Vilma Ristikangas, Laura Kuurne, Annika Rinne, Sami Kinnunen

FIREBAR - Developing wildfire observation in the Barents region

Project report

The Finnish National Rescue Association
SPEK

The Finnish National Rescue Association SPEK

Ministry of the Interior Finland

Ministry for Foreign Affairs of Finland

FIREBAR - Developing wildfire observation in the Barents region

Executive organisation: The Finnish National Rescue Association SPEK
Guiding organisation: The Finnish Ministry of Interior
Funding: The Finnish Ministry for Foreign Affairs

Authors:
Vilma Ristikangas, Laura Kuurne, Annika Rinne, Sami Kinnunen

Layout: Aleksi Salokannel

Project workers:
Sami Kinnunen, Vilma Ristikangas, Tuula Kekki, Laura Kuurne, Annika Rinne, Taina Hanhikoski

Publisher:
The Finnish National Rescue Association SPEK
Helsinki 2024

ISBN 978-951-797-739-5

Sisällys

Abstract

The report investigates aerial wildfire observation methods within the Barents region, focusing on Finland, Sweden, and Norway. Collectively, these nations have vast expanses of forest land, representing a significant portion of Europe's forested areas. However, climate change presents an immense challenge, with rising temperatures, shifting precipitation patterns, and alterations in vegetation composition increasing the risk of wildfires in Fennoscandia.

In terms of detection methodologies, the longstanding tradition of forest fire surveillance via manned aircraft remains a cornerstone of the approach employed in Finland, Sweden, and Norway. Manned surveillance crews follow a predetermined flight route, scanning the landscape for signs of smoke or fire. The surveillance flights are mostly undertaken by flight club volunteers. Beyond traditional aerial surveillance, other approaches such as sensor technologies, predictive fire risk modelling, and unmanned aviation methods have gained considerable attention. Both research and technological innovation have paved the way for enhanced wildfire understanding and management strategies.

The domain of forest fire surveillance via aircraft operation encompasses a diverse array of stakeholders, ranging from state authorities and fire and rescue services to municipalities, flight clubs, and operators. The administrative organisation of forest fire surveillance is national in Finland, regional in Sweden and local in Norway.

The data consists of interviews, documents and the results of a literature review. The interviewees argued that manned aircraft surveillance works well and they saw it as useful especially in vast areas with sparse population and difficult terrain. The challenges of manned aircraft surveillance related to the societal changes and availability of volunteer personnel to undertake surveillance operations. The authorities were interested in the possibilities that unmanned aviation and satellite technology could bring for wildfire detection and agreed that utilizing several methods simultaneously, a so-called hybrid

system, could ensure operational reliability in various weather conditions in which an aircraft cannot operate. Aviation organisations and flight clubs argued that the weaknesses of the technological alternatives are for example high costs and slow transfer of information.

The interviewees recognized that international cooperation, especially cross-border collaboration between the Nordic countries would be valuable. In particular, the stakeholders wished more active cooperation in exchanging information about best practices and sharing experiences. Several interviewees argued that the Nordic countries have the same problems regarding the wildfires and therefore fires should be tackled together. National, regional and local cooperation were seen as important, but especially cross-border national level cooperation was considered useful.

Tiivistelmä

Raportissa tutkitaan maastopalojen tähystysmenetelmiä Barentsin alueella Suomessa, Ruotsissa ja Norjassa. Näillä mailla on suuri metsäpeitto ja ne muodostavat merkittävän osan Euroopan metsien kokonaispinta-alasta. Ilmastonmuutoksen tuomat haasteet, kuten nousevat lämpötilat ja sademäärien ja kasvillisuuden muutokset, nostavat maastopalojen riskiä Fennoskandiassa.

Maastopalojen tähystysmenetelmistä miehitetyllä lentokoneella tehtävä lentotähystys on pitkäkestoisin käytössä oleva metodi ja edelleen merkittävässä roolissa maastopalojen havainnoinnissa Suomessa, Ruotsissa ja Norjassa. Miehitetyt tähystyslennot, joita lentävät useimmiten lentokerhojen vapaaehtoiset, seuraavat ennalta määrättyä reittiä ja etsivät savu- tai tulihavaintoja maastosta. Tämän vakiintuneen menetelmän lisäksi muut tähystyskeinot, kuten sensoriteknologia, ennakoiva paloriskimallinnus ja miehittämätön ilmailu, ovat kasvaneen kiinnostuksen kohteena. Tutkimus ja teknologiset innovaatiot ovat kehittäneet ymmärrystä maastopaloista ja niiden hallitsemisstrategioista.

Miehitettyyn maastopalojen lentotähystykseen liittyy useita tahoja viranomaisista pelastustoimeen ja kunnista lentokerhoihin ja palveluntarjoajiin. Lentotähystyksen hallinnollinen organisoiminen tapahtuu Suomessa kansallisella tasolla, Ruotsissa alueellisesti ja Norjassa paikallisella tasolla.

Aineisto koostuu haastatteluista, dokumenteista ja kirjallisuuskatsauksen tuotoksista. Haastateltavien mielestä miehitetty lentotähystys toimii hyvin ja se koettiin hyödylliseksi varsinkin isoilla, harvaan asutuilla alueilla, joissa on hankala maasto. Lentotähystyksen haasteet liittyvät yhteiskunnallisiin muutoksiin ja vapaaehtoisten saatavuuteen, jotta tähystystehtävät voidaan suorittaa. Viranomaiset olivat kiinnostuneita miehittämättömän ilmailun ja satelliittiteknologian tarjoamista mahdollisuuksista. He olivat yhtä mieltä siitä, että monien menetelmien hyödyntäminen yhtä aikaa eli niin sanottu hybridijärjestelmä voisi edistää maastopalojen havaitsemisen toimintavarmuutta sellaisissa sääolosuhteissa, joissa lentokoneet eivät voi operoida.

Ilmailuorganisaatiot ja lentokerhot olivat sitä mieltä, että teknologisten vaihtoehtojen heikkouksia ovat esimerkiksi korkeat käyttökustannukset ja hidas tiedonsiirto.

Haastateltavat tunnistivat kansainvälisen, erityisesti rajat ylittävän Pohjoismaisen yhteistyön olevan arvokasta. Lentotähystyksen eri toimijat toivoivat nimenomaan aktiivisempaa yhteistyötä parhaiden käytäntöjen ja toimintatapojen vaihdossa ja kokemuksien jakamisessa. Monet haastateltavat argumentoivat, että Pohjoismailla on samoja ongelmia maastopalojen kanssa ja siksi paloja pitäisi torjua yhdessä. Kansallinen, alueellinen ja paikallinen yhteistoiminta koettiin tärkeäksi, mutta erityisesti rajat ylittävä kansallisen tason yhteistyö koettiin hyödylliseksi.

1. Introduction

The population of the Barents region is about 1.8 million in the Nordic countries (827,000 in Finland, 483,000 in Norway and 523,000 in Sweden) and 3,327,000 million inhabitants in the Russian Barents (Barentsinfo.org (n.d.)). The Barents region is also the home of Sámi people, as their cultural region Sápmi stretches over the Northern parts of Russia, Finland, Sweden and Norway. The population in the Barents region is decreasing, urbanizing and getting older (Ekholm *et al*., 2017, 16–17). The Barents Euro-Arctic Council identifies the region's people as its greatest asset (Finnish Ministry for Foreign Affairs (n.d.)).

The Barents region is located in the Arctic where the consequences of climate change happen at a faster pace than in other parts of the world. Between 1954 and 2012, the annual mean temperature in the Barents region has increased by 1–2 degrees Celsius. Climate change influences temperatures, precipitation, permafrost, storms, snow and ice in the region (Ekholm *et al*., 2017, 41). The Fennoscandian forest fire risk is expected to increase because global warming decreases the topsoil moisture content. This contributes to the spread of fire, which is dependent not only on ignition but also on dry fuel (Lindberg *et al*., 2002, 20–22; Aalto & Venäläinen, 2021, 68, 72).

Both national risk assessments and researchers have argued that forest fires may pose serious threats to infrastructure, environment and the national economy. Due to climate change and warming temperatures, it is unlikely that the number of forest fires will decrease in the future in the Nordic countries, although the risks seem to be lower than in the majority of the Barents region. Dry ground and hot weather create ideal conditions for a fire to ignite, either caused by people or lightning.

All around the world, infrastructures are expected to face more climate change-driven threats, such as forest fires, flooding, storms, and extreme heat, in the future. The Nordic countries' ability to cope with these extreme events is estimated to be high, but even today, its infrastructure is challenged due to a sparsely populated land area, long distances, and challenging climate conditions (Silvast *et al*., 2021, 82–83). The "Mitigating the impacts of climate change on biodiversity in the Barents Region" project, funded by the Finnish Foreign Ministry, has recommended that the North Barents area should be provided with a comprehensive climate and nature strategy for adapting to the changes that the climate change is going to pose to nature and the economy (Finnish Environmental Institute, 2023).

Wildfire observation is a common method to mitigate the effects of forest fires by detecting them as early as possible before fire gets out of control. Wildfire observation can be undertaken by aerial means, such as surveillance from an aircraft and data received from cameras in watchtowers, unmanned aerial vehicles or satellites, or by a notification from citizens. Several states from Nordic Countries to the United States and from Canada to Australia have undertaken wildfire observations for decades. As climate change progresses affecting weather patterns, temperatures and humidity all around the globe, the need for wildfire observation is likely to be crucial for years to come.

The Developing Wildfire Observation in the Barents Region project supports the goals of the Finnish Presidency of the Barents Euro-Arctic Council for 2021–2023 and cooperation of Finland, Sweden and Norway in the Barents Joint Committee on Rescue Cooperation. The Finnish Presidency focused on sustainable development, healthy environment, people-to-people contact and transport and logistics. These themes were identified as a way to tackle the challenges of fast-paced climate change and current societal and economic developments in the Barents region. Detecting and extinguishing forest fires was recognized as one of the key priorities to address the effects of climate change and extreme weather conditions in the Barents region. The Finnish Presidency also underlined the positive effects of the long-lasting Barents rescue cooperation, which contributes not only to the safety and security of the Barents region inhabitants, but also to the cooperation between the people and authorities across different Barents region states.

This project report will introduce the Developing Wildfire Observation in the Barents Region project that has been set up as a part of the Finnish presidency of the Barents Euro-Arctic Council. As a part of the presidency and its targets, the project has attempted to address rescue cooperation, connect the regions' people and authorities, and respond to the consequences of climate change. We will also look at organising wildfire observation in the whole of Finland, Sweden and Norway. Aerial wildfire observation is guided by state authorities across the whole country, although regional characteristics vary.

The Developing Wildfire Observation in the Barents Region project has two aims. First, the project aims to explore the differences and similarities between Swedish, Finnish and Norwegian models of aerial forest fire surveillance. We will analyse wildfire observation methods from operational, administrative, and technological perspectives. In addition, the future and its challenges and possibilities are central research objectives. Second, we are aiming for the development of a network between the stakeholders and operators in aerial forest fire surveillance. This will contribute to further international cooperation on common issues, such as operational matters, and a stronger joint response to promote the interests of wildfire observation.

Most of the wildfire observation in the Barents region is done by aircraft, but there is also a growing interest in looking at alternative options and technologies to take advantage of different systems that can support each other. Also, the question of Nordic cooperation in wildfire observation will be analysed in this report. In surveying wildfire from a manned aircraft, the operational work, motives and goals are the same in all three countries – to limit the spread of wildfires. However, Finland, Norway and Sweden have their own way of organising wildfire observation at the administrative level. In this report, possible future developments regarding technological advancement, international collaboration in wildfire observation will be analysed.

2. Methodology

2.1. Scope of the project

The Barents region covers the Northern parts of Finland, Sweden, Norway and Russia. This study focuses on Finland, Sweden and Norway and their aerial wildfire observation methods. Hence, referring to the Barents region considers Finland, Sweden and Norway. Wildfire observation is synonymously called forest fire detection or forest fire surveillance, and these terms are used interchangeably. More specifically, this research investigates forest fire surveillance by manned aircraft, which from here on will be referred to as forest fire surveillance by aircraft. In this report, forest fires and wildfires are considered as synonymous terms, referring to fires that take place in the nature.

As the project focuses on aerial forest fire surveillance methods, for practical reasons, the scope of the research has been extended to the whole of Finland, Norway and Sweden. During the project, it was concluded that considering forest fire surveillance systems only in the Barents region is not meaningful for a few reasons. First, forest fire detection by aircraft is not operated in the Norwegian Barents region due limited number of forest fires in the treeless tundra area. Second, while forest fire risk is expected to rise in the Nordic countries because of global warming, it is estimated that the forest fire risk is not going to increase in the Barents region (Ekholm *et al*., 2017, 47). Third, the aerial forest fire surveillance systems have national guidelines and monitoring in Sweden by MSB and in Finland by PSAVI, but the system is local or regional in Norway. Therefore, it is difficult to separate wildfire observation from the national context and investigate the activities only in the Barents region.

Russia is not part of the study. The Barents Euro-Arctic Council discontinued cooperation with Russia due to Russia's illegal attack war on Ukraine. However, it has to be recognized that forest fires do not recognize national borders and large-scale fires in the Russian Barents may spread or affect especially Finland and Norway. For example, in 2018 fire spread from Russia to Inari, Finland (Aalto & Venäläinen, 2021, 117). Smoke may also affect all Nordic countries. Therefore, some details from the Russian forests will be added separately if considered relevant.

In the next chapter, the following will be investigated: the Barents region's characteristics , how the national risk analyses of Finland Sweden and Norway discuss forest fires, current forest fire surveillance methods, and the kind of research and development that has been conducted on forest fire prevention and fighting.

2.2. Methodology and data

The primary data of the project has been gathered mainly by conducting expert interviews with different stakeholders that operate in the field of forest fire surveillance. In addition, participation in seminars and conferences that have discussed the rescue services and forest fires have been an important asset (Annex 2). In addition, data on forest fire surveillance in Finland and Sweden has been analysed in brief. Secondary data consists of literature relating to forest and wildfires in the Barents region and forest fire surveillance methods.

During the project, the *Barents Region Aerial Forest Fire Surveillance Workshop* was organised in Oulu. The international workshop on aerial forest fire surveillance was a pioneering event that invited stakeholders and operators of aerial forest fire surveillance from the Barents region. The aim was to discuss the future possibilities and challenges of forest fire surveillance in Sweden, Finland and Norway and invent solutions to current problems. The event aimed to initiate cooperation between different authorities, operators and other organisations of different countries within the field.

