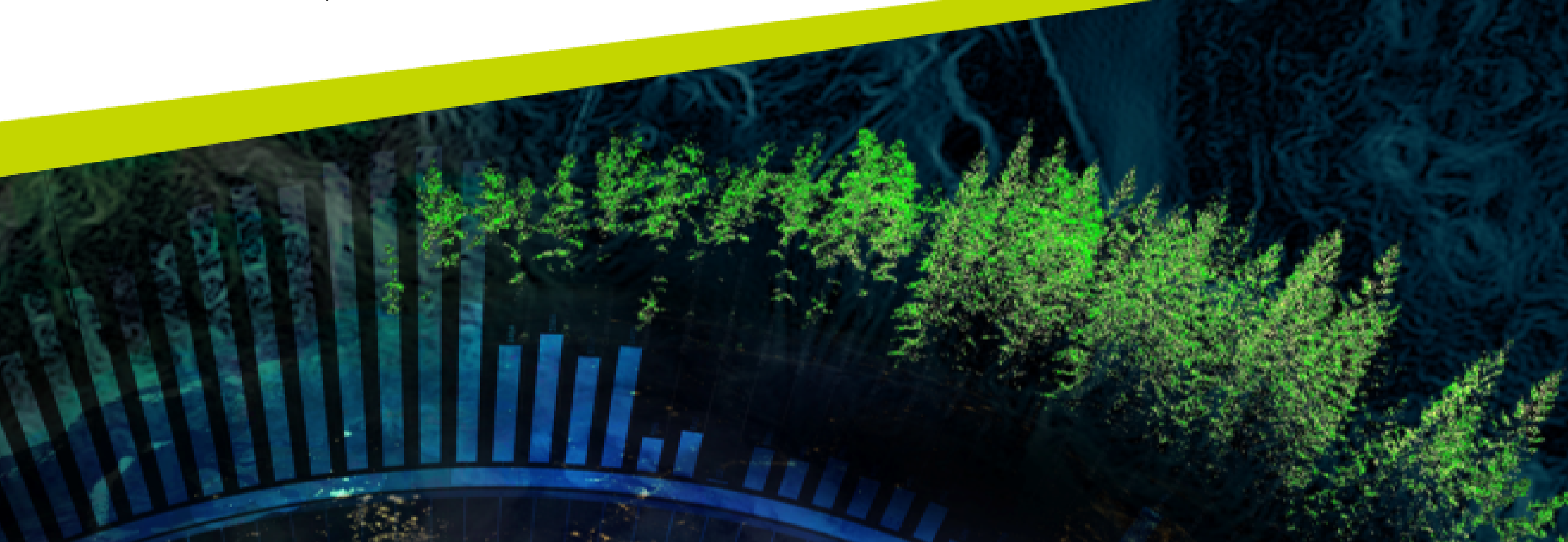

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# Contents

# Abstract

Focusing on the Swedish context, this thesis investigates whether acquiring a forest fire insurance is beneficial from an individual owner's perspective. In doing so, cost-benefit analysis is carried out under three scenarios varying assumptions about how fire probability may be *calculated* by individual owners. It is assumed that the individual owner looks to historical information on probability of fire when deciding whether to acquire insurance or not. In this thesis, three different probabilities of fire are used based on the average probability of fire over the past ten years, five years and the year with the highest probability in the data set. The scenarios include a fixed probability, probability in regards to a climate change factor and probability in regards to the trend of fires in the past. Context on the situation regarding fire presence and climate change is established. Calculations in this thesis rely on our own estimates of probabilities of fire per hectare, which we infer from information about burnt area of productive forest land that is publicly available from the Swedish Civil contingencies agency (MSB). Insurance premiums representing northern, central and southern Sweden are used in order to give individual owners in different regions a reasonable representation. The average costs and benefits related to forestry are also divided by region. From the calculations, we highlight that 1) if using historical probabilities of fire, individual owners do not seem to benefit from fire insurance; and 2) the probabilities of fire that would make fire insurance profitable are as high as 0,0408 (Southern Sweden), 0,0281 (Central Sweden) and 0,0196 (Northern Sweden) when using a climate change factor. Since data from the past was used when creating the probabilities of fire, the future impact of climate change is not yet accounted for. A probability of fire less than the two percent required for northern Sweden to be profitable might not be an unreasonable scenario in the not-so-distant future. When this tipping point is exceeded, acquiring insurance for the individual owner is instead profitable.

# Summary

Forest insurance is seen as a management tool for preventing losses in a business. 48 percent of the forest landscape are owned by Individual owners (IO´s) and are divided into 222 000 user units. A large share of them are insured today.

The aim of this thesis is to answer these questions: 1) Based on the burnt area for the past 24 years, when is it profitable, with factors from climate change and past trends of fire, to acquire forest fire insurance? 2) Based on the burnt area in the past 24 years, at which fire probability is it beneficial to acquire forest fire insurance?

Results from the report were the following: 1) It is not beneficial for IO´s to acquire forest fire insurance in the next 24 years investigated in the report. 2) Profitable scenarios when acquiring forest fire insurance need probabilities of fire of at least 0.068, 0.047, 0,033, in southern, central and northern Sweden respectively.

In the worst case scenario, the point at which it is beneficial to acquire a forest fire insurance is when the probability of fire becomes 30 times higher that the probability today.

The results of this thesis shows that probability of fire today makes the investment of forest fire insurance a bad investment for an individual owner, based on a cost benefit analysis.



# Sammanfattning

Försäkringar ses som ett verktyg för att förebygga eventuella försluster som kan drabba företag. Av all skogsmark som finns i Sverige ägs 48 procent av enskilda ägare, vilka är uppdelade i 222 000 brukningsenheter. Av dessa är en stor andel försäkrade idag.

Syftet med rapporten är att svara på dessa frågor: 1) Är det lönsamt för en enskild skogsägare att anskaffa en brandförsäkring? 2) Vid vilken sannolikhet för brand är det lönsamt att skaffa en brand-försäkring i de södra-, centrala- och norra delarna av Sverige? 3) Är de beslut som en enskild skogsägare gör idag angående en brandförsäkring rationellt?

Resultaten från rapporten är följande: 1) Det är inte lönsamt för en enskild skogsägare att försäkra sin skog för de kommande 24 åren undersökta i rapporten. 2) I det värsta scenariot bör sannolikheten för brand vara 30 gånger högre än vad den är idag för att en brandförsäkring ska vara lönsam. 3) Enskilda ägare tar inte rationella beslut angånde att investera i en brandförsäkring.

Resultat från rapporten visar att dagens sannolikhet för skogsbrand inte gör investeringar av brandförsäkring lönsam för en ensklid ägare, genom kostnads-nytto analys.

# 1 Introduction

The notion that climate change is a real threat to society is widely accepted across the world. A symptom of climate change is the increase over the last 50 years in frequency and magnitude of natural disasters such as wildfires, storms and floods [WMO, 2021]. Sweden is not exempted from climate change. For instance, forest fires in Sweden have had an increasing trend [Krikken et al., 2021] and extreme cases have been observed during the warm summer of 2018 [Granström, 2020].

The increasing trend in magnitude and frequency of forest fires in Sweden poses a threat to society in general, and to the forest sector in particular. Specifically, individual forest owners are at the core of this threat. During the last two decades, individual forest owners in Sweden have been affected by natural hazards such as the storm Gudrun in 2005 which affected the entire country but mostly the southern part of Sweden [SMHI, 2021]. The great fire in Västmanland during the warm summer of 2018 in central Sweden is another example frequently brought up in the debate about potential risks involving a warmer climate [SVT, 2020].

In this context, management of risk becomes an important element of forest management. In particular, insurance contracts represent a tool to transfer risk of losses from forests owners to private insurance companies that, through the reinsurance market, are able to spread such risks. In general, this is the way in which insurance companies operate. By pooling risk from several different sources the insurance company can repay those affected with the means received from unaffected insurance owners.

More specifically, insurance schemes against forest fire can be designed to incentivize forest management practices that prevent fires from happening. For example, this could be done by lowering the premium for forest owners that practice fire preventative silviculture. Through all these incentives from climate change, society and other loan providers may request that the property is insured to provide a loan [Länsförsäkringar, 2022]. These incentives in line with forest fire insurance could be a reason that individual forest owners have adopted and invested in insurance for their property.

