Post-fire forest management methods in Sweden:

Societal perception and biological aspects

Julia Redegren Gomes
Supervisors: Natascha Kljun & Nils Droste
Lund University, Department of Biology
BIOK01 Bachelor's thesis, 15hp
Spring 2022

Post-fire forest management methods in Sweden:
biological aspects and social perception
Julia Redegren Gomes
BIOK01 Spring 2022

Abstract

With an increasing global temperature, at rates twice as fast as the global average in the northern boreal forests, an increasing wildfire frequency is to be expected. Previous studies have shown that forest areas in Eurasia with high risk of wildfires today are expected to more than double in size in the following 30 years. This will have a great impact on the fire regime, biodiversity, economic and social quality as well as ecosystem services between forest and society in these areas. Sweden is one of many countries at risk, with forest cover being 60% of the country's total land cover. Furthermore, the forest products industry accounts for between 9-12% of Swedish industry's total employment, exports, sales and added value. It is needless to say that the Swedish population is largely dependent on the forest and will be affected by these altered fire regimes on an biological and social level. However, little research has been done on the societal perceptions of wildfires and different post-fire forest management methods in the country. Furthermore, knowledge about societal perceptions in combination with biological aspects of different post-fire forest management options is of great interest. In this study, I analyzed vegetation data from five boreal forest sites in the Ljusdal fire complex, where 9500 hectare of forest burned down during the summer season 2018. I analyzed the vegetation cover based on fire intensity and the post-fire forest management method that was applied. Moreover, I also conducted a survey in order to gain perspective of the Swedish population's perceptions of wildfires and the forest management methods that could be realized after a wildfire. The results showed that vascular plant cover was significantly different between sites that had been affected by different degrees of fire severity as well as different post-fire forest management methods. Three years after the fire, the vascular plant ground cover and naturally generated pine seedling number was the highest at both of the unlogged fire-severity sites in contrast to the salvage-logged sites. However, the pine-seedlings proved slightly taller at the salvage-logged sites than at the unlogged sites. Regarding the societal perceptions, a small majority of participants prefered salvage-logging (42,4%) over leaving the forest unlogged (39,9%). There also proved a relationship between forest ownership and logging method, where people who own forest were more inclined to pick salvage-logging as the prefered post-fire forest management option. If forest owners as well as people with interest in forests were made aware of the forest soil properties potentially being negatively altered many decades post disturbance, their opinion might prove different. After all, leaving a forest unlogged might lead to a higher economical- and biological value than that which would be provided short-term by salvage-logging. Furthermore, a lot of the time, money and energy of forest owners could be spared since less interaction would be necessary and equal, if not higher, forest value would be achieved.

Keywords: Wildfire, post-fire forest management, societal perceptions, vegetation regrowth, boreal forest, climate change

Acknowledgements

I want to thank Natascha Kljun and Nils Droste for providing invaluable guidance throughout the project. I want to thank Julia Kelly for all of the help and support with analyzing vegetation regrowth and providing background information about the project. I want to thank Rosie Watts, for all of the help with the survey design and distribution. Overall, I want to thank all of the researchers of the Forest Fires research team for all of their time and help. Lastly, I want to thank my friend Sofie Andersson for all the encouragement and support throughout the project.

LUND UNIVERSITY

Table of contents

1. Introduction

1.1 Background

Wildfires have been and remain a common occurrence in many forests around the world. They occur in areas with a sufficient amount of dry fuel (such as leaves, shoots and litter) when provided with some source of ignition. Wildfires vary in frequency, intensity and severity depending on the type and amount of fuel that is available, weather conditions and the climate in the area (Bond & van Wilgen, 1996, Chapter 2; Keeley, 2009). Furthermore, they can burn in canopies, on the ground surface or underground to a varying extent. Together, all of these factors are what collectively describes a fire regime, which in turn is closely related to different types of vegetation and forest types (de Groot et al., 2013).

After a wildfire a common approach is salvage-logging the forest (78% of wood volume that is damaged by a natural disturbance is salvage-logged in Europe), in order to capture some of the economic value that otherwise would be lost (Lindenmayer, 2008). In practice, salvage-logging results in the removal of undamaged trees along with the dead or damaged ones, and as a result also removing understory vegetation, logs and other biological legacies. The removal of these recolonization and regrowth starter points heavily affects the post-fire vegetation recovery in the affected area (Lindenmayer, 2008). For example, some of the effects of the removal of the biological legacies are increased soil temperature, reduced soil moisture and a reduced amount of ecologically important soil properties (such as available phosphorus and nitrate) up to eight decades post-fire (Marcolin et al., 2019; Bowd et al., 2019). This in turn limits the germination process of many plant species, and thus also the abundance and performance of different seedlings post-fire (Marcolin et al., 2019). Salvage-logging also decreases the amount of available habitats for species deeply dependent on dead trees. Ecosystem revitalization is therefore strongly influenced by the type, number and spatial arrangement of biological legacies post-fire, which is manipulated by these post-fire forest management practices (Lindenmayer & Franklin, 2002; Lindenmayer et al., 2004). Also, salvage-logging post-fire has been shown to alter succession dynamics and delay the overall vegetational regrowth through the removal of biological legacies and negatively manipulating the soil properties. (Beschta et al., 2004).

Sweden constitutes mostly of the boreal forest type, which contain a mosaic of different habitats shaped by various disturbance regimes, such as wildfires (Skogsstyrelsen, 2015). The wildfires have helped maintain diversity and long-term stability in the forests, and are thus considered as a natural part of the boreal forest ecosystem (Zackrisson 1977). For example, the coniferous tree *Pinus sylvestris* possesses thick, heat insulating bark and roots, as well as the ability to recover its cambial layer, and thus have great qualities that are beneficial when exposed to recurrent high intensity forest fires (Zackrisson 1977). The boreal forest wildfires have been a natural part of the forests for over thousands of years and have, at the same time, constituted a threat to people, property and infrastructure (Sjöström & Granström, 2020).

The most common reason for wildfire ignitions in Sweden are burning of grass or other material close to residential areas, children playing with fire, or escaped campfires. Usually, those types of ignitions cause small, low intensity fires that might not seem as intimidating as high-intensity fires, but still have the ability to pose a threat to buildings when being located close to human settlements. Large-scale fires are on the other hand commonly ignited by lightning, forestry machines or through re-ignition (which stands for the ignition of 48% of all fires larger than 100 hectare) (Sjöström & Granström, 2020). With increased access to the forest and larger human populations, an increasing number of wildfires begin because of human-related ignitions. At the same time, however, fires are also further limited in size and extent because of large urban areas, roads as well as a faster and more effective suppression. In short, human populations alter forests original fire regime by additional sources of ignition, silvicultural services, active suppression and demarcation as a consequence of extended urban areas (Danley 2021; Pinto et al., 2020; Bowman et al., 2011).