To understand the driving factors of the project and rationalize the motivation for exploring wildfire observation in the Barents region, a literature review on wildfire observation, forest fire risk and climate change has been completed in chapter 3. The chapter encompasses the characteristics of the Barents region, Nordic forests, risk analysis, relevant cooperation frameworks, wildfires, and existing wildfire observation methods. In chapter 4, the various wildfire detection methods are analysed.

Administrative and operational organisation of forest fire surveillance by manned aircraft is introduced and analysed in chapter 5. The future outlook of forest fire surveillance is examined in chapter 6. These chapters consist of the data from 12 expert interviews (Annex 3). Eight of these were held by visiting the organisation in person, and four interviews were held on Microsoft Teams. The interviewees represented the main stakeholders in forest fire surveillance in Finland, Sweden and Norway, including the state authorities, organisational level and flight clubs. The interviews were semi-structured and lasted about two hours. The interviewees were provided with the questions beforehand. The interviewees were asked similar questions on three themes, administrative organisation of forest fire surveillance, operative organisation, and the future. The questions were modified to correspond to the profile of the organisation represented.

The interviews were analysed thematically. Each interviewee represented their organisation but also provided information of other organisations that they worked with, and in these cases, the information was cross-checked. Operational organisation has also been complemented with data on the Finnish and Swedish forest fires, surveillance flights and costs. Unfortunately, similar data from the Norwegian state level does not exist. The quantitative data will be used to showcase the differences and similarities between Finland and Sweden in wildfire observation.

Chapter 7 introduces a suggested process for organising international cooperation in wildfire observation. Summary of the project results is provided in chapter 8.

3. Forest fires and wildfire observation in the Barents Region and Nordic Countries

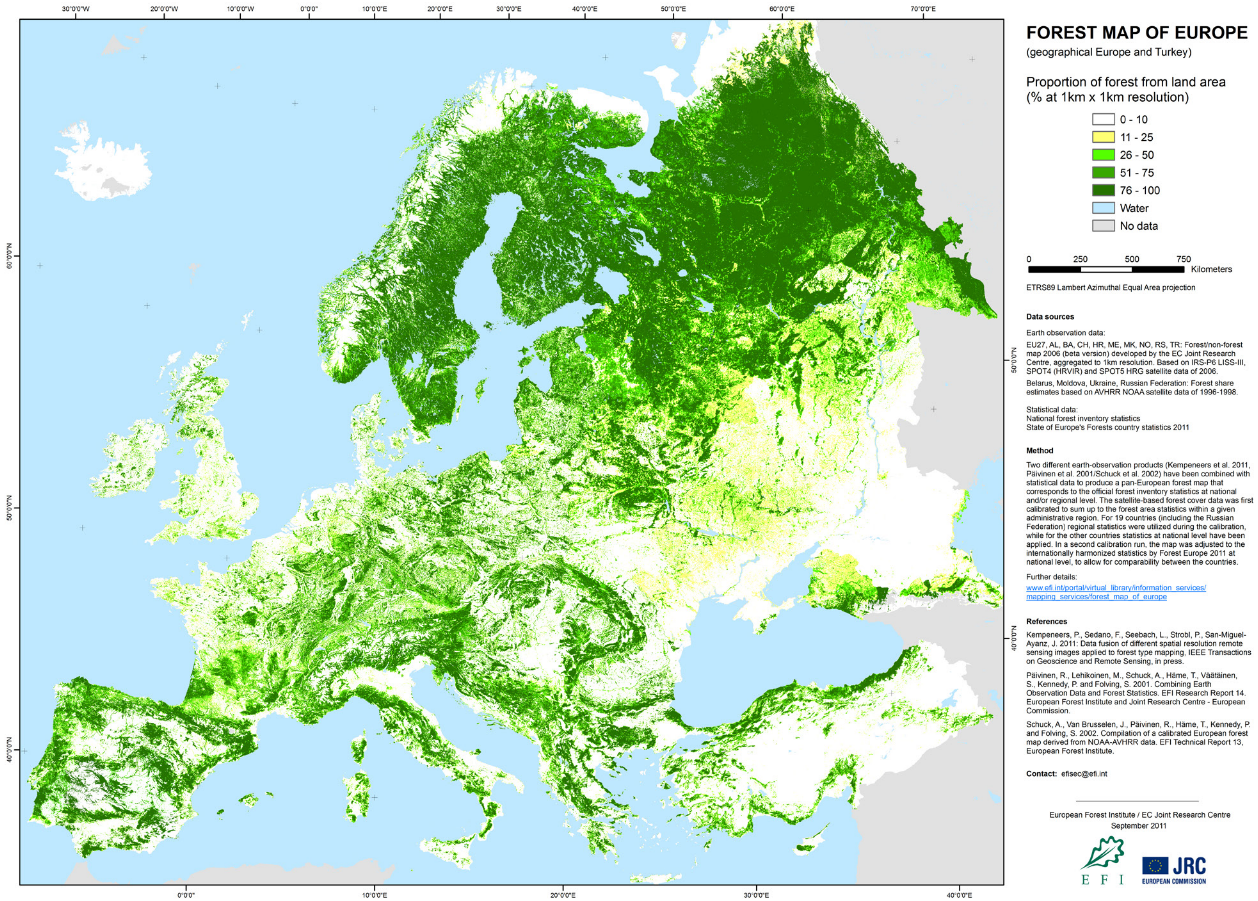
3.1. Barents region: forests and wildfire

Finland, Sweden, and Norway are rich in forests and nature. Their combined forest land area amounts to 23 percent of the forests in Europe. Finland and Norway have about 30 million hectares of forest and in Sweden grows about 41 million hectares of forest. Forestry is an important industry especially in Finland and Sweden, producing for example sawn wood, pulp and paper. Nordic forests are coniferous forests, as pine and spruce trees are the dominating species, adding up to 80 percent of the forest tree species in Finland and Sweden and 70 percent in Norway. The birch tree is the third common species in all countries.

Forest ownership varies. In Norway, 66 percent of the forest is owned by small-scale forest owners, whilst it is 59 percent in Finland and 49 percent in Sweden. In Finland, public ownership is more common than in Sweden and Norway. In Sweden, private businesses own about 25 percent of the forests, whilst it is less than 10 percent in Finland and Norway (Hannerz & Ekström, 2023).

The vegetation in the Barents region consists of Boreal forests and forest tundra (Annex 1). Global warming means that the Barents region environment and ecosystem is going to experience changes in the future, affecting also the region's forests and forestry sector. It is possible that the forest coverage will spread further North to tundra areas which have little to no trees (Ekholm *et al*., 2017, 46–47).

Due to climate change driven environmental change, wildfires are expected to become more frequent in future (Barbero *et al.,* 2015; Hurteau *et al.,* 2014; Westerling *et al.,* 2006). Wildfire is a natural phenomenon in forest



■ Figure 1. Forest map of Europe. Source: Schuck, A., Van Brusselen, J., Päivinen, R., Häme, T., Kennedy, P. and Folving, S., 2002. Compilation of a calibrated European forest map derived from NOAA-AVHRR data. European Forest Institute. EFI Internal Report 13, 44p. plus Annexes.

ecosystems, and it is an important part of terrestrial and atmospheric systems (Jolly *et al*., 2015; Hekkala, 2015; Lindberg *et al*., 2021). The objectives and methods of forest restoration with controlled fire and, on the other hand, protecting forests from fire are widely debated (Brown *et al*., 2004, 904). Unpredictable and uncontrollable fire can cause severe social distributions and affect communities and economy by threatening human lives and infrastructure (Diaz, 2012; Joseph *et al*., 2019). When wildfires are growing in scale and duration, they can also cause forest mortality, alter air and water quality, and damage natural resources in an irreversible manner (Westerling *et al.,* 2016; Földi, 2016; Ribeiro-Kumara *et al*., 2020; Kelly *et al*., 2021).

Given that climate change will alter forest ecosystems in Europe, wildfires are also expected to pose a new threat in higher altitudes and latitudes (Lindner *et al*., 2010). In Fennoscandia, rising temperatures, prolonged dry spells, and changes in precipitation patterns contribute to an increased risk of forest fires. In boreal ecosystems, climate change will promote tree growth through higher temperatures and CO2 fertilization, but it also heightens the risk of forest fires, leading to increased carbon release into the atmosphere (Aalto & Venäläinen, 2021). Warmer temperatures in winter and summer may expose forests, making them more prone to insects and storms (Ekholm *et al*., 2017, 47). The climate influences fire patterns not only through direct impacts on weather conditions but also by shaping the composition of vegetation.

In 2021, Aalto & Venäläinen investigated forest fire risk in the Fennoscandian region, considering climate change and forest cover. They modeled how projected climate change would impact forest fires in Fennoscandia in future. The boreal forests in northern Sweden and Finland are particularly susceptible to forest fires. These regions have a combination of dry conditions, flammable vegetation, and lightning strikes that contribute to fire incidents. In Finland, vegetation zones are shifting northwards, altering the living conditions for plants and animals. In addition to the increased risk of wildfires, the major risks in future include windstorms, heavy snow loading, drought, and insect pests (Venäläinen *et al.,* 2020). The Karelian region in northwestern Russia also faces significant fire risk as the area is prone to ignition during dry and warm periods (Aalto & Venäläinen, 2021). Ekholm *et al*. (2017) argue that wildfire risk is not expected to increase in the Barents region except for the Russian Barents. However, they claim that the Southern parts of Finland, Norway and Sweden are projected to face more wildfires (Ekholm *et al*., 2017, 46–47).

Forest fires are most often caused by human activity, such as negligent use of fire and forest machinery (Aalto & Venäläinen, 2021, 18). Ninety five percent of the wildfires in Europe originate from human activity, and 5 percent are ignited by lightning strikes (Khabarov *et al*., 2016, 22–23). In examining the anticipated shifts in wildfire patterns, it's crucial to take into account Wildland Urban Interfaces (WUIs), where urban expansion meets wildland vegetation. These areas present distinct challenges due to the coexistence of human infrastructure and natural environments. A prevalent concern among many Wildland Urban Interfaces (WUIs) is the buildup of biomass surrounding residences. This surplus vegetation, coupled with human actions, escalates the likelihood of wildfire ignitions (Defossé, 2023). WUIs, or Wildland-Urban Interfaces, have been extensively researched in regions such as America, Australia, and southern Europe. Wildland-urban interface (WUI) fires have increased as a result of climate change in Finland, Sweden and Norway (Gjedrem & Metallinou, 2023, 2). However, there remains a notable gap in research concerning WUIs in Northern European countries.

A Swedish study on droughts and wildfires argues increasing temperature due to climate change predicts higher forest fire risks that drought conditions influence fire frequency (Ou, 2017, 19). While high forest fire index signals a higher risk for ignition, even then a wildfire is a rare phenomenon. In the case of wildfire ignition, a high index indicates a more aggressive spread of fire, resulting in a wider burnt area (Venäläinen *et al*., 2016, 19).

In recent years, extreme wildfires have caused severe destruction in many areas around the world (Aragão *et al*., 2018; van Wagtendonk *et al*., 2020; Kinver, 2021; Horton & Palumbo, 2022). Also, Finland, Sweden and Norway have experienced large fires. In Kalajoki, Finland, a fire spread from a wind farm construction site to the forest nearby, burning 227 hectares of forest and employing about 1,500 fire fighters and other personnel during a two-week period. In 2019, 250 hectares burned in Muhos, Finland (Puustinen *et al*., 2022). In summer 2018, Sweden experienced a record number of forest fires across the country due to record-warm temperatures. The total area burned was 22,700 hectares. In addition, Sweden requested help to put off the fires via European Union's Civil Protection Mechanism (Ahlström, 2019; MSB, 2019a). Wildfires were at a record high also in Norway in 2018. In 2014, two large-scale fires required evacuations and set houses on fire in Norway (DSB, 2019a) and in the same year, Västmanland wildfire in Sweden burned 13,000 hectares and forced a thousand people and two thousand animals to evacuate (Sjökvist & Strömberg, 2015). This indicates that the wildfire regime is shifting towards Fennoscandia (Aalto & Venäläinen, 2021).

3.2. National risk assessment and forest fires

Forest fires have been recognized as a major threat to the infrastructure, climate, economy and internal security in Finland, Sweden and Norway, as highlighted by the forest fire risk scenarios in the national risk analyses (Finnish Ministry of Interior, 2023; MSB, 2019b; DSB, 2019b). National risk assessments systematically identify risks that have an impact on national safety and security. National risk assessment can be understood as a policy tool for civil contingencies planning and informing stakeholders, such as citizens, businesses and politicians, of possible risks (OECD, 2018, 26–28).

Two thirds of Sweden's area is covered by forests. The Risk Assessment produced by MSB (2019b) estimates that the ignition of forest fires is common in Sweden during summertime and long heat periods. The probability of forest fires is difficult to estimate as it is usually caused by human activity. The risk for ignition is therefore higher in densely populated areas. However, the risk for a wide-scale fire is higher in sparsely populated areas, because early detection, extinguishing and resources are limited. Climate change and heat waves are recognized as contributing to a higher risk, but it is difficult to estimate the weather conditions in the future (MSB, 2019b, 40–42).

DSB's Risk Assessment (2019b) expects that, while most of wildfires are small, under certain conditions a fire's scale can magnify. Forest fires are recognized to be ignited most often by humans. The wildfire season lasts from April until September, spring and early summer being most prone to an ignition of wildfires. While the number of forest fires has decreased between the 1970s and 2000s, they are estimated to double by 2100. Early extinguishing is the most important method for fighting wildfires. Preparedness and response are the responsibility of the local fire and rescue departments, Norwegian Meteorological Institute, forest fire detection by satellite and aircraft (DSB, 2019b, 81–83).

The Finnish National Risk Assessment (2023) estimates that long-lasting high temperatures and drought, wind and low precipitation increase the risks of a forest fire in Finland. These conditions are intensified as a result of climate change and the forest fire risk is expected to increase in the future. The risk assessment argues that several simultaneous forest fires close to human settlement may cause challenging conditions and taking control of the situation may last weeks and cause recurring risks to critical infrastructure. Smoke and combustion gases emitted from wildfires are considered to be the most dangerous element for the citizens. While human activity is the most common cause of ignition, it is argued that wildfires ignited by lighting cause the largest fires, as they may be ignited in a difficult terrain and far from roads (Finnish Ministry of Interior, 2023, 88–91).