Forest fire insurance in Sweden is widely available today for IO's. Since insurance does come with a premium, acquiring it might not be worth it from an individual owner's perspective. According to previous studies, the IO's are insuring their forest due to historical hazards that have affected the property, securing a pension amongst other things [Kvennefeldt and Lindström, 2016]. While these decisions are not directly implying that the decisions are based on rationality the outcome might still be positive, however, if the outcome instead is negative this is a poor economical choice for the IO's. For instance, if the IO's were to presume that the probability of fire in the past is representative of the probability of fire in the future, when making a cost benefit analysis they may underestimate the actual chance of a fire happening. Due to this underestimation they may not decide to buy insurance. Another example would be that IO´s might not have observed a fire in the past and this in turn might make them underestimate the probability of a fire occurring. IO's using the trend of fires to make their decision may be closer to a correct estimation.

The aim of this project is to explore whether acquiring a forest fire insurance passes a cost-benefit analysis from a perspective of an individual forest owner that keeps in mind the probability of fire. We carry out cost-benefit analysis under two probability scenarios: i) as if the probability reflects past probabilities of fire; and ii) as if the probability reflects updated expectations that take into consideration future increase in probabilities of fire that climate change will bring.

These probability scenarios can be represented by two separate hypotheses.

The first hypothesis is that, based on past information on fires, acquisition of fire insurance is not profitable from the perspective of the individual forest owners.

The second hypothesis is directed towards whether a probability of fire for which acquiring forest fire insurance is profitable. In order to answer this a number of sequential hypothesis tests were made, considering one probability at a time.

## 1.1 Thesis structure

Brief content in the chapters in the thesis.

**Literature review:** examines the environment around the topic based on previous literature regarding: a) Climate change in the world. b) Climate change's role in a future increase of the frequency of forest fires in Sweden c) Forest insurance in the Swedish forest sector.

**Context:** provides a closer look at the different parameters involved in the report and gives context around them. This section is divided into 4 parts: a) Forest land distribution in Sweden b) The current forest insurance uptake in the forest sector. c) The insurance uptake for IO´s today and what the decisions are based on. d) Rational decision making for IO´s. making for IO's.

**Theoretical framework:** This section describes the theory behind parameters and assumptions to be able to perform the cost-benefit analysis. The theoretical framework is divided into: a) Cost benefit analysis. b) Prediction on net present benefit by using fire probabilities from past data.

**Data compilation:** compiles and presents the data used in the model, divided into four parts: a) Forest fire probability based on previous years (1998-2021). b) Revenues and costs related to forestry. c) Forest insurance premium according to Länsförsäkringar. d) Assumptions.

**Methodology:** explains how the data was processed and the workflow when creating and applying the model.

**Results:** illustrates and explains the results gotten from the model. The result is divided into: a) Results of the cost benefit analysis b) Results from increasing probability c) Probability of fire at which point benefits from forest fire insurance become positive.

**Discussion:** explains and and puts the results into context. Analyses the trends and outcome of the scenario's results. The discussion is divided into: a) Results interpretation and analysis b) Connection of research questions to the results. c) Limitations in the model. d) Future research.

**Conclusion:** summarises the most relevant parts of the project. Reconnects the result and discussion to the research questions to be answered in this thesis.

# 2 Literature review: Forest insurance in a climate that changes

This section provides relevant information about the literature used to create the framework of the project. This section is divided in three parts: 1) Climate change in the world 2) Climate change's role in a future increase of the frequency of forest fires in Sweden 3) Forest insurance in the Swedish forest sector.

## 2.1 Climate change in the world

Natural hazards are assumed to happen more frequently in the future (e.i fires, storms, flooding) in a climate that changes. During the two first decades of the 21th century the global surface temperature has increased by the anthropogenic impact on the climate. In the IPCC report from 2021 there is a high correlation between natural hazards and global warming. According to their model there is absolute certainty that hot extremes have become more frequent and more intense in most regions around the world since the 1950´s. On the other hand, the frequency of cold extremes have decreased. In the year 2019 the $CO_2$ concentration in the atmosphere were the highest it has been in the last 2 million years. With an increasingly warmer climate the extremes will become more frequent and affect larger areas with related hazards. For every 0.5°C the intensity and frequency of hot extremes (i.e heatwaves and heavy precipitation) increase dramatically. The climate change has already caused a warming trend and will continue in the future regardless of the extent of measures taken to mitigate climate change [IPCC, 2021].

## 2.2 Climate change's role in a future increase of the frequency of forest fires in Sweden

The frequency of fires has decreased since the industrial forestry was introduced at the end of the 19th century. In the historical context the intervals of fires in the southern part of Sweden was between 30-50 years and in the northern part of Sweden the intervals of fires was 80-100 years. The interval has decreased by 99 percent compared to before the introduction of industrial forestry [Sjöström and Granström, 2020]. 2014 and 2018 two large scale fires devastated much of the forest land. In July 2014 in Västmanland 13 100 hectares of forest land was affected by fire [Skogsstyrelsen, 2021b], and the fires in year 2018 it was 25 locations over 50 hectares and 7 of them were over 500 hectares [Granström, 2020].

With regard to climate change, Sweden is not an exception. In a report from MSB it is shown that with a higher temperature the season of forest fires is extended [Sjöström and Granström, 2020]. In practice, forest fires are also very hard to predict as there are many variables related to fires. The ignition probability will increase by a factor of 1.1 given the current climate situation 2021 but with an increasing temperature the factor increases significantly to 2.0 given a $2°C$ increase in temperature in the atmosphere [Krikken et al., 2021]. Furthermore, climate change is unfortunately a very real risk to the composition of our forests today. This development increases the chance of the individual forest owner being affected. The practical effects of the increase in temperature and prolonged fire season, however, are hard to draw concrete conclusions from when assessing forest fire risk [Wallenius, 2011].

## 2.3 Forest insurance in the Swedish forest sector

Insurance in the forest sector is not a new concept [Andersson and Keskitalo, 2016]. Insurance works by dividing the risk one faces to a broader group that faces risk as well. The affected stakeholders then pay a premium to the insurance company in order to pay for their share of the risk. By pooling the risks this way the insurance company can pay for the actualized risk with the money from stakeholders that were not affected.

The forests of Sweden are 28.1 million hectares and 23.1 million hectares of the total is productive forest land[1]. The forest land is divided into 5 different owner categories. 48 percent are of the forestland is owned by IO´s - 313 084 individuals, followed by 24 percent being owned by the private sector businesses, 21 percent belongs to state owned companies, 6 percent and 1 percent respectively, belongs to other individual owners and other state owned companies [Skogsstyrelsen, 2021a].

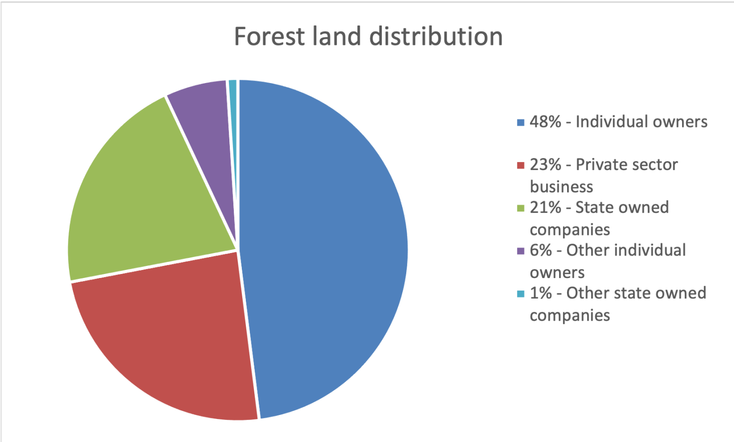


*Figure 1: Forest land ownership categorised modified from Swedish forest agency*

25.5 percent of the productive forest land has been insured by the year 2015 [Welten, 2015]. The low insurance rate in Sweden can be explained by the low insurance uptake among the private sector businesses (e.g. Holmen Skog) [Holmen, 2022] and state owned companies (e.g. Sveaskog).

[1]Productive forest land refers to land with at least 10 percent coverage with trees at least 5m high [Nilsson, 2021].