Furthermore, the boreal forest ecotype is experiencing climatic warming at rates twice as fast as the global average, and is thus very susceptible to recurrent high-intensity wildfires in the future (Young et al., 2016). Burrell et al (2022) showed that the forest areas in Eurasia which had high or extreme risk of wildfires in 1985-2015 are expected to more than double in size in 2015 to 2045. This in turn will have a prominent impact on ecosystem services between forest and society, potentially with large economic- and social consequences in societies in proximity to these areas (Danley, 2021; Burrell et al., 2022). In Sweden, wildfires mostly affect forested land, which constitute about 60% of the country's land area below the mountain ranges (Sjöström & Granström, 2020). Furthermore, Sweden provides 10% of the sawn timber, pulp and paper that is traded to the global market and forest products industry accounts for between 9-12% of Swedish industry’s total employment, exports, sales and added value (Skogsstyrelsen, 2015).

During summer 2014 and 2018 in Sweden, wildfires spread with a speed and intensity that never before have been observed in the country (Sjöström & Granström, 2020). The 2018 wildfire is to this day one of Sweden's most recent large-scale wildfires. It took place in Ljusdal, and a total of 9500 hectare of forest burned down in the area. It was the worst wildfire the country had experienced in 140 years. The fire was ignited by lightning, and affected about 150 forest owners (mostly private owners but also three forestry companies) (Ljusdal municipality, n.d.). The fire-complex contains a range of different sites that differ in fire-intensity, fire-severity and post-fire forest management method. It provides meaningful insight into how different types of wildfires and post-fire forest management methods reflect on the forest after a wildfire. There is an urgent demand to further understand the effects wildfires and post-fire forest management have on Sweden's boreal forest. Sweden is a country at risk of recurrent high-intensity wildfires in the future, a country with a large boreal forest cover and is to a great extent economically relient on cultivating this forest. With an altered fire regime and little previous research on how to handle the aftermath of wildfires in the country, further research in the field is of great interest.

1.2 Purpose & research questions

There are many biological and societal aspects followed by wildfires that need to be further investigated in a rapidly changing climate. Although there are many studies that have been made in the field, there’s a growing demand for more knowledge on societal perceptions of wildfires and post-fire forest management methods in combination with the biological aspects in Sweden. With the current rate of climatic warming, the wildfires are expected to increase in Sweden's boreal forest. In order to ensure a sustainable development with societal and biological aspects in mind, there is a need to further investigate how wildfire and post-fire management methods reflect on forests as a whole.
In order to study this, I have researched different sites in the Ljusdal fire complex and conducted an online survey with the following three research questions in mind;

(1) How do different fire-severity degrees and post-fire forest management methods affect vegetation regrowth in Sweden's boreal forests? How does it affect the regrowth of bryophytes, vascular plants and pine trees?

(2) Which of the two post-fire forest management methods are prefered by people that own forest and people who do not own forest? How does the Swedish population as a whole perceive wildfires and different post-fire forest management methods?
(3) Is there a way to manage burnt forest that is favored by both the environment, people interested in forest and forest owners alike?

I predicted that the low-severity, unlogged site will have the highest amount of vascular plant cover, moss cover and pine seedlings out of all of the sites, as a result of an increased amount of biological legacies, less disturbance and favorable soil properties.

Regarding societal perceptions, I predicted that people that own forest will prefer salvage-logging over leaving burnt trees standing, since it is a commonly accepted method and is economically beneficial. Regarding people who do not own any forest, I predicted that they will prefer leaving the burnt trees standing since it could be perceived as more welcoming, and they might not have an economical interest.

2. Method and materials

2.1 Data collection, vegetation regrowth

The data used in this analysis was collected from five boreal forest sites in the Ljusdal fire complex (see figure 1). The sites were grouped by burn severity (high-severity, ~100% tree mortality and low severity, ~100% tree survival), as well as applied post-fire forest management method (salvage-logged or unlogged forest). All of the sites that were analyzed were localized in mature forests, with trees with an average age of about 100 years. The data were collected as a part of the Forest Fires research project at Lund University in 2021 (P.I, Natascha Kljun).

Figure 1, Photos of the different forest sites in the order HM (unlogged, high severity forest site), LM (unlogged, low severity forest site), SHM (salvage-logged, high severity forest site), SLM (salvage-logged, low severity forest site) and UM (control site) starting from left to right. Source: Natascha Kljun (2021)

The sites were located in an area $1 < km^2$ and named:

(1) HM: High-severity burn on a mature forest site which was left unlogged.
(2) LM: Low-severity burn on a mature forest site, which was left unlogged.
(3) SHM: High-severity burn on a mature forest, where burnt trees were salvage-logged.
(4) SLM: Low-severity burn on a mature forest, where burnt trees were salvage-logged.
(5) UM: Unburnt forest (control site).

For the understory vegetation regrowth analysis, 12 quadrats of 25×25 centimeters were sampled in each of the different sites. Both vascular plant cover and moss cover were visually estimated as percentage ground cover in each quadrant. Type of species was also noted for all of the vascular plants, but not for the mosses and lichens.

For the analysis of Scots pine seedlings, 4 circular plots with a 3 meter radius were randomly sampled in each of the four sites (HM, LM, SHM and SLM). No data were collected from the UM site, as no seedlings were seen. The naturally generated pine-seedlings within the plots were counted and their height measured in centimeters.

2.2 Survey design and distribution, societal perceptions

The data on social perceptions of wildfire and post-fire management methods were collected through an online survey (see Appendix A) in order to collect a lot of data efficiently during the short time-frame of the project. The choice of an online survey was also based on the knowledge of some of the questions being sensitive to people directly affected by the wildfires, and thus making it more feasible (Regmi et al., 2016). The program Sunet Survey was used for designing the questionnaire.

The questions in the questionnaire were phrased using two approaches. Firstly by wording, where the BOSS-model was followed, meaning the wording of all questions should be Brief, Objective, Simple and Specific (Warwick and Lininger, 1975). Secondly, the literal meaning of the questions were phrased as simple and direct as possible, to minimize the risk of them being wrongly interpreted or tentative (Peterson, 2000). As for response options, the survey primarily consisted of multiple choice alternatives, “yes” or “no” check-in boxes, and 5-point likert scales. At times, the questions were followed up by open questions in order to collect qualitative data when necessary (McGuirk & O’Neill 2016).

The structure of the questionnaire consisted of an introductory section, followed by a substantive question section and then a classification question section. For the introductory section, the goal was to encourage the participants to become involved with the project and legitimize it in a brief and concise manner. The substantive question section contained the most vital questions for the project. The less personal and difficult questions were in the beginning of the section, followed by the harder and more time-consuming questions. The section contained funnel questions, to channel the questioning process from general to specific. The classification section contained questions about the participants demographic characteristics and other personal questions (Peterson, 2000).

Before release, the survey was pretested by a total of 10 individuals of different ages, gender and with varying degrees of knowledge chosen out of a convenience sample. They were asked to answer the survey from different platforms (mobile versus computer) and in two different languages (Swedish versus English). It proved an opportunity to make sure that the questions were interpreted as anticipated (Peterson 2000), and also to look at how the answers would be presented.