3.3. International cooperation within forest fire extinguishing and data exchange

While states have primary responsibility for their national disaster risk management, regional and international assistance can complement national response capacities in case of disaster when they are overwhelmed or in need of support. Pooling resources, efficient mutual assistance, knowhow, and use of specialized equipment are essential to build stronger regional civil protection services and networks.

Several countries in Europe have bilateral agreements for cooperation in the field of forest fires.For example: Spain and Portugal, Spain and France, France and Italy, as well as Italy and Germany have this sort of regional cooperation. Reaching out to a neighbouring country is a low-threshold means of asking for help.

In situations where a forest fire has gotten too bad, it is possible to alert the Emergency Response Coordination Centre (ERCC) (working as the alarm centre for the European Union rescue service mechanism) and receive help via the RescEU. The RescEU has its own equipment capacity. This provides assurance that there is available extinguishing capacity, fire fighting aircraft, and other equipment also in situations where there are simultaneous forest fires in different areas of Europe. Hot and dry summers increase the likelihood of this.

Within the RescEU, individual countries can form their own module and apply for a certification from the ERCC. After the certification has been granted, the country's module is shown on the list of help providers. Whenever there is a forest fire, flood or other disaster requiring help from other countries, the country in need can choose which module it chooses from the certified help providers which have answered yes to the call. When a country's module has been certified, it needs to commit to alert readiness for 5–7 years. For example, the Finnish forest fire module GFFF-V has been deployed in Portugal and Greece.

In the Nordic countries, there is an agreement for cooperation called the Nordred. Nordred is a Nordic rescue service cooperation between Denmark, Finland, Iceland, Norway, and Sweden. The framework agreement enables cooperation between responsible authorities in the Nordic countries aiming to facilitate mutual assistance and to accelerate the deployment of responders and equipment, not only in relation to forest fires but also to other peacetime accidents. For example, when there is a cross-border forest fire in the northern parts of Finland and Sweden, the NordRed agreement makes it easy to receive and offer help between the countries. In the so-called 'Haga' declaration from responsible Ministers, there is a Nordic agreement on developing the cooperation (MSB, 2019c).

Similar arrangements to NordRed can be found in the Mediterranean area too. The Union for the Mediterranean (UfM) is an intergovernmental organization bringing together 43 countries to promote dialogue and cooperation in the Mediterranean region, within the framework of civil protection and the cooperation of rescue services within the area. Along with the 27 EU member states, 16 Mediterranean countries are members of the UfM: Albania, Algeria, Bosnia and Herzegovina, Egypt, Israel, Jordan, Lebanon, Mauritania, Monaco, Montenegro, Morocco, North Macedonia, Palestine, Syria (currently suspended), Tunisia and Turkey. Libya has an observer status. UfM aims to define cross-border operational protocols for preventing and fighting fires between the member countries.

MeteoAlarm is an Early Warning Dissemination System that has been developed for EUMETNET, the European Network of National Meteorological Services. MeteoAlarm visualizes, aggregates, and provides accessible awareness information from 38 European National Meteorological and Hydrological Services. It is designed to consistently visualize awareness information from the MeteoAlarm Members, following an easily understandable colour code of yellow, orange, and red, to ensure coherent interpretation throughout Europe.

Finland and the Netherlands have recently been leading an EU-funded project for the development of MeteoAlarm. The project has been developing MeteoAlarm towards a more comprehensive multi-hazard system with the following new features: extension of the forecast period to five days (from two currently), further development of Flood and Rain Warnings, and warnings for coastal sea areas and avalanches.

GDACS is an alert coordination system between the United Nations, the European Commission and disaster managers worldwide to improve alerts, information exchange and coordination after sudden and major disasters.

EFFIS (European Forest Fire Information System) supports the services in charge of the protection of forests against fires in the EU and neighbouring countries. It also provides the EU Commission and Parliament with updated information on wildfires in Europe. EFFIS is supported by a network of experts, which is called the Expert Group on Forest Fires. EFFIS is a part of the Emergency Management Services in the EU Copernicus program.

There are many diverse forums and networks within the forest fire theme. The International Wildfire Conference gathers experts in the area from around the world. EARSeL Forest Fire Special Interest Group Workshop gathers on a yearly basis. At the United Nations level, there are International Wildland Fire Conferences. At the European level, within the CTIF framework, there is a separate Forest Fires Commission. In the Nordic level, there is a Nordic network for forest and vegetations fires. The International Association of Wildland Fire is an association for wildfire professionals on a global level.

4. Wildfire surveillance methods

The Finnish rescue services personnel emphasises that since human activity is the main cause of forest fires, education and public safety communication are necessary to prevent forest fires (Aalto & Venäläinen, 2021, 120). However, people's mistakes and uncontrollable lightning-ignited fires make it necessary to recognize, that not all fires can be prevented. Early detection of wildfires is vital to limit the fire from spreading and getting out of hand (Aalto & Venäläinen, 2021, 121; Alkhatib, 2014, 1; Kosenius *et al*., 2014, 38).

While people are the major reason for the ignition of most wildfires, citizens are also one of the main observers of wildfires. Meteorological institutes in Finland, Sweden and Norway inform the citizens of the national wildfire warning. In Finland and Sweden, the warning forbids everyone from starting an open fire outdoors. In Norway, it is forbidden to start an open fire in the wilderness from mid-April until mid-August in any form.

Various forest fire detection methods have been implemented in the recent decades. Alkhatib (2014) discusses different means to detect a wildfire, including fire weather forecasts, watch towers, lightning detectors, satellite surveillance by optical smoke detection and infrared sensoring, aerial surveillance patrols and people's observation. Also unmanned aviation vehicles (UAV, also knowns as drones) have received a lot of attention in developing the surveillance methods (see Al-Kaff *et al*., 2020; Georgiev *et al*., 2020; Gabbert, 2019, 2022).

In this chapter, certain forest fire detection and prediction methods will be discussed and analysed. First, forest fire surveillance by manned aircraft, widely used in Finland, Sweden and Norway, will be discussed. After that, human observation will be introduced in short. Next, analytical methods and machine learning in forest fire research will be investigated and finally, several remote sensing technologies will be analysed as an alternative approach to manned aircraft surveillance.

4.1. Forest fire surveillance by manned aircraft

The main objective of forest fire surveillance by manned aircraft is to detect smoke or fire as early as possible and prevent the fire from getting out of control (Kurvinen, 2023; Ruuska, 2020; Foster, 1962). The first forest fire surveillance flights date to 1920s Canada. One of the first main descriptions of aerial forest fire detection from Ontario, Canada, explains that since the early days of aerial detection, the aircraft has been used for "detection, transportation, scouting and direct attacks" (Foster, 1962, 38, 40). Foster (1962, 41) argues that communicating with ground forces is important and aircraft have been an important asset in localising distant fires, guiding the rescue department to the fire, gathering information about the fire and the surrounding area, and taking photographs of the scene.

Aircraft surveillance is used in several countries, such as Finland, Sweden, Norway, the US, Canada and Australia. The surveillance operations by aircraft have remained more or less the same since the early 20th century. A crew consisting of at least a pilot and an observer patrol a predetermined route in a certain area with a small aircraft. The pilot manages aerial operations while the observer searches for smoke and takes care of communication. The crew cooperates with the rescue services if a wildfire is found by providing coordinates of the wildfire, water sources, the road network and other relevant information of the surrounding area. Communication and camera technology have improved and the crew is able to send either live video or photos of the scene in real time to the rescue services. Allison *et al*. (2016) argue that human observers in an aircraft have the advantage of adjusting the aircraft's angle and altitude to observe the area as efficiently as possible. However, human vision is limited on the light spectrum that may reveal heat sources (Allison *et al*., 2016, 8).

Aircraft surveillance is seen as a cost-effective (Soisalo, 2021, 69) and efficient method to reduce the risk of a major fire (Sjökvist & Strömberg, 2015, 271–272). Several studies emphasise utilizing several fire observation systems side by side, as aircraft patrolling can be complemented by towers (Foster, 1962, 41), analytical models to organise surveillance routes (McFayden *et al*., 2020, 39), satellites and the wildfire index (Soisalo, 2021, 71–72), and new technology for early detection to maintain the operating reliability and versatile data to enhance detection methods (Ruuska, 2020, 58).

4.2. Forest fire prediction and detection – analytical methods (risk analysis and machine learning in forest fire research)

Research related to forest fire risk analysis and risk prediction has become increasingly popular in last 20 years. The amount of peer-reviewed research on the topic has increased exponentially in recent years (Li *et al.,* 2023). The integration of technologies, such as remote sensing, satellite imagery, and computational models, has played a pivotal role in advancing our understanding of wildfires (Chuvieco *et al.,* 2020). Forest fire research is extensively conducted, not only because of the significant environmental and material damages caused by wildfires, but also because it intersects with numerous scientific disciplines. Meteorologists, ecologists, geographers, soil scientists, hydrologists, atmospheric scientists, biologists, social scientists, and computer scientists collectively contribute to a holistic understanding of wildfires. This collaborative approach not only enhances comprehension but also drives innovation, making wildfire research an appealing and vital field for addressing the intricate challenges posed by these events.

The spatiotemporal shifting in wildfire regimes has been studied to some extent, particularly in areas that are used to seasonal wildfires. For example, Duane *et al*. used predictive modelling techniques to study how fire spread patterns will change in Catalonia as a result of climate change (Duane *et al*., 2015). In Australia, Salehi *et al.* used unsupervised machine learning algorithms to predict spatiotemporal occurrences of wildfire (Salehi *et al.,* 2016). They created a Context-Based Fire Risk (CBFR) model to help the emergency services better prepare for these events. Also, Fernandes *et al*. modelled the fire activity in western Amazon by using sea surface temperature forecasts and they have also published an interactive map that displays the predicted wildfires (Fernandes *et al*., 2011; Staiger, 2020).

As machine learning (ML) becomes increasingly prominent in risk analytics, it is also widely applied in wildfire research, particularly in developing models for predicting and detecting forest fires. For example, Alkhatib *et al.* (2023) conducted a review of ML algorithms in forest fires science, aiming to explore the utilization of various artificial intelligence techniques for predicting and detecting forest fires, assessing the risk of fire-induced damage, and identifying research gaps and recent studies in the field (Alkhatib *et al*., 2023). Their research highlights that the progress in remote sensing technology, numerical weather prediction, and ML has notably improved the observation and monitoring of forest fires. Nevertheless, challenges arise from limited data availability during forest fires, the substantial computational power required for ML systems, and the complexity in assessing the real-world accuracy of predictions, underscoring the importance of expertise in forest fire research for developing realistic models.

A good example of a country that has explored more advanced analytical methods in forest fire management is South Korea. For example, they have used high resolution geostationary satellite systems and machine learning models to detect and monitor forest fires (Yang *et al*., 2019). The proposed algorithm outperforms more traditional methods in detecting forest fires, especially small-scale incidents. Over half of the detected forest fires are identified within 10 minutes, indicating the potential for real-time monitoring and management with advanced geostationary satellite sensor data. Furthermore, Bahari *et al.* developed effective wildfire susceptibility maps using deep learning algorithms and two distinct remote sensing datasets (Bahari *et al*., 2023). The model evaluation results showed significantly high modelling accuracy. The study identified temperature, wind speed, slope, and the topographic wetness index as significant factors influencing wildfires.

It is noteworthy that AI and remote sensing have been widely used and researched for forest fire surveillance worldwide. However, there is relatively little research on this topic in the Nordic countries.

4.3. Forest fire prediction and detection with remote sensing technologies – alternative approaches to traditional air surveillance

Remote sensing technologies have become integral in forest fire surveillance, providing valuable tools for early detection, monitoring, and assessment (Chuvieco *et al*., 2020). These technologies, including satellite-based systems, unmanned aerial vehicles (UAVs), and ground-based sensors, enable comprehensive data collection over large and often inaccessible forested areas. Satellite imagery, equipped with various sensors, allows for the identification of fire hotspots, smoke plumes, and changes in vegetation patterns (Li *et al*., 2019). UAVs equipped with advanced sensors provide high-resolution aerial views, contributing to detailed mapping and real-time monitoring. Ground-based sensors, such as weather stations and infrared cameras, enhance the spatial coverage and accuracy of fire surveillance. The synergy of these remote sensing technologies offers a multi-faceted approach, enabling timely response, effective resource allocation, and a better understanding of fire behaviour, ultimately aiding in the management and mitigation of forest fires (Chuvieco *et al*., 2020).

4.3.1. Satellite imagery

Satellite imagery plays a pivotal role in forest fire surveillance, offering a wide-reaching and comprehensive perspective on wildfire activity (San-Miguel-Ayanz *et al*., 2013). Satellites equipped with various sensors, including optical and infrared, can capture imagery even in remote or inaccessible areas. This enables the detection of fire hotspots, smoke plumes, and the extent of affected regions. Continuous monitoring from space provides crucial real-time data for early fire detection, rapid response, and ongoing assessment of fire dynamics. Additionally, satellite imagery assists in mapping the progression of wildfires, assessing burned areas, and evaluating the impact on ecosystems. The global coverage and frequent revisits of satellite systems make them indispensable tools in modern forest fire surveillance, facilitating timely and informed decision-making for fire management and containment efforts.

Satellite imagery has been used to detect forest fires in many parts of the world. For example, the European Forest Fire Information System (EFFIS) uses satellite imagery to monitor wildfires in Europe. The system provides real-time data on the location, extent, and severity of fires, which is used to inform firefighting efforts and evacuation procedures (San-Miguel-Ayanz *et al*., 2013). In the United States, the National Interagency Fire Center (NIFC) uses satellite imagery to detect and monitor wildfires across the country (Chuvieco *et al*., 2020). The NIFC's Geospatial Multi-Agency Coordination (GeoMAC) system provides up-to-date information on the location and size of fires, as well as the status of firefighting efforts. These examples demonstrate the effectiveness of satellite imagery in detecting and monitoring forest fires and highlight the importance of using advanced technologies to prevent and mitigate the impact of wildfires.

While satellite imagery remains an indispensable tool in forest fire surveillance, it is not without its limitations. Cloud cover can impede visibility, limiting the effectiveness of optical sensors, and atmospheric conditions may affect the accuracy of certain measurements. However, advancements in satellite technology, particularly the development of synthetic aperture radar (SAR) and the use of multi-sensor platforms, have addressed some of these limitations (Carta *et al.,* 2023). In recent years, the spatial resolution and frequency of satellite observations have significantly improved, allowing for more detailed and frequent monitoring. Satellite imagery is predominantly used in regions prone to wildfires, such as the western United States (Berman *et al.,* 2023), Australia (Thangavel *et al*., 2023), Canada (Chuvieco *et al*., 2020), and parts of Southern Europe (Sifakis *et al.,* 2011). Its global coverage makes it particularly valuable in monitoring vast and remote forested areas.