# 3 Context: Forest insurance among individual forest owners

The aim of this section is to give an understanding on what basis IO´s make business decisions. To give better overview of the context section it is divided in to four parts: 1) Forest land distribution in Sweden 2) The current forest insurance uptake in the forest sector. 3) The insurance uptake for IO´s today and what the decisions are based on. 4) Rational decision making for IO´s.

## 3.1 Definition of IO´s and IO´s as small scaled companies

Private forest owner is commonly used when describing individual owners, non-industrial private forest owners and family forest owners. The definition that is used in the report refers to the forest agency's definition of single owner, estates and small companies (sole trader) as individual owners [Skogsstyrelsen, 2014]. Therefore, these types of forest owners will be referred to as IO´s.

IO´s are the biggest owner category of forest land, divided to 222 000 user units [Skogsstyrelsen, 2021a]. Due to this, there are as many small scaled private businesses as there are user units. IO´s are in essence a small business in which investments are made in order to receive a profit. Such examples might be planting and pre-commercial thinning where profits directly related to the investments are not seen until later on in the process. Forest insurance can be looked at in the same context. However, the cost is continuous and not related to the stage of growth in which the forest is in.

## 3.2 Increasing probability of fires in different parts of the country and potential losses for IO´s

The extended season of forest fire's differ between different parts of the country, although as a whole it will increase nationwide. The regions subject to a longer fire season today will be the most affected in the future. The season will extend in the northern part with 10-30 days and in the southern parts by 50 days [Sjökvist et al., 2013]. The region which has had the most call out's for emergency services and the largest burnt area over the last 24 years is in central Sweden.

Another very important parameter that comes with long rotation periods is discount rate. Discount rate determines the future value of the forest in relation to a investing the money elsewhere. The discount rate has a larger effect with longer time periods as the effect of the discount rate is measured on the value from the previous year [Wentzell and Toft, 2020].

With all of this in mind, are the business decisions that a IO making rational in a business point of view? The main aim of the thesis is to estimate at what point in time it is beneficial for a forest owner to acquire insurance considering a changing climate where fires tend to happen more frequently and if today's adoption of forest insurances assuming they are rational, (i.e, they take in insurance decision with the goal of maximizing profit).

When is it beneficial to acquire a forest insurance for a private forest owner? By modeling with different probabilities of fire and aim to identify a tipping point that tells which is the probability that makes it beneficial from a private point of view.

## 3.3 The insurance uptake for IO´s today and what the decisions are based on

Despite the low uptake of insurance in the Swedish forest sector it tends to be well adopted among the IO´s. In two different studies independent of each other the uptake of forest insurance is evidently high among IO´s. From these studies the type of insurance they have adopted and what the insurance covers is not specified or investigated [Mensah, 2021], [Kvennefeldt and Lindström, 2016]. Today there are two main forest insurances provided by Länsförsäkringar[2] that IO´s can acquire. One that covers fire damages and the other an overall cover insurance.

In order for Länsförsäkringar to provide a loan where forest is the security, that forest needs to be insured. In the report of Kvennefeldt and Lindström it is also shown that an IO may be insured because of prior events and also to have a secured pension in the revenues from forestry [Kvennefeldt and Lindström, 2016].

From a business point of view it may be a good idea to entertain acquiring insurance to prevent losses due to a changing climate. As of now the corporate insurance available has the highest premium since the introduction of private insurance in the 1920's [Andersson and Keskitalo, 2016]. Considering insurance uptake in the past and future predictions on the risks increasing lays the foundation on how beneficial it will be to insure property for an individual owner in Sweden. From a micro-economic perspective the decisions that an individual forest owner makes are rational.

In Sweden a very important event for forest insurance was the storm "Gudrun". The storm affected around 3 percent of the standing timber volume. Gudrun also led to restructuring in the forest industry with a significant amount of the affected forest being uninsured this led to the government needing to intervene in order to protect IO's without insurance. However, this event still made a large difference in the insurance uptake among IO's due to them being worse off despite the government intervention [Andersson and Keskitalo, 2016].

## 3.4 Rational decision making for IO´s

Getting an answer on when it is beneficial for an IO to acquire insurance based on them making rational decisions will be central to evaluate the insurance role in the future for IO's. Giving the IO's facts in order to base their decisions on something will instead give them more leverage when entertaining the idea of getting insurance. If insurance companies price their premiums too high, consequently there would be less incentive to get insurance [Andersson and Keskitalo, 2016].

[2]Länsförsäkringar is a Loan provider and insurance company located in the most parts of Sweden.

# 4 Theoretical framework: Business administration adoption for IO´s

This section of the thesis is to give an understanding on how a cost benefit analysis is useful for IO´s to make business investment decisions, this section is divided into two parts: a) Cost benefit analysis. b) Prediction on net present benefit by using fire probabilities from past data.

## 4.1 Cost-benefit analysis

Cost-benefit analysis can be helpful when it comes to decision making in a company. When the time comes to make an investment the company may decide to weigh the cost against the benefits in order to make the right decision about said investment [Stobierski, 2019]. The reason for doing the cost-benefit analysis is in order to motivate the decision behind acquiring or not acquiring insurance. When the benefits outweigh the costs the investment is seen as profitable. In this case the comparison is made on difference in profitability between acquiring and not acquiring forest fire insurance.

## 4.2 Prediction on net present benefit by using fire probabilities from past data

$$NPVENB_{uninsured} = NPVER - NPVMC \tag{1}$$

$$NPVENB_{insured} = NPVR - NPVMC - C_i \tag{2}$$

$$NPVR = \frac{V \cdot P_{sp} \cdot S_{th}}{(1+i)^{T_{th}}} + \frac{V \cdot P_{sp} \cdot S_h}{(1+i)^{T_h}} \tag{3}$$

$$NPVER = NPVR \cdot (1 - Pr_{F1}) \cdot Pr_{FX}, \qquad Pr_{FX} = 1 \tag{4}$$

$$NPVMC = C_{rf} + \frac{C_{pct}}{(1+i)^{T_{pct}}} + \frac{V \cdot C_{th} \cdot S_{th}}{(1+i)^{T_{th}}} + \frac{V \cdot C_h \cdot S_h}{(1+i)^{T_h}} \tag{5}$$

Expected present value of net benefits $NVPENB$ is the discounted value of the current sum in the future [Fernando, 2022].

Net present value of expected revenues $NPVER$ in this context is the future value of losses in timber value. Since fire and other factors that are associated with fire development has a probability this value will be an expected value.

Net present value of revenues $NPVR$ in this context is the future value of prevented losses in timber value. This value is certain since the insurance company will cover the losses. $V$ is the volume in $m^3 fub$ on one hectare of productive forest land. $S_{th}$ represents the volume share taken out during thinning. $S_h$ represents the share taken out during harvesting. $P_{sp}$ represents the stumpage price. $T_{th}$ represents the time at which thinning is done and $T_h$ represents the time at which harvesting is done.

The cost of acquiring forest fire insurance $C_i$ is described by a yearly premium per hectare which is then multiplied by the number of years the insurance is active.

The discount rate $i$ can be described as the rate at which forest is discounted. According to Lantmäteriet a fixed discount rate of 2.13 percent is recommended otherwise the recommendation is to have a discount rate between 2.10 percent and 2.30 percent. [Lantmäteriet, 2020].

$Pr_{F1}$ is the probability of one hectare of productive forest land being affected by fire and the probability of other factors that are associated with fire development $Pr_{FX}$ are seen as a constant when there is no data for fire fighting, infrastructure, forest management to preventing fires. The value of $Pr_{FX} = 1$.

NPVMC is the net present value of management costs. This value is discounted based on the time the costs of management are in the rotation period. $C_{rf}$ represents the costs of reforestation, this accounts for soil preparation and planting per hectare. $C_{pct}$ represents is the cost of pre-commercial thinning per hectare discounted by $T_{pct}$ which is the time at which the pre-commercial thinning is done. $C_{th}$ is the thinning cost per hectare. This is then discounted by $T_{th}$. $C_h$ is the harvesting cost per hectare which in turn is discounted over $T_h$.

The cost-benefit analysis will be made without uncertainty related to fire probability. It will weigh the total sum of insurance payments against the amount of forest land lost to fire. In this case even though the amount of forest lost to forest fire could be seen as a loss the insurance company will pay us for it hence making it an expected benefit instead.