The survey was launched in a total of 9 Facebook groups with a range of 3000-84000 members in each group. The groups were picked based on their field of interest, such as mushroom picking, hunting, forestry, hiking as well as groups made for people residing in Ljusdal or Sala (see Appendix B). The aim was to get an even distribution of participants from the groups, so the sample could be interpretable as representative for a bigger part of the population. The survey was launched for a total of three weeks in each group. An English (translated) version of the survey (see Appendix C) was also designed and launched. However, because of the limited time-frame of the project and very few english-speaking participants, the data from the questionnaire was not included in the analysis.

2.3 Statistical analysis

All data were analyzed in the program IBM SPSS Statistics (version 28). For the regrowth analysis, data of moss cover, vascular plant cover and naturally regenerated seedling height and number of Scots pine were used. A Shapiro-Wilk's test ($p<0{,}05$) and a visual inspection of normal Q-Q plots were done prior to any other testing, in order to determine if the data were parametric or non-parametric (Shapiro & Wilk, 1965). To analyze the variance (of moss cover and vascular plant cover) between the sites, a one-way ANOVA was used if residuals were normally distributed and showed even variance across groups. If not, a Kruskal-Wallis test was used instead. To analyze the difference (in moss cover, vascular plant cover, Scots pine seedling amount and height) on a more detailed level between the sites, an independent samples T-test was used if the data met the assumptions of parametric tests. If not, a nonparametric Mann-Whitney U-test was used instead. The following research design was used:

(1) Moss cover and vascular plant cover for site UM, LM and HM were tested against each other through a one-way ANOVA or Kruskal-Wallis, to analyze the effects of burn severity.
(2) Moss cover, vascular plant cover, pine seedling amount and height for site HM and SHM were tested against each other through an Independent samples T-test or Mann-Whitney U-test, to analyze the effects of salvage-logging after a high severity fire.
(3) Moss cover, vascular plant cover, pine seedling amount and height for site LM and SLM were tested against each other through an Independent samples T-test or Mann-Whitney U-test, to analyze the effects of salvage-logging after a low severity fire.

For the social perception analysis, the following research design was formed and tested:
(1) Preferred method was tested for dependency of Forest ownership.
(2) Preferred method was tested for dependency of Occupation with ties to forestry or forest fires.

Preference for salvage-logging as a post-fire forest management method as well as preference for leaving forest unlogged was tested for dependency of forest ownership. The same, preference for salvage-logging as compared to preference for leaving forest unlogged was tested for dependency of occupation having ties with forestry or forest fires. This was tested with chi-square tests of independence. Furthermore, descriptive data of preferred methods, background information and knowledge about forest fires for all of the respondents were also realized.

3. Results

3.1 Vegetation regrowth

3.1.1 Moss cover

There was a significant difference in moss cover between the sites that had been exposed to different fire-severity and those which had not been exposed at all (one-way ANOVA: $H_2 = 26{,}406, p < 0{,}001$). The control site (UM) had a significantly higher moss cover than the sites exposed to fire.

For the SHM site and the HM site, there was no significant difference in moss cover between the salvage-logged and unlogged high-severity forest sites (Mann-Whitney U-test: $U_{12,12} = 70, p = 0{,}859$). For the SLM site and the LM site, there was no significant difference in moss cover between the salvage-logged and unlogged low-severity forest sites (Mann-Whitney U-test: $U_{12,13} = 61, p = 0{,}282$).

In short, total moss cover did significantly differ between the LM, HM and the control site (UM), but not between the LM and SLM or HM and SHM sites (see figure 2).

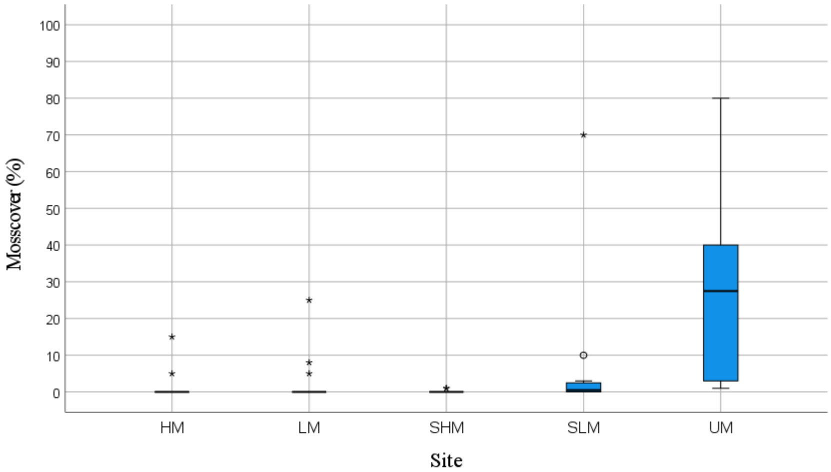


Figure 2. Percentage ground cover of mosses at the different sites, were HM= unlogged high-severity forest site, LM= unlogged low-severity forest site, SHM= salvage-logged high-severity forest site, SLM= salvage-logged low-severity forest site and UM= control site (unaffected by the fire).

3.1.2 Vascular plant cover

The was a significant difference in vascular plant cover between site LM, HM and UM (one-way ANOVA: $H_2 = 12{,}905, p = 0{,}002$) where vascular plant cover was significantly lower in areas exposed to fire (LM and HM site).

Based on a Shapiro-Wilk's test (p<0,05) for the vascular plant cover at several of the sites, Mann-Whitney U-tests were used as a nonparametric equivalent for an independent samples T-test.

There was a significant difference in vascular plant ground cover between the HM and SHM forest site (Mann-Whitney U-test: $U_{12,12} = 24.50, p = 0{,}005$) where it was significantly higher at the HM site. There was also a significant difference in vascular plant ground cover between LM and SLM forest site (Mann-Whitney U-test: $U_{12,12} = 14, p < 0{,}001$) where it was significantly higher at the LM site. In short, both of the unlogged sites showed a significantly higher total percentage of vascular plant ground cover than the salvage-logged sites. Vascular plant cover was dependent on both fire-severity and post-fire management method, especially between the low-severity forest sites (see figure 3).