4.3.2. Unmanned aviation

Unmanned aviation vehicles (UAV) have provided an alternative way to conduct forest fire surveillance. Equipped with advanced sensors, UAVs provide real-time data on fire location, size, and intensity, aiding early detection and rapid assessment. For example, a study conducted in Spain presents a fire monitoring system based on perception algorithms implemented on a UAV (Al-Kaff *et al.,* 2020). Equipped with RGB and thermal cameras, temperature sensors, and communication modules, the UAV conducts autonomous surveillance tasks for real-time monitoring of specific areas to detect and respond to forest fires, demonstrating its efficiency and robustness through multiple flights in various weather conditions. UAVs are also employed for controlled burns and mapping affected areas, enhancing the efficiency of forest fire prevention and response efforts. Controlled burning can help to limit the spread of fire towards infrastructure or settlement, as the fuel has combusted ahead of the fire front.

A good example of the use of UAVs in early forest fire detection is a Bulgarian study that has developed a method that employs real time video from

UAVs and autonomous image recognition based on a convolutional neural network (Georgiev *et al*., 2020). This enables automatic fire detection without human intervention. The UAVs are equipped with a thermal camera. The data is shown on a web-based platform in real-time and relevant stakeholders are notified if needed.

While UAVs have proven highly beneficial in forest fire surveillance, they do have some weaknesses. UAV's are widely restricted from conventional air spaces due to flight safety reasons. According to EASA's Standardized European Rules of Air, it is possible to fly UAVs in U-space (unmanned-space) but operational use is still on an experimental level (EASA, 2023, Section 6).

Another significant limitation is their dependence on favourable weather conditions for safe and effective operation. High winds, heavy rain, or dense smoke can hinder drone flights and compromise data collection. In Al-Kaff's study (2020), the challenges posed by weather were addressed by outfitting the UAVs with optical and thermal sensors, communication modules, processing units, and implementing perception algorithms.

In addition to weather challenges, the limited payload capacity of drones may restrict the types of sensors they can carry, impacting the comprehensiveness of surveillance capabilities. Also, regulatory constraints and privacy concerns may pose challenges to widespread and unrestricted drone deployment in certain regions. Battery life is another constraint, limiting the duration of flight and coverage area. However, an Australian company has developed a long-endurance drone that can fly over a wildfire area for 24 hours at a time and provide real time data of the wildfire and the location of the fire fighters (Gabbert, 2019, 2022).

4.3.3. Watchtowers

Watchtowers, also known as fire towers, are a traditional early warning system for wildfire detection. While some regions continue to operate manned watchtowers with trained personnel stationed onsite, modern iterations often incorporate advanced technology, such as surveillance cameras.

Unmanned forest fire watchtowers represent a modernized approach to wildfire detection, employing advanced sensors, cameras, and satellite communication systems for real-time monitoring. These automated towers eliminate the need for a human presence, enhancing safety and reducing operational costs in the areas where they can be effectively installed. If the towers are equipped with artificial intelligence algorithms, they can continuously analyze data to swiftly identify potential fire incidents, contributing to more efficient and technology-driven wildfire prevention and response strategies. For example, In Brazil, scientists have deployed an AI system that processes images from tower-mounted 360-degree cameras, alerting local officials about any apparent fires. In three years, the system has helped to reduce the number of fires by 30% (Barxton, 2021).

4.3.4. Other remote sensing detection methods

In addition to the previously described methods, there are several other ways to conduct forest fire surveillance.

- Ground-based surveillance that utilizes strategically positioned sensors, cameras, and weather stations in fire-prone areas, including automated weather stations and infrared cameras.
- Balloon observations, whether tethered or unmanned, equipped with sensors or cameras.
- Implementing networks of ground-based sensors distributed across forests detects changes in temperature, humidity, or smoke density, indicating potential fires.
- Aerial reconnaissance involves traditional piloted aircraft with specialized sensors for monitoring wildfires.
- Crowdsourced data, gathered from citizen scientists, social media, and public reports, provides real-time information on fire locations and conditions.
- Weather balloons with attached sensors are deployed to collect atmospheric data, aiding in understanding fire behaviour.

4.4. Air surveillance and machine learning

Artificial intelligence can assist in analyzing large volumes of data, such as images and videos, providing faster and more accurate interpretations than traditional human analysis. This can enhance the efficiency of aerial surveillance operations, particularly in large areas or situations requiring rapid decision-making. While satellite imagery provides a broad overview, it may not fully replace air surveillance by plane or UAVs in areas where satellites do not provide real time information. Aircraft equipped with cameras could also offer higher spatial resolution images than satellites, which is crucial for detailed mapping and assessing specific fire behaviours. According to the latest research, technological advancements in fire monitoring are emphasizing the use of drones in conjunction with artificial intelligence (Georgiev *et al*., 2020; Al-Kaff *et al*., 2020; Gabbert, 2019, 2022). In areas where manned flights are still ongoing, similar technology in terms of camera and image analysis, as used in modern drones, should be considered.

5. Administrative and operational organisation of aerial forest fire surveillance in Sweden, Finland and Norway

5.1. Overview of forest fire surveillance by aircraft in Norway, Finland and Sweden

Forest fire surveillance by aircraft includes different stakeholders such as state authorities, fire and rescue services, municipalities, flight clubs, organisations, operators and subcontractors. The stakeholders organise administrative and operational tasks, such as guidance, operational work, planning, purchasing services, designing the services, and analysing data.

Administrative organisation of aerial forest fire surveillance is related to the legislative and regulative framework regarding the surveillance operations, as well as evaluating the role and responsibility of different stakeholders. Operative organisation describes the practical arrangements such as training, routing, communications and of course, flying.

In forest fire surveillance by airplane, both national and international regulations are relevant. In Sweden, Finland and Norway forest fire surveillance flights are treated as state aviation. In addition, aviation operators in Sweden, Finland and Norway follow the EU regulation 2018/1139 on civil aviation, which aims to establish and maintain a high uniform level of civil aviation safety in Europe. However, the regulation does not apply to forest fire fighting and detection aircraft, because there is an exemption in the regulation for an aircraft that is carrying out, among other things, search and rescue and firefighting activities that serve the public interest and are ordered by the public authority (European Parliament and European Council, 2018/1139).

The legislative basis of forest fire surveillance and the approach on organising the service from administrative to the operational level varies in each

Nordic country. In Finland, detection services are organised at state level, in Sweden regionally, and in Norway the regional and local authorities are responsible for organisation. Organising forest fire surveillance is not necessary for the whole country. In Sweden, Länstyrelsen decides if surveillance is needed in the region. In Finland, the law requires organised surveillance in sparsely populated areas. In Norway, the counties and municipalities can decide if they wish to organise surveillance. Organising surveillance by aircraft is not necessary, either. However, in all countries, it has become one of the main methods of detecting forest fires. In addition to aircraft surveillance, citizens and satellites detect and report fires to the emergency centres or to the fire and rescue departments.

Despite the various administrative structures, the operative work that the service providers execute is almost identical. Whether a service provider, be that a flight club or a commercial actor, takes off at a local airfield in Norway, Finland or Sweden, they all fly a predetermined route in search of a smoke. If smoke or fire is detected, they depart from the route to observe it and alert the national or local emergency centre. The observer maps coordinates, the water sources, road and critical infrastructure by the fire while the pilot takes care of operational flight safety including flying. Once the rescue unit is alarmed, the crew follows the orders of the rescue department chief. Nevertheless, the amount of forest fire surveillance flights, costs, and total amount of wildfires in each country vary each year (see Annex 4 on the Finnish and Swedish forest fire surveillance data (comparable Norwegian data was not accessible.))

In this chapter, the administrative and operational features of wildfire detection by aircraft will be introduced comprehensively. The Swedish, Finnish and Norwegian organisation systems will be investigated in sub-chapters in the respective order. They will be analysed by looking into the responsibilities and tasks of the stakeholders in the chain of events that finally realises the physical forest fire detection service. The sub-chapters starting with a short, general overview of the organisation in the country and then move from the higher administrative level towards the service providers' operational work.

5.2. Sweden

5.2.1. Forest fire surveillance by aircraft in Sweden

Forest fire surveillance has been organised for a long time in Sweden. Up to the 1950s, forest fire towers were the main method of surveillance. Surveillance by aircraft consolidated its role in the 1960s and in the more recent years, satellite surveillance has emerged alongside aircraft as an important asset in finding wildfires. In the early 2000s, national financing of surveillance by aircraft was discontinued for a few years, although some regions finance flights on their own. The flight operations were started over on a national scale in 2008. Forest fire surveillance is organised mainly by small aircraft that follow a predetermined route to search for smoke or fire.

In Sweden, both the municipality and the individual are required to take measures to prevent fires in Lag om skydd mot olyckor (Civil Protection Act, 2003:778). There is no specific law or regulation that would oblige the authorities, such as Swedish Civil Contingencies Agency (Myndighet för Samhällsskydd och Beredskap, MSB) or County Administrative Board (Länstyrelsen) to organise forest fire surveillance. Nevertheless, surveillance is recognized as a necessary service and the government grants a budget to the stakeholders to organise it.

In a nutshell, MSB is the state authority that coordinates and provides guidance over forest fire surveillance in Sweden. Länstyrelsen is the administrative authority that orders and designs the operation in the County by organising a public procurement competition to determine the service providers. In most cases, Kungliga Svenska Aeroklubben (KSAK) is the service provider that signs the agreements with Länstyrelsen and manages flight safety and subcontracts its member flight clubs to do the operative work on the flight routes. The flight clubs train their pilots and staff for the operations. In some cases, commercial aviation enterprises fly the routes, too. The Swedish Transport Agency (Transportstyrelsen) is the aviation authority giving the service providers and subcontractors permits to fly forest fire surveillance flights.

5.2.2. MSB – guidance and national coordination

The responsible state authority for forest fire surveillance flight operations is the MSB. It is an administrative authority under the Ministry of Defence and cooperates with, for example, municipalities, public and private sector and organisations. MSB takes care of emergency preparedness and operational measures to risk and emergency scenarios such as fires, road traffic accidents and infrastructural failures, is responsible for issues concerning civil protection, public safety, emergency management and civil defence. It provides guidance and regulations to rescue services operators and develops and supports their functions.

MSB is the authority in charge of coordinating forest fire surveillance in Sweden. MSB's role includes financing, data management, guidance, and coordination of forest fire surveillance. MSB holds the budget for forest fire surveillance, granted by the Swedish government. MSB communicates with other main stakeholders such as the County Administrative Boards, operators such as KSAK and Frivilliga Flygkåren (FFK), and subcontracted flight clubs. MSB cooperates also with the Swedish, Finnish and Norwegian Meteorological Institutes.

Each year MSB produces guidelines for forest fire surveillance by aircraft. The guidelines are targeted at Länstyrelsen to organise surveillance flights for the upcoming forest fire season (MSB 2023). The forest fire season in Sweden lasts from April in the South of Sweden and from May in the North of Sweden until September.

The costs of surveillance flights have increased in the last six years. Before 2018, each year cost less than 10 million Swedish Crowns, but since then, the costs have increased by several million. The large-scale forest fires in Sweden in 2018 increased the costs to 30 million Swedish Crowns (Hertzberg & Lundqvist, 2022, 7), and in the 2023 season the costs were 18.5 million Crowns (MSB, 2024).

5.2.3. Länstyrelsen – administrative level of forest fire surveillance

The County Administrative Board, in Swedish 'Länstyrelsen', is a higher regional administrative body in Sweden, and it decides whether forest fire surveillance will be organised in the county during the forest fire season. The differences between regions and counties mean that needs are also different. If forest fire surveillance is organised, the Länstyrelsen is responsible for the administrative tasks and delivering the services following MSB's guidelines. Länstyrelsen oversees operational planning, such as designing the flight routes and deciding on the flight frequency according to local risk assessment and MSB's forest fire risk prediction system (MSB, 2023, 4, 6).

Regions are encouraged to cooperate to organise forests fire surveillance, but the practice differs across Sweden. For example, the seven southernmost regions cooperate to organise the services, whilst the northernmost regions Norrbotten and Västerbotten organise surveillance independently.

Länstyrelsen acquires the services following the law on public purchases, which also means that public procurement is open to all EU states according to EU's public purchases directive (Lag om offentlig upphandling, 2016:1145; The European Parliament and The Council of the European Union, 2014/24/EU). Länstyrelsen may bid for service providers or their subcontractors, such as where there are , several flight clubs that want to survey the route for the season. The contract for the group can be signed for one or several subcontractors at a time- for example, if the flight clubs agree to take turns on a weekly basis. The public procurement procedure takes place at the beginning of the calendar year before the forest fire surveillance season.

Once Länstyrelsen acquires the services via public procurement competition it makes an agreement with the service provider on the route for the forest fire season. Länstyrelsen inspects the service providers' competence to undertake surveillance flights before signing the contract (MSB, 2023, 4). In many instances, Länstyrelsen selects the service provider to be either KSAK or FFK and in some cases a commercial aviation enterprise. KSAK and FFK are general civil aviation organisations that produce forest fire surveillance flights by subcontracting their member flight clubs to do the operational work and fly the surveillance routes.

Even though the forest fire surveillance contract is between KSAK and Länstyrelsen, KSAK is not paid any compensation. During the forest fire surveillance season, Länstyrelsen pays only the operative parties which are the commercial aviation enterprises or flight clubs. The compensation is based on flight time, butin addition, compensation to maintain the aircraft and cover the costs of maintenance may be up to 6,400 Swedish Crowns per flight club. (MSB, 2023, 9–10).

In Västerbottens Län, Länstyrelsen's starts the preparations for the surveillance early in the spring in February. Länstyrelsen sends their operational surveillance plan for MSB and reviews the equipment, resources, and organisation of the operators. Before, during and after the forest fire season, all operators working in surveillance have a joint meeting. Forest fire surveillance by aircraft starts only in mid-May and ends in mid-September. During the season, Länstyrelsen keeps in contact with the flight clubs. The surveillance season ends in November and Länstyrelsen conducts feedback interviews with the operators and subcontractors. Länstyrelsen invoices and reports the costs of the season to MSB within the deadline provided in MSB's guidelines.