# 5 Data compilation

This section presents the data used in the calculations and where the data is applied. This section is divided into four parts: a) Forest fire probability based on previous years (1998-2021). b) Revenues and costs related to forestry. c) Forest insurance premium according to Länsförsäkringar. d) Assumptions.

## 5.1 Forest fire probability based on previous years (1998-2021)

The fire probabilities are made using Swedish civil contingency agency (MSB) statistics database [MSB, 2021]. The data can be found in appendix A and is based on a burnt area of productive forest land. Each county is placed in one of three regions based on location and the resulting probabilities for the region are a summary of probabilities from each county.

## 5.2 Revenues and costs related to forestry

The average $m^3 fub/ha$ for productive forest land in northern, central and southern Sweden is shown in table 1. These calculations are made on statistics from the Swedish forest agency [Skogsstyrelsen, 2020]. The data on productive forest land is taken from skogsdata [SLU, 2021].

*Table 1: Average $m^3 fub$ per hectare of productive forest land*

| **Area** | $\boldsymbol{m^3 fub/ha}$ |
|---|---|
| Northern Sweden | 132,4 |
| Central Sweden | 121,9 |
| Southern Sweden | 181,5 |

Stumpage price $P_{sp}$ $(SEK/m^3)$ is shown in the table 2. The price is averaged out for each region in the model. The assortments that comes from harvesting are divided into 3 categories, 47 percent is saw logs and 45 percent goes to the pulp mill, 8 percent is firewood and specific assortments [SvensktTrä, 2018]. Data on prices and share of firewood and specific assortments are not available hence, the calculations will assume a 50 percent split between saw logs and pulpwood.

*Table 2: This table taken from Skogskunskap [Skogskunskap, 2021] shows the prices in Sweden for different types of wood during the last quarter of 2021*

| $(SEK/m^3 fub)$ | **Northern Sweden** | **Central Sweden** | **Southern Sweden** |
|---|---|---|---|
| Sawlogs Pine | 459 | 497 | 639 |
| Sawlogs Spruce | 438 | 496 | 694 |
| Pulpwood Pine | 288 | 254 | 343 |
| Pulpwood Spruce | 292 | 267 | 331 |
| Pulpwood Birch | 287 | 265 | 337 |

## 5.3 Forest fire insurance premium according to Länsförsäkringar

The fire insurance cost are based on information from Länsförsäkringar. This information was gotten by e-mailing and phoning länsförsäkringar offices deemed representative of the respective regions.

Each proposal are given from a located office in northern, central and southern Sweden. The given proposal is based on the average property in respective area. Price for forest fire insurance $C_i$ is based on a proposal from Länsförsäkringar in Kronoberg, Uppsala and Västerbotten. The cost for a fire insurance is showed in table 3 for each area.

*Table 3: Price proposals for fire insurance from Länsförsäkringar.*

| $(Sek/ha/year)$ | **Northern Sweden** | **Central Sweden** | **Southern Sweden** |
|---|---|---|---|
| Forest fire insurance | 15 | 22.56 | 72 |

The changing probability of fire with regards to climate change is hard to predict. The fire probability is based on burnt forest land in relation to forest land. The factors will be multiplied by the percentage of burnt area in relation to forest land in their respective time frames thus creating an index in which fire probability increases over time.

## 5.4 Assumptions

The method applied was deemed to be the best way to empirically illustrate whether investing in an insurance is profitable or not using only monetary values. The method might not be ideal when taking into account that IO's might not entirely base their decisions on monetary value which has been shown in previous studies [Kvennefeldt and Lindström, 2016] [Mensah, 2021]. Infrastructure and fire preventative silviculture and other uncertainties related to the fire probability are very hard to quantify and there is a lack of available data. A cost.-benefit analysis is a relatively easy concept to understand, this ties back to being applicable for IO's.
In order for the model itself to work and produce a result assumptions about some components had to be made due to time constraint. When it comes to shares of different tree species and timber assortments the assumption was that the volume available was split in 50 percent timber and 50 percent pulpwood. Assumptions about tree species on the estate also had to be made in order for the model to work and the decision was to include Scots pine (*Pinus Sylvestris*), Norway spruce (*Picea Abies*) and Birch (*Betula spp.)*. These have different pricing both in regards to timber and pulpwood shown in table 5.2. The decision made was to split timber into 50 percent spruce timber and 50 percent Pine timber and pulpwood was split evenly in thirds with 33 percent spruce pulp, 33 percent pine pulp and 33 percent birch pulp.

Assumptions about harvesting regiments and silvicultural measures also had to be made. It was determined that soil preparation and planting happens year 0, pre-commercial thinning at year 15, thinning at year 40 and a final felling at year 100. Assumptions about volume taken out during thinning and final felling was determined to be 30 percent in thinning and 70 percent in final felling. The rotation period, which in Sweden is 70-100 years on average depending on if the forest is located in the southern or northern parts of the country [Holgén, 2002]. Due to this the rotation period was decided to be 90 years for northern-, 80 years for central-, and 70 years for southern Sweden.

Assumptions regarding regions also had to be made. The sectioning of the regions were made differently than the traditional sectioning of "Norrland", "Svealand" and "Götaland" in order to more accurately represent the insurance premiums given. The representation of counties linked to insurance is given in figure 6. In this project the respectively will be refereed as southern-, central-and northern Sweden. As this sectioning removed Gävleborg county from northern Sweden and instead added it to central Sweden the figures regarding timber volume for the county had to be modified. This modification is based on the assumption that Gävleborg county's timber volume share is the same as its share of the productive forest land.

In order to be able to apply the model assumptions regarding IO's decision making process had to be made. The IO's have to base their decision entirely on the monetary aspect of acquiring insurance. Rational behaviour in this instance would be to acquire the insurance if the result of the cost- benefit analysis is positive. Irrational behaviour instead would be to still acquire the insurance despite the benefits of it being negative and vice versa [Kenton, 2020].


*Figure 2: The distribution of counties for each region, modified from pegy22 [Pegy22, 2015]*

# 6 Methodology

The first step was to gather all of the relevant data and statistics associated with forest management, these can be seen in Appendix A. An excel-sheet was made describing three different scenarios of insurance related to fire probability. In each of these three scenarios calculations were made on three regions in Sweden each with their respective insurance premiums and discounted forest management costs and benefits. The probabilities were summarized and an average was taken over a period of the last ten, five and worst year. The mean burned area per hectare was translated over a period of 24 years. The past data is given for the past 24 years, due to this the model is applied for 24 years in the future. The net present value of expected benefits was calculated for both uninsured and insured IO's and the difference between them noted. The difference being negative was used to illustrate an example in which it was profitable to be uninsured.

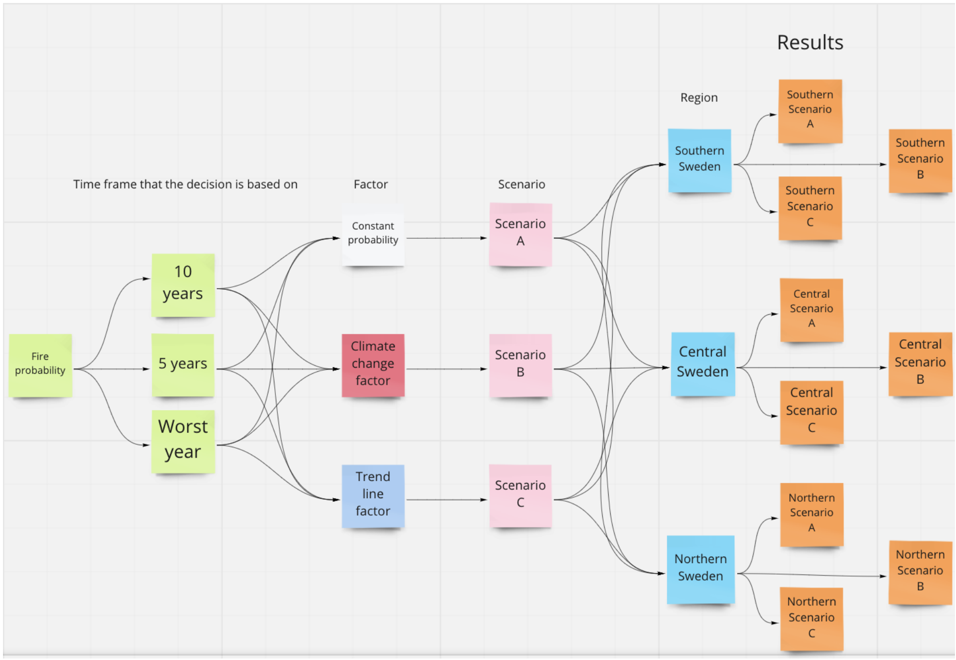


*Figure 3: The different stages and components of the model*

In scenario A a constant probability was used based on burnt area. Scenario B uses the same constant probability but instead multiplied by a climate change factor of either 1.1 between year 2020 and 2028 or a factor of 2 between 2029 and 2044 to represent the increasing temperature [Krikken et al., 2021]. For scenario C a context in which probabilities increased gradually was created based on the trend of the forest fires over the last 24 years. The initial probabilities used were the same as in scenario A for year 0 and then a fixed probability was added yearly in accordance with the trend line slope for each specific region. In order to create the graph illustrating the tipping point probabilities for each region the solver tool in excel was used. The difference between net present value of expected net benefits for insured and uninsured was set to be solved to zero using fire probability as the variable in each scenario.