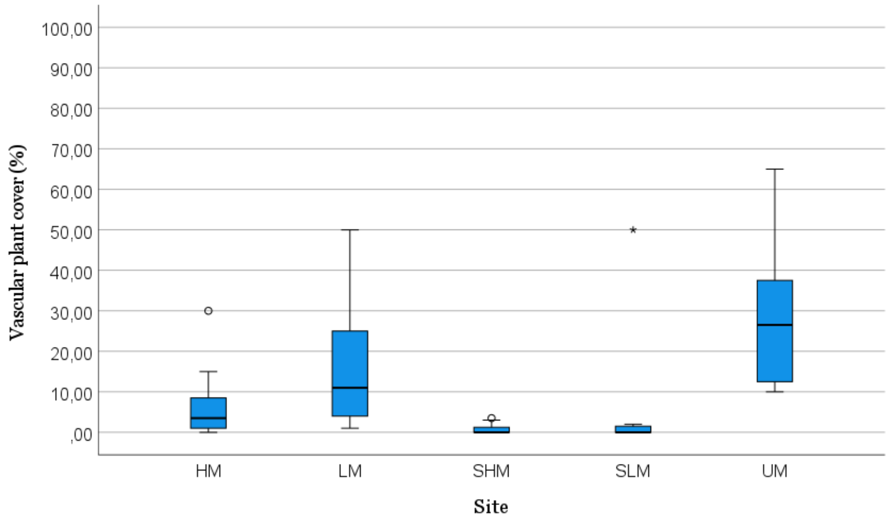


Figure 3. Percentage ground cover of vascular plants at the different sites, were HM= unlogged high-severity forest site, LM= unlogged low-severity forest site, SHM= salvage-logged high-severity forest site, SLM= salvage-logged low-severity forest site and UM= control site (unaffected by the fire).

The most commonly occuring species at the fire complex was *Vaccinium vitis-idaea* (lingonberry), followed by *Chamaenerion angustifolium* (willowherb/fireweed) and *Vaccinium myrtillus* (blueberry) (see table 1).

Table 1, percentages of how many plots the species in question occurred in out of the total amount of plots at each site.

Site/Species	*V. vitis-idaea*	*C. angustifolium*	*V. myrtillus*	*C. vulgaris*	*P. sylvestris*	*Betula sp.*	*Salix sp.*
HM	67%	33%	0,8%	0%	0,8%	0%	0%
SHM	42%	0,8 %	0%	0%	0%	0%	0%
LM	92%	0,8%	0,8%	0,8%	0,8%	0%	0%
SLM	0%	1,7 %	0%	0%	0%	1,7%	1,7%
UM	100%	33%	0,8%	0%	0%	0%	0%

More specifically, at the HM site, *V. vitis-idaea* was present in 8 of 12 plots, *C. angustifolium* in 4 out of 12 plots and *V. myrtillus* in 1 of 12 plots. Only 1 of the 12 plots contained no vascular plant species. For the SHM site *V. vitis-idaea* was identified at 5 of the 12 sites and *C. angustifolium* at 1 of 12 sites. The rest of the plots at the site contained no plant species. At the LM site, *V. vitis-idaea* was present in 11 out of 12 plots, *C. angustifolium* in 1 of 12 plots and *V. myrtillus* in 1 out of 12 plots. There was no plot that lacked species. For the SLM site, *V. vitis-idaea* was present in 0 out of 12 plots, *C. angustifolium* in 2 out of 12 plots and *V. myrtillus* in 0 out of 12 plots. There were a total of 8 plots without any plant species. Moreover, species of *Calluna vulgaris* (heather), *P. sylvestris, Betula sp.* (birch) and *Salix sp* (willow) were seen at the sites, but not as common. All of the plots at the UM site contained *V. vitis-idaea*, 4 out of 12 plots *C. angustifolium* and 1 out of 12 plots *V. myrtillus*.

3.2 Scots pine

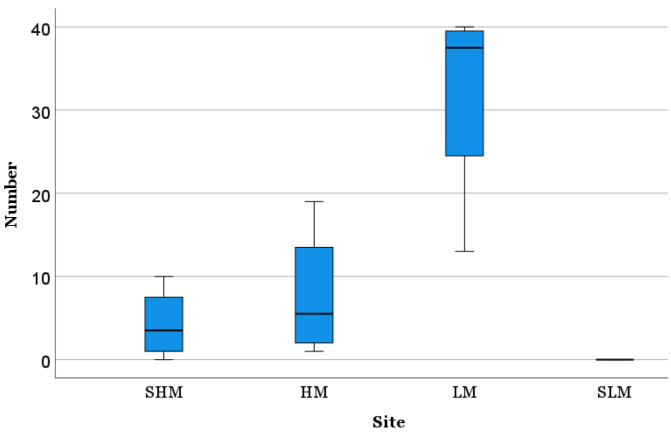
The number of naturally generated pine seedlings were not significantly different between the SHM and HM forest site (Mann-Whitney U-test: $U_{4,4} = 6, p = 0{,}564$). At the SLM and LM site, the number of seedlings were significantly higher at the LM site (Mann-Whitney U-test: $U_{4,4} = 0, p = 0{,}014$) than at the SLM site, which had no naturally generated seedlings (see figure 4a).

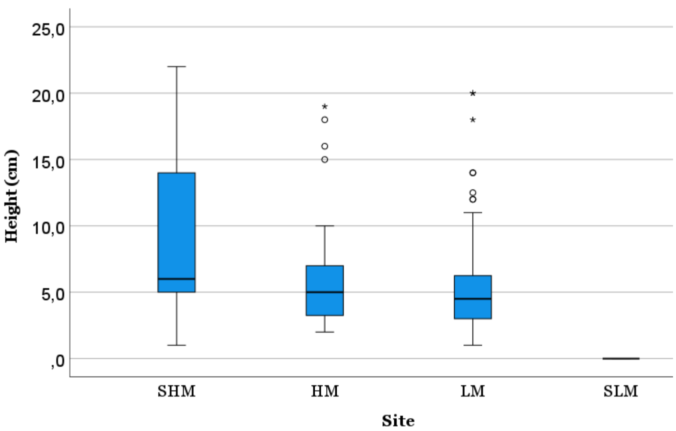
Figure 4a. The number of pine seedlings at the different sites

Figure 4b. The height of the pine seedlings at the different sites

The height of the pine seedlings was significantly higher at the SLM site compared to the HM site (Mann-Whitney U-test: $U_{17,31} = 220{,}50, p = 0{,}352$). However, the LM site had significantly higher seedlings compared to the SLM site (Mann-Whitney U-test $U_{4,128} = 0, p < 0{,}001$) (see figure 4b).

3.3 Societal perception





3.3.1 Descriptive statistics

The questionnaire had a total of 158 participants, all which gave consent to their answers being a part of this study. There was an even distribution between male and female respondents, of which 83 were males (52,5%) and 74 were females (46,8%). 1 respondent were non-binary (0,06%). The age-range of the participants was relatively equally distributed, but with few respondents younger than 20 or older than 70 years. A great majority, 136, of the participants (86,1%) had seen a fire in reality, not through social media, tv, or other. Furthermore, a total of 64 participants own forest (40,5%), versus 94 non-owners (59,5%) (see figure 5).