The start of the season is unnegotiable, but the season may end sooner if there is no forest fire risk anymore in the fall. For example, in 2023 season, subcontractor Umeå Flygklubb did not fly surveillance flight after July because there was no forest fire risk in the region.

5.2.4. Contractor's tasks between the flight club and Länstyrelsen

In forest fire surveillance, KSAK is the primary service provider in Sweden. KSAK is an administrative organisation that works between the flight clubs and Länstyrelsen. KSAK's role is to work as a contractor, whose member flight clubs act as subcontractors. In this way, KSAK arranges the flight clubs to provide forest fire detection services to Länstyrelsen. FFK has a similar position as KSAK as their member clubs also take part in forest fire surveillance, but the scale is smaller, since FFK's focus is on search and rescue, home guard aviation and maritime surveillance (Frivilliga Flygkåren (n.d.)). Therefore, in this chapter, contractors will be analysed by investigating KSAK's functioning.

KSAK is a national organisation that works in the field of general aviation and organises forest fire surveillance flights. KSAK has operated in forest fire surveillance for more than 50 years and its member flight clubs fly from 3,500 up to 7,500 hours of forest fire surveillance flights yearly. KSAK has 120 member flight clubs and about 4500 members. The member flight clubs work as subcontractors for KSAK, while KSAK is the party making the contract for wildfire surveillance services with Länstyrelsen. KSAK has a call each winter for aspiring flight clubs that want to fly forest fire surveillance flights.

In addition to forest fire surveillance, KSAK is a general civil aviation advocate and has other functions in the field, such as flight training. KSAK's main tasks are monitoring flight safety and making contracts on forest fire surveillance flights. They also offer services for their member flight clubs and organise pilot training and competition flights. KSAK has developed an administrative system, Brandflygportalen. It is a web-based platform used by flight clubs and authorities to handle administrative tasks, such as reporting and data storage, and operational tasks, such as ordering a surveillance flight (KSAK (n.d.)).

KSAK cooperates closely with the Swedish Transport Agency (Transportsyrelsen), which is the institution that gives KSAK the operating license to operate in forest fire surveillance by aircraft. KSAK's member flight clubs operate under this license as subcontractors in forest fire surveillance. Transporstyrelsen requires that KSAK is a contracting party in the contract between Länstyrelsen and the subcontractor (flight club). Transportstyrelsen also audits the work of KSAK. Transportstyrelsen and KSAK cooperate to maintain and coordinate documentation of surveillance flights, infrastructure and airspace management.

KSAK and Transportstyrelsen have established an agreement regarding flight safety conditions so that KSAK's permit for a flight club to operate in forest surveillance flights meets Transportstyrelsen's flight safety conditions. Hence, Transportstyrelsen monitors KSAK and KSAK monitors its member flight clubs. Transportstyrelsen expects flight clubs to follow European Commission Regulation 965/2021 on technical requirements and administrative procedures related to air operations and satisfy KSAK's Drifthandbok requirements. Drifthandbok is KSAK's guidebook to forest fire surveillance flights and it adheres to Transportstyrelsen's flight safety conditions. The guidebook consists of guidance on flight safety, upholding air worthiness requirements, risk assessment, and list of flight clubs' aircraft in surveillance flights. (KSAK Motorflygförbundet, 2019).

5.2.5. Subcontractors – flight clubs as service providers

The flight clubs are the final operational level forest fire surveillance in Sweden that produce the service. Surveillance operations are treated as state aviation in Aviation Regulation (Luftfartsförordning, 2010:770, kap. 14). Flight clubs are subcontractors to KSAK (or FFK), which makes the agreement with Länstyrelsen on surveillance flights during the forest fire season. In order to fly forest fire surveillance flights, the service provider must either register the type of business as fire surveillance to the Swedish Transport Agency, or if surveillance flights are part of the operation, satisfy the air safety condition issued by the Transport Agency (MSB, 2023, 5).

The flight clubs are responsible for training their pilots and staff and fulfil the requirements in the agreement between Länstyrelsen and KSAK. The flight clubs must be able to perform two surveillance flights per day and they are responsible for reporting their flights to MSB and Länstyrelsen. Surveillance flights are conducted with a civil aircraft and civil flight permit. The minimum requirement for a pilot in command of the surveillance flight is the light aircraft pilot license.

Each flight club's key person is the Motorflygchef who is granted certain responsibilities in KSAK's Drifthandbok. The Motorflygchef works as the local flight club's head and delegates tasks and reports of the flight club's data to KSAK.

Currently, the Swedish forest fire surveillance system is dependent on flight clubs. Surveillance helps the flight clubs to get income and keeps their operations versatile. However, the equipment and personnel at the flight clubs are aging which creates challenges for the continuity of surveillance in the future.

The service provider executes a surveillance flight at the request of Länstyrelsen. Länstyrelsen may outsource ordering the flights to the rescue department. The decision is based upon the weather forecast and the fire weather index (MSB, 2023, 7). The flight request is assessed on a daily basis but during a high-risk period, flights can be ordered for the following days or weeks. During intense risk and a high forest fire index in at least 50 percent of the area, the routes are flown twice a day. If the risk applies to less than half of the route, the route is flown once. For certain risk spots, only part of the route is observed.

If a fire is detected during a surveillance flight, the crew contacts SOS central to report the fire. The crew provides SOS central with coordinates and additional information relevant to the rescue department, which the scene of the emergency will be alerted to. The flight stays in the vicinity of the forest fire area to guide the firefighters about the terrain, location, spread and other factors that affect putting the fire out. The crew then reports the mission to KSAK. When fire is detected, the responsibility of the mission and covering the flight costs is transferred from Länstyrelsen to the local rescue department.

5.3. Finland

5.3.1. Forest fire surveillance by aircraft in Finland

Finland's national forest fire surveillance system is based on wildfire observations from an aircraft that flies on a prescribed route, like in Sweden. The use of watchtowers was gradually discontinued in the second half of the 20th century. Other technology is also used by the rescue services, such as satellite imagery of hot spots collected once or twice a day.

The Finnish system has fewer administrative and operative levels than the Swedish way of organising surveillance. The Finnish government grants forest fire surveillance an appropriation on a yearly basis which is administered by Regional State Administrative Agency of Northern Finland (Pohjois-Suomen Aluehallintoviranto, PSAVI). PSAVI organises surveillance for routes by public procurement and compensates the service providers for their services. Service providers are mainly local flight clubs or commercial aviation enterprises that operate the route independently during the forest fire surveillance season.

The season starts in April and ends in September in Southern Finland. In Northern Finland, the season starts a month later in May. The Finnish Meteorological Institute provides forest fire warnings and the forest fire index for the forest fire surveillance operators. There are 22 surveillance routes that are spread across Finland.

In Finland, the legal basis for forest fire surveillance comes from the Rescue Act (Pelastuslaki, 29.4.2011/379) 31 § (28.12.2018/1353): if the risk of a wildfire is apparent, the Regional State Administrative Agency of Northern Finland must organise effective wildfire detection in sparsely populated areas - only the Uusimaa region, the most populated region in Finland, does not have a forest fire surveillance route. The Rescue Act obligates the Finnish Meteorological Institute to provide a wildfire warning to the area where the risk is apparent. Forest fire surveillance is the only national task of the Finnish Recue Services, as other services, such as firefighting, are organised on a regional basis in the Wellbeing services counties.

5.3.2. The Regional State Administrative Agency of North Finland – organising the services nationwide

The Regional State Administrative Agency of North Finland (PSAVI) organises forest fire surveillance in Finland, set out in the government decree 1742/2015, section 12 (Valtioneuvosto, 30.12.2015/1742). PSAVI is an administrative state body whose main task is to acquire the services, hold the finances, and guide, lead and oversee the forest fire surveillance operations. They do not take part in operational work, training work or development of the service.

PSAVI is responsible for acquiring the services from service providers which are usually local flight clubs or private aviation enterprises. Acquiring the services starts with a public procurement process and the organisation of a competition between offers. The public purchase procurement is open to service providers from all EU states. However, the tender requires Finnish language skills from the service provider. The Rescue Act does not specify which method of forest fire surveillance should be conducted, but so far surveillance has been carried out by aircraft surveillance, and there have been no tenders that would conduct surveillance by unmanned aerial vehicles or other methods.

PSAVI requires the service provider to have enough personnel and equipment to carry out forest fire surveillance service. However, the resources do not have to be confirmed when the tender is set. The only measure that determines the competition is how many euros per flight minute the service provider charges for the route, the cheapest offer winning. One route can be operated by a maximum of two service providers at a time, but one service provider may operate on several flight routes. The procurement decisions are made public.

PSAVI receives a yearly appropriation, which is about 1.3 million euros for 2024, from the Ministry of Interior to organise forest fire surveillance (Finnish Ministry of Finance, 2023). Weather conditions that can cause a higher risk of a forest fire may lead to a supplementary appropriation. From these funds, PSAVI pays the service providers for their operation per flight minute and compensates for three hours of training. PSAVI pays service providers compensation each year for completing all flights, finishing reporting in time, and participating in a three-hour pre-season flight training.

PSAVI gives guidance for service providers mainly by producing comprehensive documents on forest fire surveillance, and by offering guidance via phone during the forest fire surveillance season. PSAVI has produced a guidebook for surveillance and a related placement test for the service provider. The personnel of the service provider must pass the test to fly on the routes. The test is the same for all and PSAVI can measure the number of eligible personnel on routes.

PSAVI cooperates with other institutions, such as the Finnish Meterological Institute on forest fire index that is provided for the routes, and with rescue services to establish common ground on surveillance and operating model. While PSAVI administers forest fire surveillance operations, once a fire is located, the task changes into a rescue mission and the responsibility of the operative mission is shifted to the rescue services.

5.3.3. TRAFICOM

Prevention of fires by aerial means is defined as state aviation by the Aviation Act (Ilmailulaki, 7.11.2014/864). The Aviation Act determines that the Finnish Transport Agency Traficom, which is the Finnish aviation authority, must mediate between rescue authorities service providers to organise and provide the necessary regulation for search and rescue, and rescue services, by aircraft.

Traficom has set in an Aviation Regulation (Ilmailumääräys OPS M1-34) that the aircraft in forest fire surveillance needs an airworthiness license valid by EASA or ICAO standards. Aerial detection operations do not require a separate operating license. The minimum requirement for operating in aerial detection is private pilot license and a medical certificate.

5.3.4. Service providers: flight clubs and commercial aviation enterprises

Forest fire surveillance flights are operated by service providers that are local flight clubs or commercial aviation enterprises. For the 2024 season, 16 routes are operated by flight clubs and six routes are operated by commercial aviation enterprise. The flight clubs function on a volunteer basis, whilst commercial aviation enterprises are private businesses. The flight clubs and commercial aviation enterprises take part in AVI's public procurement competition. The operational work of the commercial aviation enterprises is the same as for flight clubs, but they are independent organisations. All volunteer flight clubs that fly surveillance flights are part of the Finnish Air Rescue Association (FARA) and also receive their training for the operations. Service provision is considered from the volunteer clubs' point of view because they are the major actor in surveillance flights.

The service providers are required to fly the route once or twice a day if the route-specific forest fire index, provided by the Finnish Meteorological Institute for forest fire surveillance operations, exceeds a set limit for the route. Flying the route is therefore determined independently by the service provider day by day based on route-specific wildfire index which is provided by the Finnish Meteorological Institute. The flight is carried out by following the predetermined flight route. When the index rises above 4.1 or 4.3 depending on the area, the service provider must complete the forest fire surveillance flight during the same day. If the index rises above 5.4 for the route, it will be flown twice a day.

If a forest fire or smoke is spotted in the middle of the area or 20 km outside of the route line, the crew locates and approaches the fire. They inform the emergency centre about the fire's coordinates and other information. Within ten minutes, the on-duty fire officer of the local rescue department should reach out to the crew. While waiting, the crew takes photos of the area and maps out the possible water sources and roads in the area for a fire truck. Upon contact, the fire officer can command the flight to stay in the vicinity of the fire to help the fire truck with guidance. When given permission, or not receiving a message, the crew continues along the route from where they left off.

The service providers in forest fire surveillance are reimbursed based on flight minutes. The service providers receive compensation before the flight season, and another compensation after the season, if they take part in a three-hour flight training, organised by PSAVI before the season. If the service provider cannot carry out a surveillance flight when needed, there is a fine of 100 euros.

For flight clubs, surveillance flights are monetarily beneficial as the compensation can pay the costs of maintaining the equipment and upholding the club's functions. It is up to the flight club how they spend the compensation, but usually the pilots and other personnel work on voluntary basis. Volunteer forces compose 80-90 percent of the operative personnel in forest fire surveillance flights. With aviation enterprises, the compensation is only part of the income, as they may also charge some money for pilots for flying.

Flight safety is monitored by the service providers themselves, and they must follow Traficom's flight safety regulations. Surveillance flights set minimum flying height and guidelines regarding the weather. The service providers report their missions and any abnormalities.

The service providers must pass PSAVI's placement test to qualify for operational work, but there supplementary training is offered by the Finnish Air Rescue Association. The Finnish Air Rescue Association provides training to all its member clubs. Training consists of theory training in an online learning management system, ground training and flight training. Flight clubs and commercial operators offer their own training to the crew as well.

5.3.5. The Finnish Air Rescue Association

The Finnish Air Rescue Association (Suomen Lentopelastusseura, FARA) is a national organisation that supports the Finnish authorities by providing volunteer search and rescue services via its member clubs. They have a round-the-clock on-call duty for alarms.

The Air Rescue Association does not have an official position or role in forest fire surveillance, but it coordinates and educates the volunteers in their member clubs for search and rescue missions, including forest fire detection operations. This is important as most of the forest fire surveillance routes are flown by the Air Rescue Association's member clubs. However, the flight clubs can operate in forest fire surveillance and fulfil their agreement with PSAVI without engaging in any of the services that the Air Rescue Association provides.

The education that FARA provides supports the surveillance operations, as PSAVI's guidebook and placement test are limited in measuring real-life operational skills on ground or in air. The member flight clubs and the crew must go through the education programme if they wish to organise an alert group for search and rescue missions, as FARA has internal requirements for forest fire surveillance flights. Everyone needs to pass the education, but FARA does not monitor the number of eligible personnel. The flight club's chief is responsible of monitoring the crew's qualifications and report of the trainings to FARA.