# 7 Results

The focus in this section is to present the results to answer the research questions for the project, the following parts in this section are: 1) Results of the cost benefit analysis. 2) Results from increasing probability. 3) Probability of fire at which point benefits from forest insurance become positive.

## 7.1 Results of the cost benefit analysis

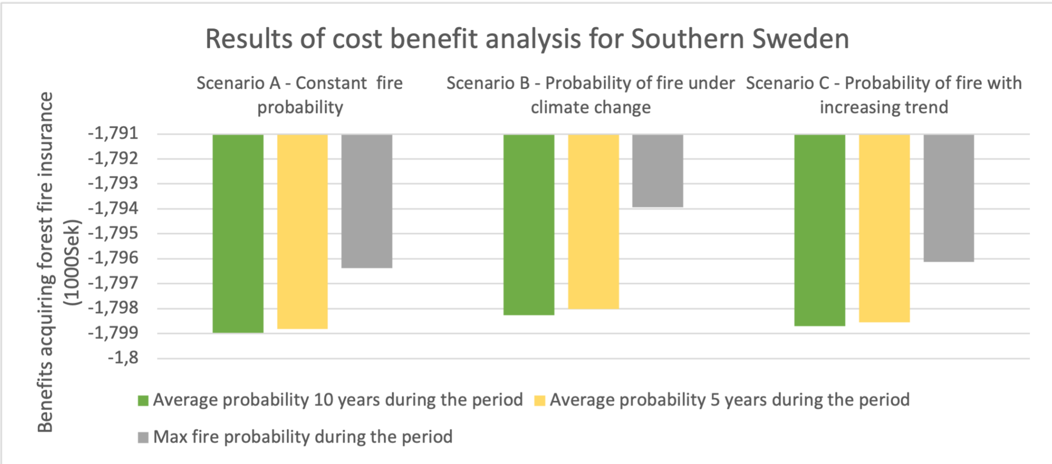


*Figure 4: Results of cost-benefit analysis for southern Sweden with a changing fire probability due to the climate change factors*

Figure 4 shows the benefits of acquiring a forest fire insurance in three different scenarios in southern Sweden. The scenarios contain probabilities of fire based on the time frame in which the decision to acquire insurance is made. The time frame is based on the average probability of fire over ten years, five years and the year in which the probability of fire was the highest during the period. Max fire probability is the largest amount of burnt area for one year during the 24 years where the data was taken. The benefits are shown in thousands of Swedish kronor (SEK). Patterns for the fire probabilities in each scenario are very similar. As scenario A is with a constant fire probability this scenario should always yield the least benefit as the other scenarios are associated with factors increasing the probability of fire. The most beneficial scenario to acquire insurance in southern Sweden is in scenario B with the decision being based on the max fire probability over the time period.

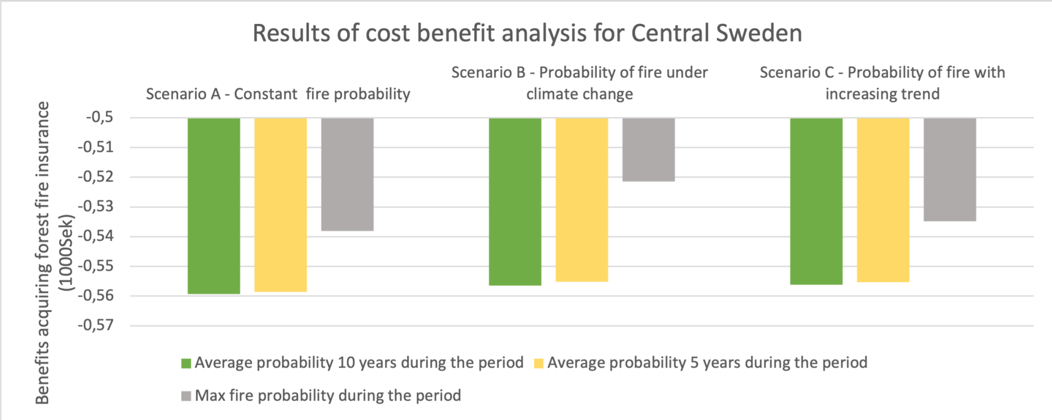


Figure 5: Results of cost-benefit analysis in scenario B for northern Sweden with a changing fire probability due to the climate change factors

Figure 5 shows the benefits of acquiring a forest fire insurance in three different scenarios in central Sweden. The scenarios contain probabilities of fire based on the time frame in which the decision to acquire insurance is made. The time frame is based on the average probability of fire over ten years, five years and the year in which the probability of fire was the highest during the period. Max fire probability is the largest amount of burnt area for one year during the 24 years where the data was taken. The benefits are shown in thousands of Swedish kronor (1000SEK). Patterns for the fire probabilities in each scenario are very similar. As scenario A is with a constant fire probability this scenario should always yield the least benefit as the other scenarios are associated with factors increasing the probability of fire. The most beneficial scenario to acquire insurance in central Sweden is in scenario B with the decision being based on the max fire probability over the time period.

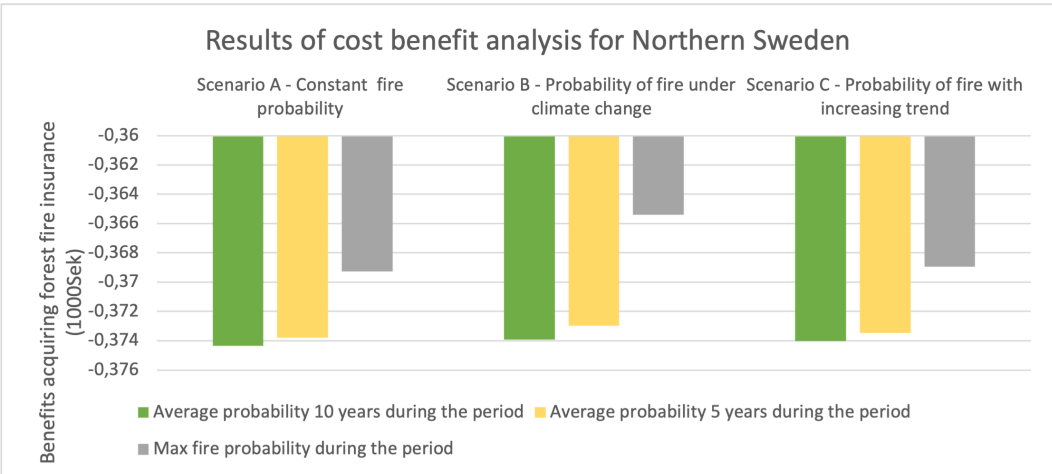


*Figure 6: Results of cost-benefit analysis with different factors that for northern Sweden with a changing fire probability due to the climate change factors*

Figure 6 shows the benefits of acquiring a forest fire insurance in three different scenarios in northern Sweden. The scenarios contain probabilities of fire based on the time frame in which the decision to acquire insurance is made. The time frame is based on the average probability of fire over ten years, five years and the year in which the probability of fire was the highest during the period. Max fire probability is the largest amount of burnt area for one year during the 24 years where the data was taken. The benefits are shown in thousands of Swedish kronor (SEK). Patterns for the fire probabilities in each scenario are very similar. As scenario A is with a constant fire probability this scenario should always yield the least benefit as the other scenarios are associated with factors increasing the probability of fire. The most beneficial scenario to acquire insurance in northern Sweden is in scenario B with the decision being based on the max fire probability over the time period. This scenario is also the most profitable over all regions.