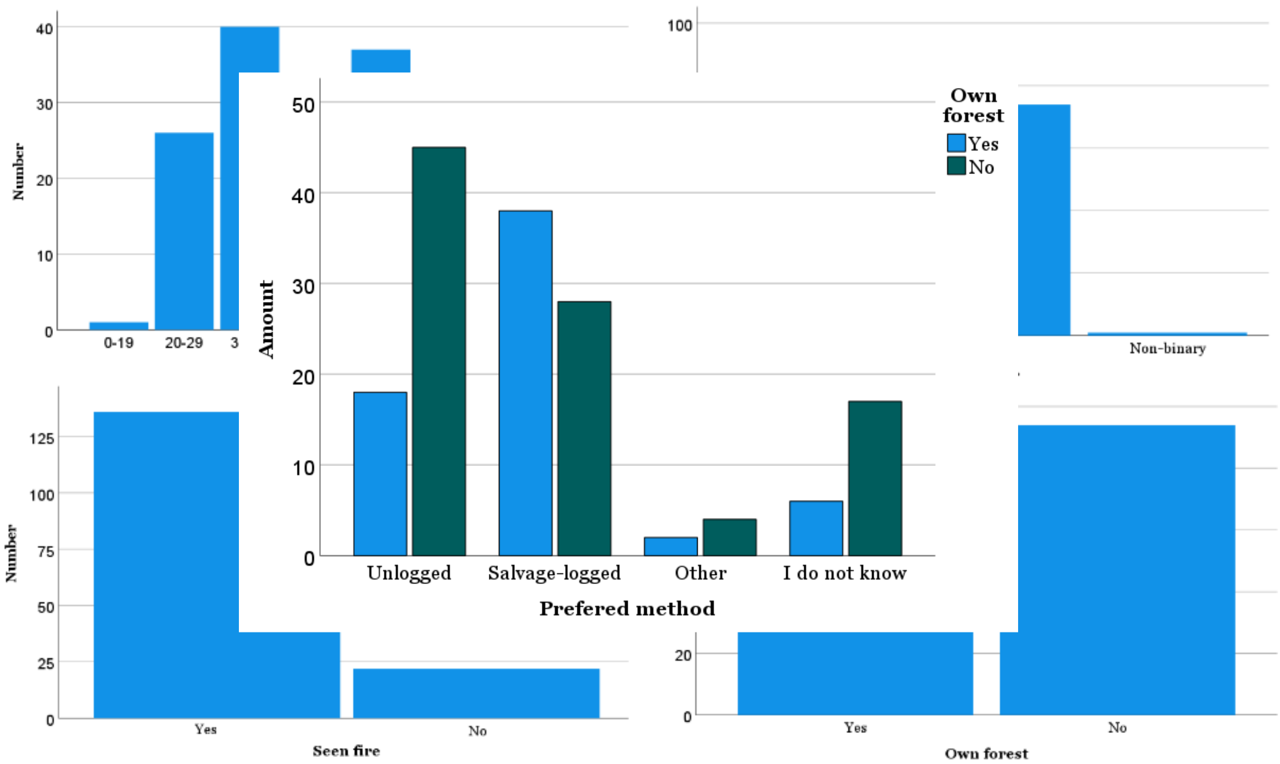


Figure 5. A collection of descriptive data of the survey respondents age, gender, fire knowledge and forest ownership.

The participants were asked to rate on a scale of 1 to 5 how much time they spend doing a certain activity in the forest, 1 being never and 5 being almost every time. The highest mean value for an activity was doing sports (Mean value=3,11, Standard Deviation=1,292), followed by mushroom- and berrypicking (M=3,04, SD=1,102) , forestry (M=2,11, SD=1,496), hunting (M=1,76, SD=1,233) and lastly bird-watching (M=1,61, SD=1,021).

As for the preference for different post-fire forest management methods a small majority, 67, of participants (42,4%) preferred salvage-logging whilst 63 preferred leaving the forest unlogged (39,8%). However, a moderate number of participants (24 and 6 respectively) did not know which they preferred, or preferred another method than those which were presented in the questionnaire.

3.3.2 Inferential statistics

Preference for salvage-logging had a significant relationship with forest ownership (Chi-square: $x^2{}_1 = 13{,}704, N = 158, p < 0{,}001$). Preferring salvage-logging as a post-fire forest management option was dependent on forest ownership. Preference for leaving burnt forest unlogged had a significant relationship (Chi-square: $x^2{}_1 = 6{,}193, N = 158, p = 0{,}013$) with forest ownership as well. Participants that own forest were more inclined to prefer salvage-logging as opposed to participants without forest ownership, who on the other hand were more inclined to prefer leaving the forest untouched (see figure 6).

Figure 6. The relation between preference of a certain post-fire forest management method and forest ownership.

Preference for salvage-logging and occupation connected to forestry or forest fires had no significant relationship (Chi-square $x^2{}_1 = 2{,}498, N = 158, p = 0{,}114$). Preference for leaving burnt forest unlogged and occupation connected to forestry or forest fires (Chi-square $x^2{}_1 = 0{,}292, N = 158, p = 0{,}589$) had no significant relationship either. The prefered post-fire forest management method was independent of whether the participant had an occupation with ties to forest-fires or forestry according to these results.

4. Discussion

The different sites of mature boreal forest had clear differences in understory plant cover, both in density and species composition. The vascular plants were the most abundant in the unlogged low-severity forest site, followed by the unlogged high-severity forest site. The most commonly occurring species at the two sites were V. vitis-idaea, which also was the most commonly occurring species at the control site. It has previously been shown (Schimmel & Granström 1993) that the species has favorable adaptations for surviving forest fires of moderate intensity, partly because of the ability to sprout from surviving rhizomes. Furthermore, in line with the same study, an increased density of the early pioneer species *C. angustifolium* was present at the HM site in contrast with the LM site. As for the species composition and abundance in the salvage-logged sites, SHM also had a large number of *V. vitis-idaea* present. The SLM site on the other hand had none, only some *C.angustifolium*, a few seedlings of deciduous tree species and in general a sparse vegetation ground cover. However, something to note is that the species composition was not statistically tested, because of the limited timeframe of the project.

The moss cover was sparse in all of the analyzed areas, except at the control site. This could be explained by the fact of a longer germination process or unfavorable soil properties. In previous studies, it has been shown that bryophytes in the Eurasian boreal forests generally are less commonly occurring than vascular plant species post-fire, at least in the first years following a fire (Gustafsson et al., 2021). Since no particular species were noted, and they differ a lot in survival strategies and adaptations, no further assumptions regarding the sparse moss cover will be made.

As for the pine seedlings, both the number and height of the naturally generated seedlings differed significantly between sites. At the two unlogged sites, HM and LM, a larger amount of pine seedlings occurred although with a smaller mean height than those present at the SHM site. At the SLM site, no naturally generated seedlings were found. Although *P. sylvestris* is a fire-tolerant species and adapted to fire disturbance (Zackrisson, 1997), logging disturbance might counteract some of these adaptations. Logging has been shown to affect soil properties negatively in previous studies (eg. Bowd et al., 2019), in the sense that soil moisture and available phosphorus and nitrate is reduced. This could explain why fewer seeds germinated at the salvage-logged sites. However, the soil properties might cause a problem for the early stages of development of the species, which would explain why the height is significantly higher (although by a relatively small amount) for the seedlings at the salvage-logged site compared to the two unlogged sites. Another explanation could be competition between the vascular understory plants at the unlogged sites, making resources at the earlier stages of growth limited. Possibly, after a few more years, this could change. After all, natural regeneration of conifer forests after a high-severity, stand-replacing fire has been shown to be more abundant in unlogged stands compared to salvaged areas in previous studies (eg. Beghin, 2010; Greene et al., 2006; Donato et al., 2006).