They offer their member flight clubs safety monitoring platform (SILPI) where the member clubs can report safety anomalies, and flight safety is a consistent part of their education programme and over-all work. Still, FARA does not have a formal role in monitoring flight safety.

In addition to close relationship with the member clubs that engage in the operational work in forest fire surveillance, FARA has a close relationship with the Finnish Ministry of the Interior. The Ministry and FARA have an agreement on a yearly appropriation for FARA for training and preparedness. In addition, FARA negotiates and discusses with Traficom on the needs of its member clubs and search and rescue aviation matters. PSAVI and FARA do not have an official connection, but they have reciprocal cooperation on forest fire surveillance matters. In addition, FARA cooperates with the local rescue services, Finavia and the Finnish Meteorological institute to some degree, mainly via its member clubs.

5.4. Norway

5.4.1. Forest fire surveillance by aircraft in Norway

The authorities that lead the organisation of forest fire surveillance by aircraft in Norway are the county governor and the municipality. At the central government administrative level, county governors oversee municipalities in their area and communicate between the municipalities and the state. They decide whether surveillance is organised in the county and determine the budget for organising the operations. The municipalities are responsible for organising the operational forest fire detection service in their area, which is executed and organised by the local fire and rescue department, which may sometimes be intermunicipal departments. The municipalities purchase the service from local flight clubs that survey the area with a small aircraft in the same manner as in Finland and Sweden.

Aerial forest fire detection in Norway is based on the Fire and Explosion Protection Act (Brann- og eksplosjonsvernloven LOV-2002-06-14-20) and surveillance by aircraft is controlled in the regulations relating to civil state aviation for the purpose of public law (FOR-2020-05-26-1076) under the Aviation Act (Lov om luftfart LOV-1993-06-11-101). The Fire and Explosion Protection Act makes every citizen responsible for notifying of and limiting the harm caused by fire, explosion or other accident and for calling the emergency dispatch centre (110-central). The municipality and the fire brigade must work to prevent fires and conduct risk analysis.

The regulation relating to civil state aviation (Forskrift om sivil statsluftfart med offentligrettslig formål mv. FOR-2020-05-26-1076) establishes that among other public services, firefighting, search and rescue activities, and services executed in the public interest, together with a public authority, are considered civil state aviation. This applies to forest fire detection by aircraft. The regulation requires nonprofit organisations (which in forest fire detection services are the flight clubs, as they are most often in Sweden and Finland, too) to have a safety system approved by the Civil Aviation Authority to be eligible to fly. The safety system requires for example training curriculum, safety instructions and a reporting system. The regulation does not apply to forest fire fighting helicopters, which are privately owned, but contracted and coordinated by DSB. The helicopters are on permanent standby between 15th of April and 15th of August, when they can be requested to assist in forest fire fighting (DSB, 2019a, 12).

In addition to aircraft, forest fires are also reported by citizens and forestry sector workers in the forests. Satellite detection is also used, and information of hotspots comes from for example NASA Fire Information for Resource Management System (FIRMS). Most forest fires appear in southern, central and eastern Norway. By the coastline, low vegetation and heathland is also prone to catch fire. In Norway, the forest fire season lasts from April until

September, and starting fires in a forest or wilderness is forbidden in the whole county between 15th of April and 15th of September.

The service level is different across different counties because forest fire surveillance operations are organised on a municipal basis and there is no national approach. Therefore, specific counties are mentioned when describing how they organise the service, because the same methods may not apply to other counties.

5.4.2. DSB – State actor

On a state level, the Direktoratet for Samfunnssikkerhet og Beredskap (DSB, Directorate for Civil Protection) is a directorate under the Ministry of Justice responsible for ensuring safety and security of Norway and its citizens. Their responsibility is to guide, manage and hold an overview of Norwegian fire and rescue services, preparedness, civil protection and explosives, electrical safety and chemicals. DSB administers Fire and Explosion Protection Act-related regulations, offers training and education in related fields, conducts research, and manages the Norwegian emergency communication systems.

DSB does not have any formal role in forest fire surveillance because the operations are organised on a local level. However, DSB works with the municipal fire departments regarding fire prevention and forest fire fighting. DSB coordinates Norwegian forest fire helicopters and conducts research on forest fires. For example, DSB's *Emergency Preparedness Analysis: Forest fires* -report (2019) investigates scenarios, consequences and challenges that forest fires can cause in Norway.

5.4.3. County Governor – supervision and budgeting

The county governor is an administrative body above municipalities and below the state. It can be understood as being on a similar administrative level as PSAVI in Finland and Länstyrelsen in Sweden. Due to the lack of a national approach, each county organises forest fire surveillance independently. The county governor decides whether or not detection is organised in the county's municipalities, which resembles Länstyrelsen's authority. For example, due to varying terrain and conditions in each county, surveillance is not organised in every county. For example, the county governor of Troms og Finnmark does not organise forest fire surveillance due to the mountainous area and the lack of vegetation. The county governor may prioritize more relevant rescue operations based on a regional risk analysis.

The county governor negotiates with the municipal fire and rescue department about the organisation and funding. The local flight clubs may also take part in the negotiations in some counties. The county governors have discretion in granting a budget for the fire and rescue departments to organise forest fire surveillance. This means that in some counties the county governor pays all surveillance costs and in others, municipalities fund the surveillance independently. The system differs from the Finnish approach, in which PSAVI organises the services for all routes, and from Sweden where MSB sets the equivalent guidelines for all Länstyrelsen, which then organise regional surveillance.

For example, in Innlandet, the fire and rescue department, a flight club representative and the county governor negotiate and discuss the budget and the future season. The county governor covers the costs of surveillance for the county's fire and rescue departments. The 110-centre stores the possible leftover money for the next years in case there is a need for more funding due to for example a dry summer. In Vestfold og Telemark the situation is different, as several municipalities that organise the surveillance services jointly, fund forest fire surveillance by paying for the organisation of the service according to their area and population.

5.4.4. Fire and rescue department as the local municipal actor

The fire and rescue departments are municipal or intermunicipal organisations in Norway. The fire and rescue department's main task is to work preventatively to protect citizens from fires and inform about forest fires. The fire and rescue departments are linked to regional 110-emergency alarm centres. The 110-centres are either directly under the fire and rescue departments or under the county governor. The fire and rescue department makes a deal with the county governor about the funding for organising surveillance in the spring before the forest fire season.

The fire and rescue department organises the forest fire surveillance service in their area, usually in cooperation with other municipalities and municipal fire departments, contracting one or several flight clubs to provide the service. It is possible to organise forest fire surveillance with the Norwegian Air Sports Association (Norges Lufsportfordbund, NLF) instead of making direct contract with the clubs. The fire and rescue department uses the surveillance flights for both detecting fires from the air and to confirm already received reports of a forest fire. Aircraft are also used to receive information about the area. Aerial surveillance is organised also with satellites and drones: for example in Vestfold og Telemark, drones have been used to assist in finding and gathering information about fires.

Unlike in Finland and Sweden, there is no public procurement process in Norway for acquiring forest fire surveillance services. The fire and rescue department decide independently which flight clubs they work with in organising surveillance. The contract for acquiring and providing the service is made directly between the fire and rescue department and one or several flight clubs. The fire department (with the 110-centre in Innlandet) plans the flight routes, how many hours and how often the flight clubs will fly during the forest fire season. The fire department pays the flight clubs for flying and training. Certain amount of flight hours are compensated unconditionally, both in the Innlandet and Vestfold og Telemark counties, and the flight clubs are paid extra if they have to fly more than planned.

The fire and rescue department provides the flight clubs with information about forest fires prior to the season, devices, and access to mapping and emergency systems.

5.4.5. Norwegian Air Sports Association

NLF is a central civil aviation organisation that monitors the flight safety and training of its member flight clubs. They work with search and rescue and forest fire detection services, which their member flight clubs produce. NLF organises variety of air sports such as skydiving and paragliding.

NLF's main task is to ensure its member clubs' safety measures. They monitor clubs' adherence to flight safety regulations. NLF's competence for safety monitoring comes from the Regulations on civil state aviation for the purposes of public law (Forskrift om sivil statsluftfart med offentligrettslig formål mv, section 4). The regulation states that non-profit organisations cannot conduct civil state aviation without a safety system approved by the Civil Aviation Authority. The safety system must include training, safety regulations, operational instructions, aircraft maintenance, ground procedures, deviation reporting and compliance monitoring. NLF maintains the required safety system for the flight clubs, thus allowing them to be approved for civil state aviation. NLF receives information of the routes' waypoints, heights, frequencies and other details when the fire and rescue department is planning the surveillance season, which contributes to flight safety.

NLF also has an incident reporting system that includes reports and data from all flight clubs in Norway. To monitor qualifications, NLF has a portal to store documentation of the crew's pilot licenses, medical certificates and training diplomas. The flight clubs must be a member of the NLF to be allowed to have a TETRA radio for official rescue services' missions such as forest fire surveillance.

NLF is comparable to KSAK as they both have a central role in allowing the flight clubs to undertake surveillance operations. The main task of both organisations is monitoring flight safety. While KSAK's permit and Drifthandbok are approved by Transportstyrelsen, NLF's flight safety system is not only approved by Norwegian CAA but also established on a regulatory level.

NLF, together with the flight clubs, is responsible for designing the training for surveillance. NLF organises national and regional events and the leader of the local flight club organises local training. The training is not standardized, but NLF is working to achieve a national curriculum. NLF has an e-learning system and aims to digitalise all their courses. Local training material is compliant with the required security system.

5.4.6. The flight clubs

The flight clubs provide the operative service. They have an agreement with the fire and rescue department to be available for the season to undertake forest fire surveillance tasks and conduct smoke checks. Determining when a surveillance flight will be flown is similar to Sweden. In Norway, the fire chief of a local fire and rescue department makes the decision and orders a flight based on risk analysis and forest fire index. During a period of high forest fire risk, routine flights are completed.

The Norwegian surveillance flights follow the same pattern as in Finland and Sweden. The flight club flies along a predetermined route in search of smoke. If smoke is detected, the crew will divert towards the possible fire. They will assess the source of smoke and contact the 110-central to inform about the finding. The 110-central alerts the local fire department that is instructed to contact the surveillance crew via TETRA radio. The crew takes pictures of the scene and forwards them to the 110-central. The crew provides coordinates for the fire department and the dispatch centre, which can also see their location via tracker. The fire department will decide whether the surveillance crew has to stay in the vicinity of the smoke and if they need information about the topography, water sources, roads and other relevant information. When the surveillance crew is not needed, they continue their route and fly to refill the fuel if needed.

Several flight clubs can cooperate and organise the surveillance for one area, if the fire and rescue department has contracted two or more flight clubs to provide the service. They can share the routes on a weekly basis and balance the work during high-risk periods, when the stand-by time is within 30 minutes.

There are some qualifications that the flight clubs and the pilots must fulfil in order to fly surveillance flights. The flight clubs need to be member of the NLF to be allowed to have a TETRA radio for official rescue services missions and to conform to the Civil state aviation law's requirements. The aircraft needs have an airworthiness certificate. Executing the flight requires one pilot and one observer approved by the flight club's crew leader. The minimum requirement for the pilots is to hold a light aircraft pilot license to partake in surveillance flights. The pilot takes care of the aviation, such as flight safety and radio and air traffic. The observer handles the mission details, searching for the smoke and recording it, and communicating with the fire and rescue department, the 110-centre and other authorities. The flight clubs are not required to have a specific number of personnel to provide the service.

Flight clubs monitor their own flight safety. NLF approves the safety measures and requires the crew to take basic courses on surveillance flights and using the TETRA-radio. The flight clubs organise training based on NLF's curriculum. The curriculum is standardized, but the clubs training methods and system may differ from each other. The flight club's crew leader approves the crew members' training.

The flight clubs are not allowed profit from forest fire surveillance operations. Reimbursement from the fire department or the county governor covers the costs of training and flight hours and the maintenance of equipment. The flight clubs invoice the fire department or the county governor twice during the season for the costs. The flight clubs in Innlandet and Vestfold og Telemark receive a fixed amount of money for fixed hours of flights and extra flight hours are compensated separately.

6. The future of forest fire surveillance

The projected changes in the future climate and demography and technological development encourage us to ask, what does the future of forest fire surveillance in the Barents region and Nordic countries look like? This question will be investigated by analysing the interviewees' and workshop participants' opinions on the use of forest fire surveillance methods (aircraft and other technology) in the future, and on the challenges and possibilities in the field of wildfire observation, such as demographic changes and international cooperation. The interviewees were asked, how they perceive the future of forest fire surveillance in their country and how they see the use of different technologies in forest fire surveillance. The workshop participants were tasked with brainstorming exercises, in which they tried to solve central questions relating to organising international forest fire surveillance cooperation.

Different wildfire observation methods were introduced in chapter 3, including aircraft, unmanned aviation vehicles (drones), satellite and sensor technology, cameras, watchtowers, people's observations, and predictive risk analysis. Most of the interviewees argued that forest fire surveillance by manned aircraft will continue in the future. However, they had various views on how long aircraft surveillance will persist in its current form, and how fast technological development will take place in the field. The workshop participants agreed that hybrid surveillance methods should be explored and that the Nordic countries should prepare for cross-border cooperation.

6.1. Future surveillance methods

The flight clubs saw the future of forest fire surveillance from two points of view. They agreed that forest fire surveillance will continue by manned aircraft, at least for now. The interviewees expressed opinions such as the states being dependent on flight clubs for the continuation of forest fire surveillance and that manned aircraft is the most cost-effective and flexible method of organising wildfire observation. However, they all saw that in the future, other technology and equipment will play a bigger role in detection activities. Satellites, drones, sensors and thermal cameras were brought up as supplementary technology that can assist surveillance from a manned aircraft. Utilizing various technology and techniques in surveillance operations not only helps detecting fires, but also ensures operational reliability in different situations and provides versatility to the operations of the flight clubs.

The flight club interviewees brought up similar challenges with technological surveillance solutions that have been analysed in chapter 4. They argued that satellite sensors are sensitive to the weather and clouds, transferring information was considered slow, and drones have a limited operational range and high operating costs and they may cause airspace conflicts. In addition, one interviewee argued that drone detection would require a commercial actor to conduct surveillance operations. Sensors and thermal cameras were also described as expensive.