## 7.2 Results from increasing probability

The aim of this section is to investigate if a scenario where decisions are based on the past trend of fires results in insurance being profitable for the individual forest owner. Each specific point in the trend line is used to calculate the trend of the share of burnt area. It shows the share of burnt area by region for each specific year. The trend line was constructed by plotting the calculated probabilities over time and then adding a line that shows the general trajectory that the probabilities follow. The trend line is used for calculating scenario C in the model.

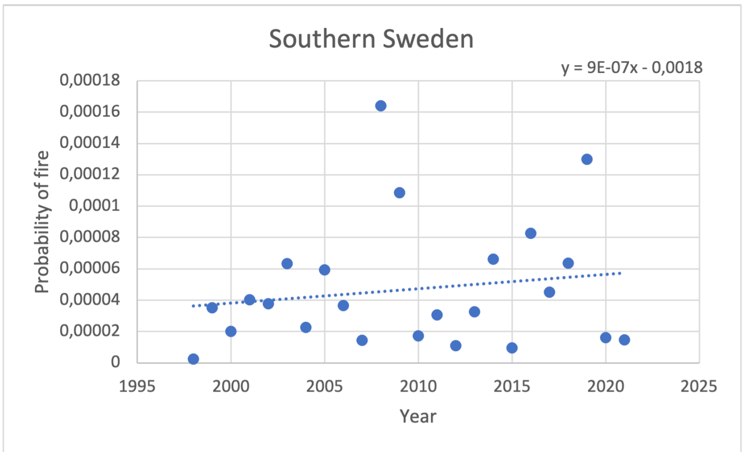


*Figure 7: The trend of burnt area over the period (1998-2021) for southern Sweden*

Figure 7 illustrates the burnt area per hectare for each year between 1998 and 2021. Also included in the graph is a trend line based on the burnt area. This trend line shows an increasing trend of fires and the slope of the trend line is added on for each year becoming a factor. When plotting the numbers for southern Sweden the resulting trend line slope becomes 0,0000009 which indicates a positive yearly but very slight increase of burnt area in the future.

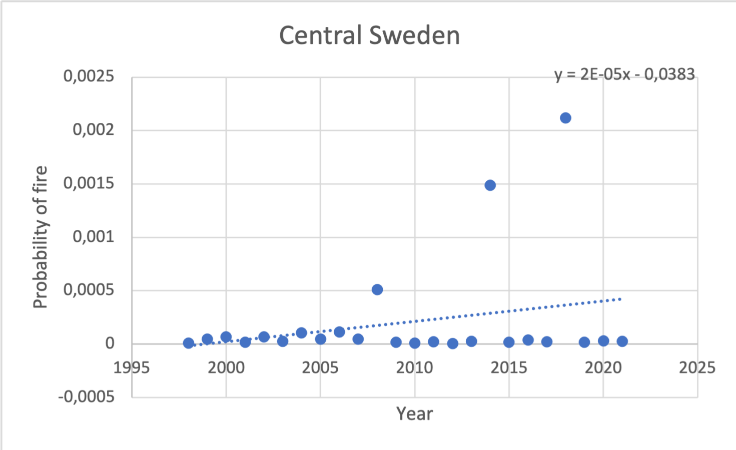


*Figure 8: The trend of burnt area over the period (1998-2021) for central Sweden*

Figure 8 illustrates the burnt area per hectare for each year between 1998 and 2021. Also included in the graph is a trend line based on the burnt area. This trend line shows an increasing trend of fires and the slope of the trend line is added on for each year becoming a factor. When plotting the numbers for central Sweden the resulting trend line slope becomes 0,00002 which indicates a positive yearly increase of burnt area in the future.

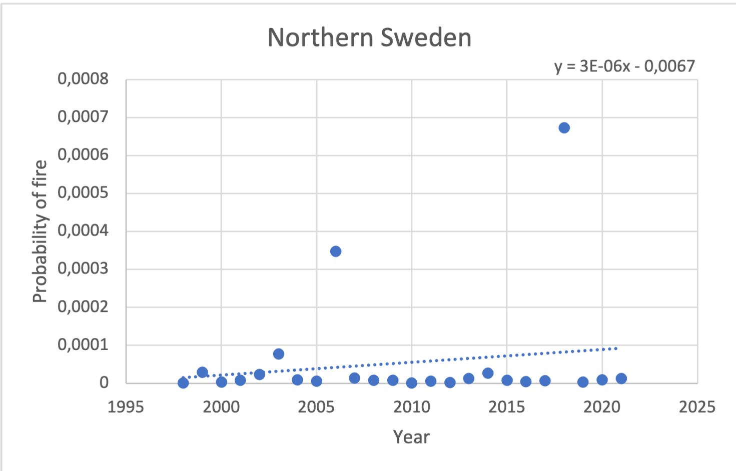


*Figure 9: The trend of burnt area over the period (1998-2021) for northern Sweden*

Figure 9 illustrates the burnt area per hectare for each year between 1998 and 2021. Also included in the graph is a trend line based on the burnt area. This trend line shows an increasing trend of fires and the slope of the trend line is added on for each year becoming a factor. When plotting the numbers for northern Sweden the resulting trend line slope becomes 0,000003 which indicates a slight positive yearly increase of burnt area in the future.

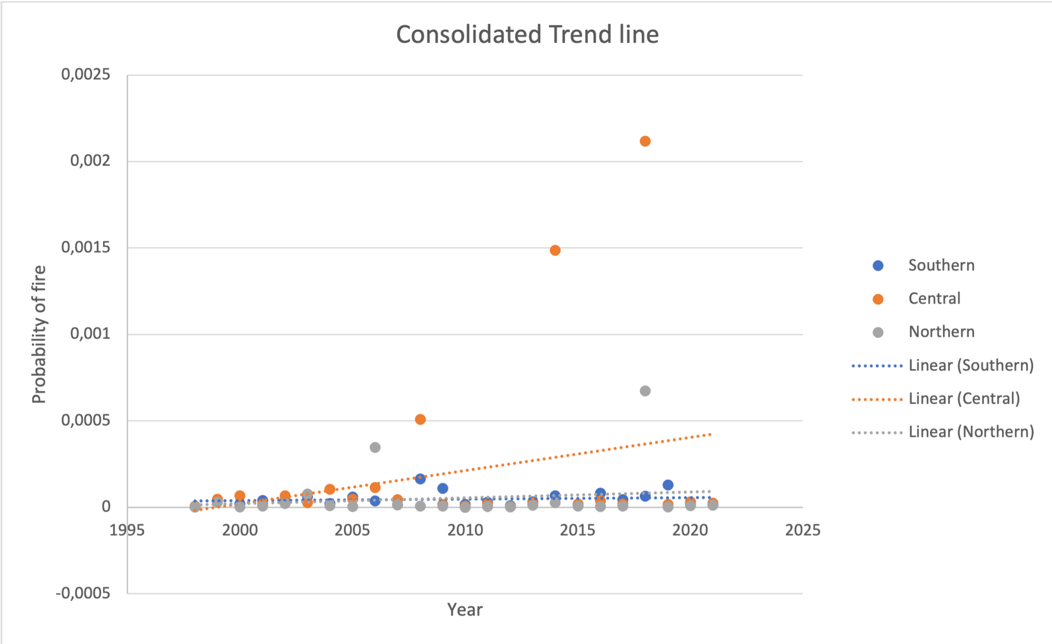


*Figure 10: The trend of burnt area over the period (1998-2021) for all regions*

The consolidated graph shown in figure 10, shows that central Sweden has a significantly greater trend compared to both northern and southern Sweden. However, from the graph it becomes evident that the trend line is structured this way because of the extreme scenarios in 2014 and 2018 for central Sweden.