As predicted, the societal perceptions of post-fire forest management in Sweden were closely related to forest ownership. People that owned forest preferred salvage-logging burnt forest in contrast to people that did not. The economical boundaries are relevant for a majority of forest owners in Sweden. Since such a large amount of forest in Sweden is privately owned, this was expected. However, if provided with information about the decade-long consequences on the soil properties and germination process from different management practices they might be more inclined to try different options. After all, this could possibly counteract some of the early economic losses, in the form of a species dense forest with better productional value in the future. Furthermore the forest owner would, by leaving the forest unlogged, diminish losses in the form of the time, money and energy that it takes to realize logging operations and the following planting of seeds or seedlings.

Although the survey sample size was small, a close to normal distribution of age was achieved (when compared with statistics provided by SCB 2022), an almost equal number of respondents were women and men, approximately 1 out of 3 owned forest, and the participants spent their time in the forest doing many different activities. Lastly, almost 90% of the participants had seen a wildfire or the aftermath from a wildfire. Thus, the sample, although small, has indications of being representative for a larger part of the population. Nevertheless, the results from the survey provide an indication in the matter of what people prefer and think about wildfires and different types of post-fire management methods, and how these opinions are related to the participants background in forestry.

For future research, it would be of interest to follow the regrowth pattern for a longer period of time. It would be interesting and valuable to see how the moss cover would develop at the sites a few years from now, just as the vascular plant cover and pine seedling height. With that information one could make further assumptions as to why the pine seedling height proved higher at the salvage-logged site compared to the unlogged sites, and if the growth rate would decrease, stay the same, or increase in later stages.

5. Conclusion

The overall vegetation regrowth in the Ljusdal fire complex was the most prominent at the unlogged sites, where both vascular understory species as well as pine seedlings were more abundant. The low-severity, unlogged sites were the most diverse with many different vascular plant species. The moss cover was sparse at all of the sites, and no conclusion could be made about their preference as a species. The highest pine seedling mean value for height was found at the salvage-logged high-severity forest site, closely followed by the high-severity and low-severity unlogged forest sites. The largest number of participants in the study prefered salvage-logging over leaving the forest unlogged, which was shown to be dependent on whether the respondent owned forest or not. No connection was shown between prefered method and occupation ties with forestry nor wildfires. It is evident that there is a lack of information available for the general public, regarding the different biological aspects and in turn future economic aspects, of different post-fire forest management methods. With an increasing risk of high-intensity and high-frequency forest fires in the future, the impact of different methods of post-fire forest management on Sweden's boreal forests has been insufficiently studied and needs to be further investigated to ensure a sustainable development in favor of the environment and society alike. Further research, over a long period of time, would benefit not only the environment, but also the population as a whole.

References

Beghin, R., Lingua, E., Garbarino, M., Lonati, M., Bovio, G., Motta, R. & Marzano, R. (2010). *Pinus sylvestris* forest regeneration under different post-fire restoration practices in the northwestern Italian Alps. *Ecological Engineering*, *36*(10). https://doi.org/10.1016/j.ecoleng.2010.06.014

Beschta, R. L., Rhodes, J. J., Kauffman, J. B., Gresswell, R. E., Minshall, G. W., Karr, J. R., Perry, D. A., Hauer, F. R. & Frissell, C. A. (2004) Postfire management on forested public lands of the western United States. *Conservation Biology, 18*(4), 957-967. http://dx.doi.org/10.1111/j.1523-1739.2004.00495.x

Bond, W. J. & van Wilgen, B. W. (1996) *Fire and Plants*, *14*. Springer. https://link.springer.com/book/10.1007/978-94-009-1499-5#about

Bowd, E. J., Banks, S .C., Strong, C. L. & Lindenmayer, D. B. (2019). Long-term impacts of wildfire and logging on forest soils. *Nature Geoscience*, 12, 113–118. https://doi.org/10.1038/s41561-018-0294-2

Burrell, A. L., Sun, Q., Baxter, R., Kukavskaya, E. A., Zhila, S., Shestakova, T., Rogers, B. M., Kaduk, J. & Barrett, K. (2022) Climate change, fire return intervals and the growing risk of permanent forest loss in boreal Eurasia. *Science of The Total Environment, 831.* https://doi.org/10.1016/j.scitotenv.2022.154885

Danley, B., Caputo, J. & Butler, B. J. (2021) A Burning Concern: Family Forest Owner Wildfire Concerns Across Regions, Scales, and Owner Characteristics. https://doi.org/10.1111/risa.13816

de Groot, W. J., Flannigan, M. D. & Cantin, A. S. (2013) Climate change impacts on future boreal fire regimes. *Forest Ecology and Management*, *294,* 35-44. https://doi.org/10.1016/j.foreco.2012.09.027

Donato, D. C., Fontaine, J. B., Campbell, J. L., Robinson, W. D., Kauffman, J. B. & Law, B. E. (2006). Post-wildfire logging hinders regeneration and increases fire risk. *Science, 311*(5759), 352. https://doi.org/10.1126/science.1122855

Granström, A. (2021). Fire management for biodiversity in the European boreal forest. *Scandinavian journal of forest research*, *16* (S3), 62-69. https://doi.org/10.1080/028275801300090627

Granström, A. & Schimmel, J. (1993). Heat effects on seeds and rhizomes of a selection of boreal forest plants and potential reaction to fire. *Oecologia, 94*(3), 307-313. https://doi.org/10.1007/BF00317103

Greene, D. F., Gauthier, S., Noë, J., Rousseau, M. & Bergeron, Y. (2006). A field experiment to determine the effect of post-fire salvage on seedbeds and tree regeneration. *Frontiers in Ecology and the Environment, 4*(2), 69-74. https://doi.org/10.1890/1540-9295(2006)004[0069:AFETDT]2.0.CO;2

Gustafsson, L., Granath, G., Nohrstedt, H., Leverkus, A. B., Johansson, V. & Halvorsen, R. (2021). Burn severity and soil chemistry are weak drivers of early vegetation succession following a boreal mega-fire in a production forest landscape. *Journal of Vegetation Science, 32*(1), 1-13. https://doi.org/10.1111/jvs.12966

Keeley, J. (2009). Fire intensity, fire severity and burn severity: A brief review and suggested usage. *International Journal of Wildland Fire*, *18*, 116-126. 10.1071/WF07049

Kljun, N. (2021). *Pictures of the forest sites.* [photograph] [2022-05-18]

Lindenmayer, D. B. & Franklin, J. F. (2002). *Conserving forest biodiversity: a comprehensive multiscaled approach.* Island Press.