The flight clubs in Finland and Sweden saw the biggest challenge to the continuation of forest fire surveillance to be the availability of personnel. Flight clubs are operated by volunteers, but the trend of new members has decreased. One interviewee argued that people seem less committed and interested in volunteering, especially if it involves lengthy training programmes. The current members are aging and there are fewer young people interested in air sports. However, the Norwegian flight club was more positive on the future of the membership of the flight clubs, but operations were complicated more by external factors affecting general aviation.

The aviation organisations looked at the future from different perspectives, but they all agreed with the flight clubs that the technological alternatives are expensive and limited. The weaknesses of drones included air space risks, high costs, slow transfer of information and small area coverage. FARA and NLF discussed on-board cameras that can send live video from the surveillance route or search and rescue missions. NLF saw that the zooming option in cameras could also help with flying in higher altitudes, which would add to flight safety.

It was also argued that with current technology, drones require one person to fly and one person to interpret the data, which is also the size of the crew in a manned aircraft. They claimed that detecting smoke is not the problem, but the main question should be, what happens after the smoke or fire is detected. Comparing drone or satellite technology and aircraft surveillance, they argued that a surveillance crew is more efficient as it can guide the rescue services and provide them situational information right away. However, the organisations also anticipated some sort of change, because the old aircraft and equipment will be replaced sooner or later, and authorities should respond to current needs. Authorities' responsibility in discussing regulation relating to drones and air space management was also brought up.

Fire and rescue departments in Norway, PSAVI in Finland and MSB and Länstyrelsen in Sweden represent the authorities that are involved in organising and administering forest fire surveillance. The interviewees from these institutions discussed research and development of wildfire detection methods. Manned aircraft surveillance was argued to work well and seen as useful, especially in vast areas with sparse population and difficult terrain. The authorities agreed that utilizing several methods simultaneously, a so-called hybrid system, could ensure operational reliability in various weather conditions in which an aircraft cannot operate.

The authorities were interested in the possibilities that unmanned aviation and satellite technology could bring for wildfire detection. With improvement in sensor technology, satellites were argued to provide better access to real time information that could be used to do localized hotspot and smoke checkups by flight clubs or rescue services. Aircraft-integrated sensors and artificial intelligence-assisted detection were also seen as a good way to improve the current system. Interpretation of imagery and video data could be analysed remotely by a third party, and a Nordic hub for monitoring wildfire data from Finland, Sweden and Norway was proposed.

Regarding drones, on one hand, it was argued that highly developed technology could result in lower surveillance costs in the end, but on the other hand, the current price level speaks for the continuation of manned forest fire surveillance flights: surveillance flights are delivered mainly volunteers with relatively low costs. The continuation of aircraft surveillance was questioned in relation to the green shift which may create difficulties for the work of flight clubs. However, one stakeholder argued that electronic planes will be used for surveillance sooner than drones, at least in large areas, where the operational range of drones is insufficient. Instead, drones were seen as an efficient tool in predetermined, limited areas. The authorities did not agree on whether drone surveillance could be offered by volunteer or commercial actors. Indeed, investing in the wildfire detection business would not be profitable for a commercial company, but at the same time, a flight club could not afford a sufficient drone by themselves.

The challenges of the technological equipment are tackled by scientists and technicians, as was argued in chapter 4. Limitations regarding weather conditions and the operational range of drones have been addressed (Gabbert, 2019, 2020; Al-Kaff, 2020) and satellites' sensors are advancing (Carta *et al.,* 2023). As the interviewees argued, it is likely that hybrid forest fire surveillance systems will develop in the near future. Hybrid systems were highlighted as a way to ensure operational reliability and versatility in wildfire detection.

The challenges of forest fire surveillance by manned aircraft relate more strongly to the societal changes and availability of volunteer personnel to undertake surveillance operations. Urbanization of the population in the Nordic countries, and especially in the Barents region, can affect the availability of new flight club members. Difficulties in combining work and personal life and a lack of time can affect taking part in operations by volunteers (Eskelinen & Nikkanen, 2020). This might indicate that the flight clubs need to consider new ways of organising their activities. Tackling large societal challenges requires input from authorities as well.

6.2. International cooperation in forest fire surveillance

The interviewees recognized that international cooperation, especially cross-border collaboration between the Nordic countries would be valuable. In particular, the stakeholders wished more active cooperation in exchanging information about best practices and sharing experiences. Several interviewees argued that the Nordic countries have the same problems regarding the wildfires and therefore fires should be tackled together. National, regional and local cooperation were seen as important, but especially national level cooperation was considered useful.

The flight clubs did not have any existing international networks, but one interviewee estimated that connections may exist on a personal level. The flight clubs agreed that exchange of information would be useful, but they were undecided whether the flight clubs' have enough competence to organise operative cooperation. For Lapin Ilmailuliitto, it was clear that if needed, Nordic cooperation across the border of Finnish Lapland and Swedish Norrbotten would be possible for them. For example, the distance between Luleå-Boden Flygklubb and Lapin Ilmailuliitto is 250 kilometres, and the distance to the border is about 100 kilometres. At the Sandefjord flyklubb, international cooperation was found to be more difficult because they do not have enough resources to reach distant places in Sweden and Finland, and crossing the border requires practical planning for volunteers. Instead, commercial aviation organisations were suggested as being more capable of operating across the border. The flight clubs considered authorities accountable for organising the operational model and regulation, because the wildfire detection operations are under state aviation. Existing international cooperation between the meteorological institutes, rescue services, border control and bureaucrats was also highlighted.

Aviation organisations did not have strong international connections either, but they saw Nordic cooperation and exchange of information in forest fire surveillance as being possible. FARA noted that the current forest fire surveillance system works fine in normal societal conditions, but in case of emergency or disruption, it would be good to formulate an international operational model. Two countries could coordinate cooperation by setting up a treaty on surveillance operations. However, the different institutional levels involved in forest fire surveillance operations in each country vary, which might make negotiations difficult. A treaty and operational model would also enable joint trainings for offering and receiving help.

The authorities highlighted the role of state deals in implementing international cooperative models and common problems. It was noted that forest fires are discussed on a ministerial level between different states. It was therefore argued that the decision-making and initial facilitation of cooperation would need to come from a ministerial level. After establishing the starting level, national authorities and stakeholders from different organisations could discuss any further steps.

Preparedness for crises and disruptions was brought up as a motivation for international cooperation in forest fire surveillance. If Norway, Finland and Sweden are in need of international assistance at the same time, it has to be sought from other European countries. Therefore, it is necessary to prepare not only among the Nordic countries, but seek European-wide connections too.

The project workshop in Oulu brought together several stakeholders from authorities to organisation representatives and flight clubs to discuss the future threats and possibilities of forest fire surveillance. In brainstorming activities, the participants suggested different crisis scenarios where international aid in forest fire surveillance with current surveillance methods would be needed. Such scenarios included extreme weather events in the Nordic countries, hybrid operations such as arson, cross border fires in the Nordic countries or wildfire spreading from Russia, a lack of national aerial assets or national monetary resources to organise surveillance, airspace restrictions resulting from military hostility in the Baltic Sea, and price peaks in aviation fuel.

Organising international assistance in such scenarios requires proactive consideration of several factors. It is necessary to recognize the most important stakeholders and responsible parties. It should be determined how often they meet and where, and who is in charge of coordinating the cooperation. Stakeholders should identify what information they would share and how it could be shared - for example, via a database. Expectations, procedures, barriers and restrictions, as well as surveillance methods should be made clear for everyone. Stakeholders should also identify measuring tools for the effectiveness and purposefulness of international cooperation.

Preparation ahead of the risk scenario and planning cooperation was highlighted by the workshop participants. Well before help is requested or offered, stakeholders and authorities should resolve issues like agreements between rescue services and authorities - for example, climate authorities, communication systems and the communication language, leadership structures and operational arrangements, including physical exercises, planning facilities and logistics, and mapping risk areas.

7. Suggestions for organising international cooperation

Preparing for offering and receiving international assistance requires strong networks, planning ahead and building an operative model that is recognized by state authorities, international networks and operational actors. Developing a model should start by engaging state authorities to recognize the importance of the risk scenario and prepare national resources and assets for operative tasks in order to ensure smooth and clear process for all stakeholders.

Based on this report, it is clearly necessary to prepare and build readiness for international collaboration, not only in the Barents region but also on larger geographical scope. This project suggests that the state authorities should initiate discussions with relevant stakeholders about organising international cooperation in forest fire surveillance. Stakeholders should follow a three-stage-process to enable offering and receiving international assistance in forest fire surveillance operations:

Stage 1: Setting up legislative and administrative preparations.

- Mutual assistance agreements among participating states outlining the terms and conditions for providing and receiving assistance.

- Protocols for requesting and coordinating assistance, including resource allocation, deployment procedures, liability issues, and reimbursement mechanisms.

Stage 2: Ensuring a common situational understanding of offering and receiving international assistance.

- Understanding of the required level of resources, including personnel, equipment, operational capacity.

- Ensuring a balanced approach to technological systems and operative methods

- Forming a knowledge base of the operation

Stage 3: Building operational and commanding systems and infrastructure.

- Implementing robust communication and information sharing systems to facilitate the real-time exchange of data and situational awareness.

- Exploring the combined use of manned aircraft, satellite imagery, unmanned aviation, artificial intelligence, and predictive modelling techniques to improve early warning systems and response capabilities.

- Guaranteeing the safety of the operations

By implementing these components, an international network of stakeholders can pursue an operational model, which enables the states to enhance cooperation in forest fire management, improve emergency response capabilities, and mitigate the impacts of wildfires on communities and the environment.

After drafting an operational plan, joint training to facilitate international cooperation in forest fire surveillance is pivotal. The public administrative frame and, therefore, the administrative and operational systems within forest fire surveillance are different in each country. Hence, operational characteristics such as national, regional, or local scope, the needs of rescue services, voluntary work and resources in general, should be taken into account in the planning process. In addition, the training should include at least basic information about the systems in hosting countries, flight safety perspectives including air space management and operational procedures related to aviation and rescue services. The training could be organized, for example, in accordance with cooperation with national or international host nation support training models, if available. Existing training platforms such as BarentsRescue or Finnish aerial forest fire fighting training could be utilized. It is imperative that all stakeholders in forest fire surveillance understand, at the very minimum, the administrative and operational scope of forest fire surveillance to ensure safe and effective international cooperation. Hence, this report can be utilized as training material to provide background information on forest fire surveillance and the comprehensive forest fire surveillance systems in Finland, Sweden and Norway.

8. Conclusion

This study investigates aerial wildfire observation methods within the Barents region, focusing on Finland, Sweden, and Norway. Collectively, these nations have vast expanses of forest land, representing a significant portion of Europe's forested areas. However, climate change presents an immense challenge, with rising temperatures, shifting precipitation patterns, and alterations in vegetation composition increasing the risk of wildfires in Fennoscandia. National risk assessments highlight preparedness and proactive response to mitigate these hazards. Furthermore, international collaborative initiatives aimed at wildfire prevention and control have been forged to tackle this shared challenge head-on.

The aim of the Developing Wildfire Observation in the Barents Region project has been to compare the Finnish, Swedish and Norwegian wildfire observation systems. This report provides an extensive comparison of the administrative and operational organisation of wildfire observation in the respective countries.

In terms of detection methodologies, the longstanding tradition of forest fire surveillance via manned aircraft remains a cornerstone of the approach employed in Finland, Sweden, and Norway. Manned surveillance crews follow a predetermined flight route, scanning the landscape for signs of smoke or fire. The surveillance flights are mostly undertaken by flight club volunteers. Beyond traditional aerial surveillance, other approaches such as sensor technologies, predictive fire risk modelling, and unmanned aviation methods have gained considerable attention. Both research and technological innovation have paved the way for enhanced wildfire understanding and management strategies. Challenges persist in accurately detecting and predicting wildfires, but ongoing research strives to develop robust predictive models and effective fire management. Especially the authorities argued that utilizing hybrid detection systems and investment in technological solutions can be expected in the future.

The domain of forest fire surveillance via aircraft operation encompasses a diverse array of stakeholders, ranging from state authorities and fire and rescue services to municipalities, flight clubs, and operators. The administrative organisation of forest fire surveillance is national in Finland, regional in Sweden and local in Norway. In Finland, the Rescue Act requires organising forest fire surveillance in sparsely populated areas and it is organised by the Regional State Administrative Agency of Northern Finland. In Sweden and Norway there is no specific legal basis for organising the operations. In Sweden each Länstyrelsen decides on organisation of the surveillance operations in the respective county. In Norway, the decision is made at the municipal and county level.

In all countries, the overarching aim of forest fire surveillance services is the same – to prevent large-scale wildfires by detecting them as early as possible. Regardless of the administrative organisation system, the greatest beneficiary of forest fire surveillance services is the national fire and rescue service, as fires can be detected and limited effectively before they get out of control.

In Finland, Sweden and Norway, the flight clubs train their volunteer crew according to curriculum provided by the authorities and aviation organisations. However, the flight clubs considered national standardization of wildfire observation training as a needed development. While most of the stakeholders saw that forest fire surveillance by manned aircraft is going to continue in the future, recruiting and committing new volunteers to wildfire observation activities could pose a challenge in the future.

The second aim of the project has been to develop a network between relevant stakeholders and operators in order to enhance international cooperation in wildfire management and observation. International collaboration is crucial in our efforts to fight wildfires, especially through cooperation among Nordic countries. Although international networks among forest fire surveillance actors are still developing, there's clear potential to share information of the operational practices, forest fire research and use of hybrid methods to detect wildfires. Developing channels for the exchange of best practices between states and stakeholders is one of the top priorities. The interviewees agreed that creating rules and system for cross-border cooperation is the primary responsibility of the authorities. Nevertheless, all stakeholders that were interviewed and all project workshop participants were interested in some level of international cooperation.

Nordic countries can work together more in aviation, for example, through joint training and agreements for emergencies. Projected increases in wildfires in Europe may result in further demand for international help and Nordic cooperative plans and models can prepare national stakeholders to assist firefighters in other countries. International collaboration can really improve observing and preventing wildfires not only in the Barents region, but also in the wider European setting.

9. Sources

Aalto, J. & Venäläinen, A., 2021. ''Climate change and forest management affect forest fire risk in Fennoscandia.'' Finnish Meteorological Institute Reports, 2021:3.

Ahlström, M., Backlund, A., Bergstrand, M., Flodin, E., Lundström, C., Wigertz, F. & Ölwing, T., 2019. ''Analys av blixtnedslag som antändningskälla för skogsbränder sommaren 2018.'' Master's Thesis, Uppsala University.