## 7.3 Probability of fire at which point benefits from forest fire insurance become positive

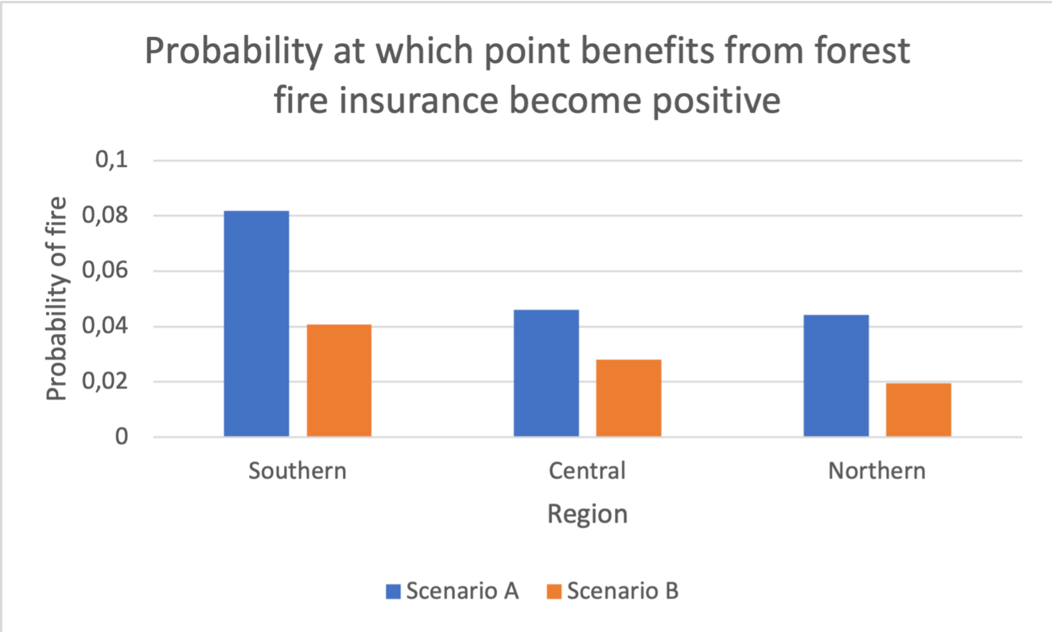


*Figure 11: The point at which probability of fire makes it beneficial to insure*

Figure 11 shows the tipping point probabilities at which insurance becomes profitable for the different regions. Southern Sweden needs the highest fire probability in order for insurance to be profitable and northern Sweden needs the lowest fire probability in order to be profitable in both scenarios. Scenario C could not be modelled in this fashion using the solver tool as the probabilities were not constant.

# 8 Discussion

The aim of this chapter is to discuss and contextualize the results. This section is divided into four sections. 1) Results interpretation. 2) Connection of research questions to the results. 3) Limitations in the model. 4) Future research.

## 8.1 Results interpretation and analysis

### 8.1.1 Analysis of the Scenarios

Scenario A with constant probabilities of fire damage reflect the least profitable scenarios. This is because both scenario B, using climate change factors, and C, using the increasing trend of fire damage in the future, provide some sort of increased fire probability. In southern Sweden the insurance premiums and the revenues from forestry are the highest. Combined with low probabilities this makes insurance the least profitable in this region.

Scenario B provides the climate change factor in the model which increases probability by a flat amount. In central Sweden the fire probability is the highest but with relatively high premiums, northern Sweden, despite having a lower probability, becomes more profitable. Southern Sweden remains the least profitable.

Scenario C uses the trend line which gives increasing fire probability over time. The results are close to scenario B but with a linear increase the differences become less when comparing the two scenarios.

The scenario where it seems to be the most beneficial, though still not beneficial to acquire a forest insurance, is scenario B with an increasing fire probability and the climate change factor in the northern part of Sweden. At this point the probability of fire is 0,000672847. This is probably due to the low insurance premium associated with the region as well as the fire probability being somewhat high. Overall northern Sweden has the most profitable outcomes in all three scenarios.

### 8.1.2 Trend line analysis and increasing probability of fire

When calculating the trend line associated with the increasing probability of fire over the years it is evident that the frequency of burnt area is increasing. In southern Sweden the trend line slope is relatively flat which indicates a small difference between the area burnt each year. This could be because of better infrastructure and closer proximity to emergency services as these areas are more densely populated. Northern Sweden has a similar trend line, though a slightly steeper slope compared to southern Sweden and the values fluctuate more between the years. What really sets the landscape apart is Central Sweden. Central Sweden shows a trend line with a steep slope which indicates a larger increase in probability. Scenario C in central Sweden is an outlier in the result. The trend line associated with central Sweden makes the probability of fire in scenario C for central Sweden exceed the probability given by scenario B. This is not in line with the results from southern and northern Sweden. This outcome can most likely be attributed to these larger fires in 2014 and 2018 in central Sweden. The extreme values of central Sweden are also the greatest represented in all regions. 2018 in general was an extreme case for all counties.

### 8.1.3 Analysis of probability of fire when forest fire insurance is beneficial

Southern Sweden has a tipping point probability of 0,0818 in scenario A and 0.0408 in scenario B. These probabilities are by far the highest in relation to central and northern Sweden. Central Sweden has 0.0460 for scenario A and scenario B is 0.0281. Meaning the numbers still are relatively high in comparison but significantly smaller than southern Sweden. Northern Sweden has 0.0441 for scenario A and 0.0196 for scenario B. These numbers are the smallest in context.

## 8.2 Connection of research questions to the results

The specific question that the thesis answer is: based on past information on fires, when is it profitable for individual owners in Sweden to acquire a forest fire insurance?

In order to arrive to an answer to this question, the model have taken the following decisions:

The first research question is to explore whether it could be profitable for IO's to acquire a fire insurance. This question is tackled by assuming that IO's make this decision with an estimation of probability of a fire in mind. If they do consider such probability, it is not clear what information they consider to inform their expectations. Thus, a present value calculation under three scenarios is performed: i) as if forest owners have the average probability over the last past 10 years: ii) the average probability over the last past 5 years: iii) and the year with the highest fire frequency in mind.

With these assumptions in mind, the question that can be answered is: based on past information on fires, is it profitable for individual owners in Sweden to acquire a forest fire insurance?

The hypothesis is that, based on past information on fires, acquisition of fire insurance is not profitable from the perspective of the individual forest owners.

This question and corresponding hypothesis can be translated into a statistical phrasing in the form of a null and alternative hypothesis.

$H_0$: $NPVR - NPVMC - C_i < 0$
$H_A$: $NPVR - NPVMC - C_i => 0$

It is not beneficial to acquire an insurance with the information about previous forest fires. When taking climate change factors into account the result is still not profitable. The case is the same when using the previous years data to predict the increasing probability for the next 24 years.

The second research question is directed towards whether a probability of fire for which acquiring a fire insurance is profitable. In order to answer this a number of sequential hypothesis tests were made, considering one probability at a time.

$H_0$: $(NPVR - NPVMC - C_i) - (NPVER - NPVMC) = 0$
$H_A$: $(NPVR - NPVMC - C_i) - (NPVER - NPVMC) \neq 0$

To answer this hypothesis, the solver tool in excel was set to solve the equation for zero by altering the probability of fire component in the net present value of expected net benefits shown in equation 4.

The probability of fire based on burnt area in the past is different for each part of the country. In the southern part of Sweden it is beneficial to acquire a forest fire insurance when the probability of fire is 0,0408 for scenario B and in the central and northern Sweden respectively is 0,0281 and 0,0196 when using climate change factors. In scenario A without using climate change factors the tipping point probabilities become higher across the board.

## 8.3 Limitations in the model

Due to the time constraint the model is limited. For starters relating burnt area directly to the probability that exactly your own forest will be set on fire is a rather loose assumption. Another important factor is the decision making for the IO's related to spreading risk locally. This might be the reason large scale forest owners decide to not be insured. The larger an estate is the more premium the IO's have to pay to have it all insured but fire probability might not scale as linearly as the insurance premium. There might be a scenario where an IO is willing to take losses from a smaller area burning down when taking the continuous premium of the whole estate into account.

The model does take probabilities other than burnt area into account, however, these are simplified as being equal to one simply due to the lack of time for the scale of the project. Investigating all these other variables was estimated to take too long and would most likely not yield a more accurate result in relation to the time invested.

One large limitation in the assumption that the IO's estates are represented by the whole region where the model is applied. Local differences in infrastructure to prevent fires and the local climate may have a large effect on the development of a potential fire. The cost and revenue are based in an average over the northern, central and southern parts of Sweden. This is misleading since the standing timber volume and species mixture likely differs a lot at the locations.