Lindenmayer, D. B., Foster, D. R., Franklin, J. F., Hunter, M. L., Noss, R. F., Schmiegelow, F. A. & Perry, D. (2004) Salvage Harvesting Policies After Natural Disturbance. *Ecology*, *303*(5662). https://doi.org/10.1126/science.1093438

Lindenmayer, D. B., Burton, P. J. & Franklin, J. F. (2008). *Salvage Logging and its Ecological Consequences*. Island Press.

Ljusdal Multiplicity. (n.d.). *Fakta om bränderna* [Facts about the fires]. Retrieved May 5, 2022, from https://www.ljusdal.se/samhallegator/krisochsakerhet/informationombranderna2018/faktaombranderna.4.12be7f0e165140d0d1895a64.html

Marcolin, E., Marzano, R., Vitali, A., Garbarino, M. & Lingua, E. (2019). Post-Fire Management Impact on Natural Forest Regeneration through Altered Microsite Conditions. *Forests*, *10*(11). 10.3390/f10111014

McGuirk, P. M & O'Neill, P. (2016). Using questionnaires in qualitative human geography. In I. Hay (Eds.), *Qualitative Research Methods in Human Geography*, 246-273, Don Mills, Canada Oxford University Press. https://ro.uow.edu.au/sspapers/2518/

Peterson, R. A. (2000). *Constructing Effective Questionnaires*. Sage Publications, Inc.

Pinto, G. A. S. J., Rousseu, F., Niklasson, M. & Drobyshev, I. (2020). Effects of human-related and biotic landscape features on the occurrence and size of modern forest fires in Sweden. *Agricultural and Forest Meteorology*, *291.* https://doi.org/10.1016/j.agrformet.2020.108084

Regmi, P. R., Waithaka, E., Paudyal, A., Simkhada, P. & van Teijlingen, E. (2016) Guide to the design and application of online questionnaire surveys. *Nepal Journal of Epidemiology*, *6*(4), 640-644. https://doi.org/10.3126/nje.v6i4.17258

SCB. (2022). Population by sex, age and country of birth 1970 and 2021 and projection 2070. Retrieved May 17 from https://www.scb.se/en/finding-statistics/statistics-by-subject-area/population/population-projections/population-projections/pong/tables-and-graphs/population-by-sex--age-and-country-of-birth-and-projection/

Shapiro, S. S. & Wilk, M. B. (1965). An Analysis of Variance Test for Normality (Complete Samples). *Biometrika, 52*(3/4), 591-611. https://doi.org/10.2307/2333709

Skogsstyrelsen. (2015). Forests and Forestry in Sweden.
https://www.skogsstyrelsen.se/globalassets/in-english/forests-and-forestry-in-sweden_2015.pdf

Sjöström, J. & Granström, A. (2020) Skogsbränder och gräsbränder i Sverige - Trender och mönster under senare decennier. *Myndigheten för samhällsskydd och beredskap.* https://www.ri.se/sites/default/files/2020-04/Rapport%20brandf%C3%B6rdelning.pdf

Warwick, D. P & Lininger, C. A. (1975). *The sample survey: Theory and practice*. McGraw-Hill.

Young, A. M., Higuera, P. E., Duffy, P. A. & Hu, F. S. (2016) Climatic thresholds shape northern high-latitude fire regimes and imply vulnerability to future climate change. *Ecography,* 40, 606-617 https://onlinelibrary.wiley.com/doi/epdf/10.1111/ecog.02205

Zackrisson, O. (1977). Influence of Forest Fires on the North Swedish Boreal Forest. *Oikos*, *29*, 22-32. https://doi.org/10.2307/3543289

Appendixes

Appendix A. Swedish questionnaire

Skogsbränder och vård av bränd skog
- vad är dina åsikter?
Syftet med enkäten är att samla in information om dina uppfattningar om skogsbränder och metoder för vård av bränd skog. Genom att genomföra enkäten, hjälper du mig med mitt kandidatarbete vid Lunds Universitet och bidrar till kunskap som kan ligga till grund för framtida förbättringar inom området. Tack!

Enkäten kommer att ta mellan 5-10 minuter att genomföra och du är helt anonym.

Q1

1.

Ger du ditt medgivande för att svaren du uppger i enkäten samlas in i undersökningssyfte?

- Ja
- Nej

Q2

2.

Har du sett en skogsbrand och/eller efterlämningarna från en skogsbrand?

I verkligheten, inte på TV, sociala medier eller liknande

- Ja
- Nej

Q3

3.

Vad tror du är huvudorsaken till varför skogsbränder sker i Sverige?

- Blixtnedslag
- Anlagd brand *(av människor, illvilligt uppsåt)*
- Olyckshändelse *(av människor, cigarettfimpar, förrymd lägereld, skogsmaskiner…)*
- Annan orsak
- Jag vet inte

Q4

4.

Till vilken grad upplever du skogsbränder som ett problem i Sverige?

1 (inget problem alls) - 5 (stort problem)

- 1
- 2
- 3
- 4
- 5

Q5

5.

Till vilken grad tror du skogsbränder kommer vara ett problem i Sverige i framtiden?

1 (inget problem alls) - 5 (stort problem)

- 1
- 2
- 3
- 4
- 5

Q6

6.

Skadades fastighet i din ägo av...

- Skogsbranden i Ljusdal, 2018
- Skogsbranden i Sala, 2014
- Annan skogsbrand.
- Ingen av ovanstående/har ej drabbats.

Q7

7.

Om en skogsbrand hade tagit fart i din närhet, till vilken grad hade du oroat dig över nedanstående faktorer?

1 (ingen oro) - 5 (mycket oro)

Min säkerhet och/eller andras säkerhet	*Skala 1-5*
Egenägd skog	*Skala 1-5*
Egenägd bostad	*Skala 1-5*
Miljön och/eller djur- och växtliv	*Skala 1-5*

Q8

8.

Till vilken grad tror du att skogsbränder hade kunnat påverka dig eller din fastighet?

1 (inte påverkat alls) - 5 (påverkat mycket)

- 1
- 2
- 3
- 4
- 5

Q9

9.

Har du sett en skog där någon av följande metoder har använts efter en skogsbrand?

	Ja	Nej	Jag vet inte

Ingen avverkning eller återplantering, skogen lämnas orörd.	.	.	.
Räddningsavverkning och återplantering.	.	.	.
Andra metoder	.	.	.

Om "*Andra metoder*" vilken? *Öppen fråga*

Q10

10.

Hur väl känner du dig informerad om följande metoder för eftervård av bränd skog?

1 (inte informerad alls) - 5 (mycket väl informerad)

Ingen avverkning eller återplantering, skog lämnas orörd.	*Skala 1-5*
Räddningsavverkning och återplantering	*Skala 1-5*
Annan metod	*Skala 1-5*

Om *"Annan metod"*, vilken? *Öppen fråga*

Q11

11.

Vilken av följande metoder för vård av bränd skog hade du föredragit?

- Ingen avverkning eller återplantering, skogen lämnas orörd (om tillåtet).
- Nedhuggning av ett urval träd (räddningsavverkning*)* samt återplantering.
- Inget av ovanstående alternativ/annat (*vilken metod?)*

- Jag vet inte.

Varför? *Öppen fråga*

Q12

12.

Hur mycket tid i veckan spenderar du i skogen i snitt?

(angivet i timmar) *Skala 0-40 tim*

Q13

13.

Hur spenderar du din tid i skogen?

1 (gör aldrig) - 5 (gör nästan alltid)

Jakt	*Skala 1-5*
Svamp- eller bärplockning	*Skala 1-5*
Vandring, cykling, skidåkning, snöskoteråkning *(eller annan sport)*	*Skala 1-5*
Fågelskådning	*Skala 1-5*
Skogsbruk	*Skala 1-5*
Annat	*Skala 1-5*

Om *"annat"*, vadå? *Öppen fråga*

Q14

14.

Äger du skog?

- Ja
- Nej

Q15

15.

Vart bor du?

- I Ljusdal kommun
- I Sala kommun
- I andra delar av Sverige
- Utanför Sverige

Om du inte bor i Sala eller Ljusdal, vart bor du? *Öppen fråga*

Q16

16.

Vilken åldersgrupp tillhör du?

- 0-19 år
- 20-29 år
- 30-39 år
- 40-49 år
- 50-59 år
- 60-69 år
- 70-79 år
- 80-89 år
- Vill ej ange

Q17

17.

Vilket kön tillhör du?

- Man
- Kvinna
- Icke-binär
- Vill ej ange

Q18

18.

Har din nuvarande sysselsättning någon koppling till skogsbränder eller skogsbruk?

- Ja
- Nej

Q19

19.

Finns det något annat rörande enkäten, skogsbränder, skogsvård eller liknande som du hade velat dela med dig av?

Öppen fråga

Tack så mycket för din medverkan!

Glöm inte att klicka "skicka nu" för att slutföra enkäten!

Om du är intresserad av att ta del av resultaten från denna studie, kan detta göras genom länken nedan!

https://docs.google.com/document/d/1YCuCVCZomrgcmzvyRfdB47HC77BveDOl_kdg9Pk2ngA/edit?usp=sharing

Länken kommer att uppdateras när studien är färdig.

Appendix B. Facebook groups

The 9 Facebook groups which the survey was distributed in were: Ljusdals anslagstavla, Att göra i Sala med omnejd, Allt om Sala, Svamp-klapp, Skydda skogen - Protect the forest, Småskaligt skogsbruk, Självverksamma skogsägare, Jägarliv, Vandring och Vildmark.

Appendix C. English questionnaire

Wildfire and post-fire forest management

- what are your opinions?

The purpose of this survey is to collect information about your perception of wildfire and management after a fire. By filling in the survey, you support my student thesis undertaken at Lund University and provide valuable knowledge for future work in the field. Thank you!

The survey will only take 5-10 minutes to complete, and is completely anonymous.

Q1

1.

Do you consent for your answers to be stored for research purposes?

- Yes
- No

Q2

2.

Have you ever seen a wildfire and/or the impact of a wildfire?

In reality, not on TV, social media or similar

- Yes
- No

Q3

3.

What do you believe is the main reason that wildfires occur in Sweden?

- Lightning
- Arson (*by humans, malicious intent)*
- Accidental (*by humans, cigarette buds, escaped campfire, forest machinery…*)
- Other
- I don't know

Q4

4.

To what degree do you consider wildfires a problem in Sweden?

1 (not a problem at all) - 5 (a big problem)

- 1
- 2
- 3
- 4
- 5

Q5

5.

To what degree do you consider wildfires a possible problem in Sweden in the future (*20-50 years from now*)?

1 (not a problem at all) - 5 (a big problem)

- 1
- 2
- 3
- 4
- 5

Q6

6.

Did/do you own property that was damaged by...

- 2018 Ljusdal fire
- 2014 Sala fire
- Other fire
- None of the above/haven't been affected

Q7

7.

If a wildfire were to happen close to you, to what degree would you worry about the factors mentioned below?

1 (not worried at all) - 5 (very worried)

My safety and/or the safety of others	*Scale 1-5*
Owned forest	*Scale 1-5*
Private residence	*Scale 1-5*
Environment and/or wildlife	*Scale 1-5*

Q8

8.

To what degree do you think a future wildfire could affect you or your property?

1 (not at all) - 5 (a lot)

- 1
- 2
- 3
- 4
- 5

Q9

9.

Have you seen a forest where any of the following techniques were applied after a wildfire?

	Yes	No	I don't know

Leave trees standing and overall forest untouched	.	.	.
Salvage-logging and seeding or planting of seedlings	.	.	.
Other techniques	.	.	.

If *"other"* what technique? *Open question*

Q10

10.

How well do you feel informed about the following post-fire forest management techniques?

1 (no knowledge) - 5 (a lot of knowledge)

Leave trees standing and overall forest untouched	*Scale 1-5*
Salvage-logging and seeding or planting of seedlings	*Scale 1-5*

Other	*Scale 1-5*

If *"Other"* what technique? *Open question*

Q11

11.

Which of the following post-fire forest management techniques would you prefer the most?

- Leave trees standing and overall forest untouched (if allowed)
- Salvage-logging and seeding or planting of seedlings
- Other *(what type of technique?)*
- I don't know

Why would you prefer that technique? *Open question*

Q12

12.

How much time *a week* do you spend in forests on average?*(hours)*

Scale 0-40

Q13

13.

What do you do during that time?

1 (never) - 5 (most of the time)

Hunting	*Scale 1-5*
Mushroom picking or berry picking	*Scale 1-5*
Walking, biking, skiing, or other sport	*Scale 1-5*

Bird-watching	*Scale 1-5*
Forestry	*Scale 1-5*
Other	*Scale 1-5*

If *"other"* what? *Open question*

Q14

14.

Do you own forest?

- Yes
- No

Q15

15.

Where do you live?

- In Ljusdal commune
- In Sala commune
- In other parts of Sweden
- Outside of Sweden

If not in Sala or Ljusdal, where? *Open question*

Q16

16.

What age-range do you fit in?

- 0-19 years
- 20-29 years
- 30-39 years
- 40-49 years
- 50-59 years

- 60-69 years
- 70-79 years
- 80-89 years
- Prefer not to say

Q17

17.

What is your gender?

- Male
- Female
- Non-binary
- Prefer not to say

Q18

18.

Does your current occupation have any connection to forest fires or forestry?

- Yes
- No

Q19

19.

Is there anything else you would like to share (about the survey, forest fires, forestry or other)?

Open question

Q16

Thank you for participating!

Do not forget to press "send now" to finish the survey!

If you are interested in the outcome of the study, the results can be found through the link below.

https://docs.google.com/document/d/1qein1A95cyjr0m4zZ2IBNnlfkesjib3a4zOGvxYZ6HM/edit?usp=sharing

The link will be updated once the results are ready.