When calculating the probability of fire all of the productive forest land was used therefore assuming no difference between private and other ownership when it comes to fire frequency. As insurance is only applicable on productive forest land, all of the calculations regarding area and volume per hectare are based on productive forest land. Fire preventative silviculture is not taken into account by the model, primarily due to us finding no applicable research regarding its effect on fire.

The IO might not base their decision entirely on the monetary costs or benefits when deciding whether to acquire an insurance or not. There might be other values of interest than production goals, for example insuring in order to guarantee a pension or monetary value for future generations. The growth stage of the forest may also influence the decision, for example an older forest which has recently been inherited contains a lot of value and the insurance premiums only apply to the new owner. This may lead them to acquire insurance as the cumulative premium only slightly impacts the net profits from the forest but guarantees the value in it.

If an IO has other values than timber production and monetary goals in mind with the model, for example recreation, foraging or nature conservation values the model will be hard to apply. However, if the benefits of these values can be translated into monetary terms the model would be applicable. On the other hand, perhaps the insurance premiums would change as well if this would be the case.

MSB describes that they are missing data from certain municipalities for a certain years from 2003-2017. Furthermore, they add that this might not affect the overall result significantly, however, certain regions might not be represented accurately [MSB, 2021].

The governments role in forest fire insurance could also be different. In the past the government has alleviated losses for forest owners by tax reductions and other subsidies [Axelsson, 2007]. There are many services other than production which the forest provides for the entire public. For example: carbon sinks, preservation, recreation, foraging etc. If the forest that provides these services burns down the value from the services are lost. However, the forest owner, if insured, only gets monetary compensation for the standing timber value [Länsförsäkringar, 2022]. Also, if these types of forests are burnt down, the non-timber values take a long time to recreate. This gives room for a discussion about the government providing subsidies for fire preventative silviculture and providing further compensation to the forest owner if these types of forests are lost, as they serve society greater than forest primarily used for timber production.

## 8.4 Future research

Future research is necessary to make more accurate models for the investment decision of acquiring a forest insurance.

- Investigate the correlation of forest fire probability and forest management in relation to infrastructure, tree species distribution and fire preventative silviculture etc.
- Explore the decision making that an IO has to deal with, what time, what insurance type etc.
- Making calculations on each individual estate using forest management plans as guidelines.
- Develop a tool which incorporates the model and assist the individual owner in the decision making process. This could be based on each individual owner's forest management plan. The tool would also need to have a function which translate the different stands in the property to monetary terms in order to apply the model.
- In order to prevent losses due to fire, the governments role in providing funds for the risks an IO faces should be calculated and applied in the model. This would be a way to include a parameter which serves the entire society.

# 9 Conclusion

From the analysis the first hypothesis cannot be discarded as there was no scenario in which fire insurance was profitable. Hence, no real conclusions about the research question can be drawn from this. The second research question analysis ties into the sensibility of the results. According to the increasing trend of fires, the probabilities are going to be realistic unless something changes. The question is just when they will be relevant. A reasonable expectation is that the insurance companies will then increase their premiums when the risk becomes greater. Another aspect of this is that it ties into the local micro climate in each area in a region. The preconditions for these local areas will most likely vary depending on a multitude of factors and greatly affect the risk in practice.

Based on the calculations, it is not beneficial to acquire a forest fire insurance in any of the selected scenarios for each part of the country. There are many reasons why it appears to not be beneficial. The fire probabilities are made by using the average fire probabilities for the counties included in the different parts of the country.

The probability of fire has to be 30 times greater for the worst case probability of fire in northern Sweden in scenario B to make it beneficial to invest in a forest fire insurance. This represents the scenario where it is the most profitable.

Since data from the past was used when creating the probabilities of fire, the future impact of climate change is not yet finalized. A probability of fire less than the two percent required for northern Sweden to be profitable might not be an unreasonable scenario in the not-so-distant future. When this tipping point is exceeded, acquiring insurance for the individual forest owner is instead profitable.

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# Appendix

| Year | Number of fires | Burnt area ($m^2$) |
|---|---|---|
| 1998 | 71 | 118 209 |
| 1999 | 203 | 1 725 662 |
| 2000 | 160 | 988 765 |
| 2001 | 177 | 1 980 520 |
| 2002 | 285 | 1 854 294 |
| 2003 | 248 | 3 119 656 |
| 2004 | 172 | 1 119 863 |
| 2005 | 207 | 2 927 929 |
| 2006 | 182 | 1 800 786 |
| 2007 | 137 | 714 446 |
| 2008 | 334 | 8 077 054 |
| 2009 | 192 | 5 341 337 |
| 2010 | 115 | 851 460 |
| 2011 | 107 | 1 513 462 |
| 2012 | 58 | 535 005 |
| 2013 | 183 | 1 609 206 |
| 2014 | 173 | 3 250 851 |
| 2015 | 96 | 472 316 |
| 2016 | 332 | 4 069 944 |
| 2017 | 205 | 2 225 028 |
| 2018 | 640 | 3 130 011 |
| 2019 | 383 | 6 391 528 |
| 2020 | 299 | 792 293 |
| 2021 | 226 | 716 435 |

Table 4: Data regarding the Southern part of Sweden [MSB, 2021]

| Year | Number of fires | Burnt area ($m^2$) |
|---|---|---|
| 1998 | 77 | 502 610 |
| 1999 | 350 | 3 137 359 |
| 2000 | 191 | 4 433 382 |
| 2001 | 248 | 1 237 572 |
| 2002 | 410 | 4 408 935 |
| 2003 | 305 | 1 740 363 |
| 2004 | 220 | 6 891 171 |
| 2005 | 264 | 3 094 356 |
| 2006 | 321 | 7 568 320 |
| 2007 | 284 | 2 992 152 |
| 2008 | 403 | 33 816 211 |
| 2009 | 170 | 1 167 825 |
| 2010 | 131 | 522 060 |
| 2011 | 239 | 1 347 557 |
| 2012 | 68 | 293 950 |
| 2013 | 303 | 1 766 825 |
| 2014 | 349 | 98 898 585 |
| 2015 | 117 | 1 241 604 |
| 2016 | 379 | 2 521 107 |
| 2017 | 357 | 1 364 821 |
| 2018 | 790 | 140 876 067 |
| 2019 | 294 | 1 137 966 |
| 2020 | 392 | 2 099 142 |
| 2021 | 186 | 1 682 071 |

Table 5: Data regarding the Central part of Sweden [MSB, 2021]

| Year | Number of fires | Burnt area ($m^2$) |
|---|---|---|
| 1998 | 27 | 151 400 |
| 1999 | 115 | 3 067 353 |
| 2000 | 45 | 382 386 |
| 2001 | 50 | 874 256 |
| 2002 | 220 | 2 504 198 |
| 2003 | 281 | 8 194 314 |
| 2004 | 98 | 947 672 |
| 2005 | 112 | 618 263 |
| 2006 | 257 | 37 088 951 |
| 2007 | 105 | 1 505 889 |
| 2008 | 99 | 908 278 |
| 2009 | 82 | 792 710 |
| 2010 | 34 | 64 095 |
| 2011 | 73 | 584 417 |
| 2012 | 34 | 257 211 |
| 2013 | 95 | 1 395 055 |
| 2014 | 237 | 2 831 402 |
| 2015 | 78 | 855 574 |
| 2016 | 79 | 500 088 |
| 2017 | 65 | 775 712 |
| 2018 | 387 | 71 821 024 |
| 2019 | 96 | 374 173 |
| 2020 | 135 | 1 037 981 |
| 2021 | 159 | 1 390 140 |

Table 6: Data regarding the Northern part of Sweden [MSB, 2021]

| | $1000000 m3sk$ | $ha$ | $m^3 fub/ha$ |
|---|---|---|---|
| Northern Sweden | 1365,8 | 11500000 | 98,6 |
| Central Sweden | 1042,2 | 6929000 | 124,8 |
| Southern Sweden | 922 | 5046000 | 151,7 |

Table 7: Data on volume per hectare used for calculating the fire probabilities [SLU, 2021]

## Kandidatarbeten / Bachelor Thesis
## Institutionen för skogsekonomi / Department of Forest Economics

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