Al-Kaff, A., Madridano, Á., Campos, S., García, F., Martín, D., & de la Escalera, A., 2020. ''Emergency support unmanned aerial vehicle for forest fire surveillance.'' Electronics, 9(2), 260.

Alkhatib, A., 2014. ''A Review on Forest Fire Detection Techniques.'' International Journal of Distributed Sensor Networks, 10(3). https://doi.org/10.1155/2014/597368

Alkhatib, R., Sahwan, W., Alkhatieb, A., & Schütt, B., 2023. ''A brief review of machine learning algorithms in forest fires science.'' Applied Sciences, 13(14), 8275.

Allison, R., Johnston, J., Craig, G., & Jennings, S., 2016. ''Airborne Optical and Thermal Remote Sensing for Wildfire Detection and Monitoring.'' Sensors, 16(8). 1310. https://doi.org/10.3390/s16081310

Aragão, L., Anderson, L., Fonseca, M., Rosan, T., Vedovato L., Wagner F., Silva C., Junior C., Arai E, Aguiar A., Barlow J., 2018. ''21st Century drought-related fires counteract the decline of Amazon deforestation carbon emissions.'' Nature communications, 9(1), 536.

Barbero, R., Abatzoglou, J.T., Larkin, N.K., Kolden, C.A. and Stocks, B., 2015. ''Climate change presents increased potential for very large fires in the contiguous United States.'' International Journal of Wildland Fire, 24(7), 892–899.

Barentsinfo.org. No date. ''Population in the Barents Region (2021).'' Website. https://www.barentsinfo.org/barents-region/Statistics/Population#. Accessed 12.4.2024.

Berman, M., Ye, X., Thapa, L., Peterson, D., Hyer, E., Soja, A. & Saide, P., 2023. ''Quantifying burned area of wildfires in the western United States from polar-orbiting and geostationary satellite active-fire detections.'' International Journal of Wildland Fire, 32(5), 665–678.

Brann- og eksplosjonsvernloven LOV-2002-06-14-20. Available at: https://lovdata.no/dokument/NL/lov/2002-06-14-20/.

Braxton, J., 2021. ''AI Could Spot Wildfires Faster Than Humans.'' Scientific American, 17.6.2021. https://www.scientificamerican.com/article/ai-could-spot-wildfires-faster-than-humans/.

Brown, R, Agee, J. & Franklin, J., 2004. ''Forest Restoration and Fire: Principles in the Context of Place.'' Conservation Biology, 18(4), 903–912. https://doi.org/10.1111/j.1523-1739.2004.521_1.x

Carta, F., Zidda, C., Putzu, M., Loru, D., Anedda, M. & Giusto, D., 2023. ''Advancements in forest fire prevention: A comprehensive survey.'' Sensors, 23(14), 6635.

Chuvieco, E., Aguado, I., Salas, J., García, M., Yebra, M. & Oliva, P., 2020. ''Satellite Remote Sensing Contributions to Wildland Fire Science and Management.'' Current Forestry Reports, 6(2), 81–961.

Defossé, G., 2023. ''Fires in the wildland urban interface: An emerging global phenomenon threatening modern society.'' Frontiers in Forests and Global Change, 6, 1137014.

Diaz, J., 2012. ''Economic impacts of wildfire.'' Southern Fire Exchange, 498, 2012-7.

DSB, 2019a. ''Emergency Preparedness Analysis: Forest fires.'' DSB Report. https://www.dsb.no/rapporter-og-evalueringer/emergency-preparedness-analysis-forest-fires/.

DSB, 2019b. Analyses of Crisis Scenarios 2019. ETN Grafisk, Skien. https://www.dsb.no/rapporter-og-evalueringer/analyses-of-crisis-scenarios-2019/.

Ekholm, T., Lindroos T.J., Sokka L., Koponen K., & Koljonen T., 2017. ''Barents 2050 – Impacts, opportunities, and risks of climate change and climate change mitigation.'' VTT Technology, 316. https://publications.vtt.fi/pdf/technology/2017/T316.pdf.

Eskelinen, K. & Nikkanen, M., 2020. ''Vapaaehtoisten ja viranomaisten välinen yhteistyö – loppuraportti.'' Spek tutkii 21. https://issuu.com/spek_ry/docs/spek_tutkii_21_8c6c5420624c82.

Fernandes, K., Baethgen, W., Bernardes, S., DeFries, R., DeWitt, D., Goddard, L., Lavado, W., Lee, D., Padoch, C., Pinedo-Vasquez, M. and Uriarte, M., 2011. ''North Tropical Atlantic influence on western Amazon fire season variability.'' Geophysical Research Letters, 38(12), 1–5.

Finnish Environmental Institute, 2023. ''BARIMS-hankkeen suositukset.'' https://www.syke.fi/download/noname/%7B95E7D48A-E1B6-44C0-8B20-5E461D16D249%7D/182110. Accessed 10.4.2024.

Finnish Ministry of Interior, 2023. ''National Risk Assessment 2023.'' Publication of the Ministry of Interior 2023:6. Available at: https://julkaisut.valtioneuvosto.fi/handle/10024/164629.

Finnish Ministry of Finance, 2023. ''Talousarvioesitys 2024: 30. Pelastustoimi ja hätäkeskustoiminta.'' Available (in Finnish) at: https://budjetti.vm.fi/indox/sisalto.jsp?year=2024&lang=fi&maindoc=/2024/tae/hallituksenEsitys/hallituksenEsitys.xml&id=/2024/tae/hallituksenEsitys/YksityiskohtaisetPerustelut/26/30/30.html.

Finnish Ministry for Foreign Affairs. No date. ''The Finnish Presidency of the Barents Euro-Arctic Council 2021-2023. Region of Opportunities.'' https://um.fi/finnish-barents-presidency-2021-2023. Accessed 10.4.2024.

Forskrift om sivil statsluftfart med offentligrettslig formål mv. FOR-2020-05-26-1076. Available at: https://lovdata.no/dokument/SF/forskrift/2020-05-26-1076?q=FOR-2020-05-26-1076.

Foster, W., 1962. Aircraft in forest fire control in ontario. The Forestry Chronicle, 38(1), 38–48. https://doi.org/10.5558/tfc38038-1.

Frivilliga Flygkåren. No date. ''Flyggrupper.'' Website. Available at: https://ffk.se/flyggrupper/. Accessed 25.4.2024.

Földi, L. & Kuti, R., 2016. ''Characteristics of Forest Fires and their Impact on the Environment.'' Academic and Applied Research in Military and Public Management Science, 15(1), 5–17. https://doi.org/10.32565/aarms.2016.1.1

Gabbert, B., 2019. ''What is the Holy Grail of Wildland Firefighter Safety?'' Wildfire Today. Available at: https://wildfiretoday.com/2019/02/10/what-is-the-holy-grail-of-wildland-firefighter-safety/

Gabbert, B., 2022. ''Australian company develops system for real-time mapping of wildfires.'' Wildfire Today, available at: https://wildfiretoday.com/2022/01/07/australian-company-develops-system-for-real-time-mapping-of-wildfires/

Georgiev, G., Hristov, G., Zahariev, P., & Kinaneva, D., 2020. ''Forest monitoring system for early fire detection based on convolutional neural network and UAV imagery.'' In 2020 28th National Conference with International Participation (TELECOM), 57–60. IEEE.

Gjedrem, A., & Metallinou, M., 2023. ''Wildland-urban interface fires in Norwegian coastal heathlands – Identifying risk reducing measures.'' Safety Science, 159, 1–32. https://doi.org/10.1016/j.ssci.2022.106032

Hannerz, M. & Ekström, H., 2023. Nordic Forest Statistics 2023, Resources, industry, trade, prices, environment and climate. Nordic Forest Research. https://nordicforestresearch.org/wp-content/uploads/2023/06/Nordisk-skogsstatistik-2023-mindre.pdf. Accessed 9.4.2024.

Hekkala, A., 2015. "Restoration of the naturalness of boreal forests." University of Oulu, PhD Dissertation. Tampere: Juvenes Print.

Hertzberg, Å. & Lundqvist, M., 2022. "Skogsbrandbevakande flyg – En beskrivning och värdering av verksamheten." Myndigheten för samhällsskydd och beredskap, MSB1898–Januari2022. https://www.msb.se/sv/publikationer/skogsbrandbevakande-flyg--en-beskrivning-och-vardering-av-verksamheten/.

Horton, J., & Palumbo, D., 2022. "Europe wildfires: Are they linked to climate change?" BBC News. Available at: https://www.bbc.com/news/58159451.

Hurteau, M., Bradford, J., Fulé, P., Taylor, A. and Martin, K., 2014. "Climate change, fire management, and ecological services in the southwestern US." Forest Ecology and Management, 327, 280–289.

Ilmailulaki, 7.11.2014/864. Available at: https://finlex.fi/fi/laki/ajantasa/2014/20140864.

Ilmailumääräys, OPS M1–34, 2018. Available at: https://www.finlex.fi/data/normit/44754/TRAFI_46233_03_04_00_00_2017_Tullin_ja_poliisin_lentotoiminta__metsapalovalvonta_ja_sammutuslennot_seka_etsinta_ja_pelastuslennot_FI_.pdf.

Joseph, M, Rossi, M., Mietkiewicz, N., Mahood, A., Cattau, M., St. Denis, L., Nagy, R., Iglesias, V., Abatzoglou, J. and Balch, J., 2019. "Spatiotemporal prediction of wildfire size extremes with Bayesian finite sample maxima." Ecological Applications, 29(6), 1266–1281.

Kang, Y., Jang, E., Im, J., & Kwon, C., 2022. "A deep learning model using geostationary satellite data for forest fire detection with reduced detection latency." GIScience & Remote Sensing, 59(1), 2019–2035.

Kelly, J., Ibáñez, T., Santín, C., Doerr, S., Nilsson, M., Holst, T., Lindroth, A. & Kljun, N., 2021. "Boreal forest soil carbon fluxes one year after a wildfire: Effects of burn severity and management." Global Change Biology, 27(17), 4181–4195. https://doi.org/10.1111/gcb.15721

Khabarov, N., Krasovskii, A., Obersteiner, M., Swart, R., Dosio, A., San-Miguel-Ayanz, J., Durrant, T., Camia, A. & Migliavacca, M., 2016. "Forest fires and adaptation options in Europe." Regional Environmental Change, 16(1), 21–30. https://doi.org/10.1007/s10113-014-0621-0

Kinver, M., 2021. "Then and now: The burning issue of wildfires." BBC News. Available at: https://www.bbc.com/news/science-environment-57946155.

Kosenius, A., Tulla, T., Horne, P., Vanha-Majamaa, I. & Kerkelä, L., 2014. "Metsäpalojen torjunnan talous ja ekosysteemipalvelut – Kustannusanalyysi Pohjois-Karjalasta." PTT Working papers, 165.

Koutsias, N., Allgöwer, B., Kalabokidis, K., Mallinis, G., & Goldammer, J. G., 2013. "Remote sensing-based fuel-type mapping and fire behavior modeling in a Mediterranean landscape." International Journal of Wildland Fire, 22(4), 493-5033.

KSAK. Motorflygförbundet 2019. Drifthandbok. Available at: https://ksak.se/brandflyg/.

KSAK. No date. "Om Brandflygportalen." Website. https://brandflyg.ksak.se/about. Accessed 25.4.2024.

Kukuk, M., & Kilimci, Z., 2023. "A comparison of traditional classifiers and deep neural networks for forest fire detection." Journal of Ambient Intelligence and Humanized Computing, 14(1), 1–12.

Kurvinen, 2023. "Metsäpalojen lentotähystys ohje 2023." Pohjois-Suomen aluehallintovirasto.

Lag om offentlig upphandling, 2016:1145. Available at: https://lagen.nu/2016:1145.

Lag om skydd mot olyckor, 2003:778. Available at: https://www.riksdagen.se/sv/dokument-och-lagar/dokument/svensk-forfattningssamling/lag-2003778-om-skydd-mot-olyckor_sfs-2003-778/&ved=2ahUKEwj15ter8NyFAxXbQlUIHfLWAlwQFnoECBkQAQ&usg=AOvVaw2-siOemcBJqaXM-w3fsiBE.

Li, W., Wang, J., & Li, X., 2019. "A review of remote sensing applications in forest fire research." International Journal of Wildland Fire, 28(8), 563–576.

Lindberg, H., Punttila, P., & Vanha-Majamaa, I., 2021. "Metsien monimuotoisuuden ylläpitämiseksi tarvitaan kulotusta ja metsäpaloalueiden suojelua." Metsätieteen aikakauskirja, 2021-10523. https://doi.org/10.14214/ma.10523

Lindner, M., Maroschek, M., Netherer, S., Kremer, A., Barbati, A., Garcia-Gonzalo, J., Seidl, R., Delzon, S., Corona, P., Kolström, M. and Lexer, M., 2010. "Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems." Forest ecology and management, 259(4), pp.698–709.

Lov om luftfart LOV-1993-06-11-101. Available at: https://lovdata.no/dokument/NL/lov/1993-06-11-101?q=LOV-1993-06-11-101.

Luftfartsförordning (2010:770). Available at: https://www.riksdagen.se/sv/dokument-och-lagar/dokument/svensk-forfattningssamling/luftfartsforordning-2010770_sfs-2010-770/.

MSB, 2019a. ''Utvärdering av MSB:s arbete i samband med skogsbränderna 2018.'' Myndigheten för samhällsskydd och beredskap, MSB1353–Februari2019. https://www.msb.se/sv/publikationer/utvardering-av-msbs-arbete-i-samband-med-skogsbranderna-2018/.

MSB, 2019b. ''Nationell risk- och förmågebedömning 2019.'' Myndigheten för samhällsskydd och beredskap, MSB1392–Maj2019. https://www.msb.se/sv/publikationer/nationell-risk--och-formagebedomning-2019/.

MSB, 2019c. ''Building Resilience in the Nordic Region: A Swedish Perspective.'' Myndigheten för samhällsskydd och beredskap, MSB1395–May2019. https://www.msb.se/siteassets/dokument/publikationer/english-publications/building-resilience-in-the-nordic-region---a-swedish-perspective.pdf.

MSB, 2023. ''Skogsbrandbevakning med flyg – inriktning för 2024.'' Myndigheten för samhällsskydd och beredskap, 2023-16798. https://www.msb.se/contentassets/904101e15c6c43a89492ca651f4efc82/msb-2023-16798-2-skogsbrandbevakning-med-flyg---inriktning-for-2024.pdf.

MSB, 2024. ''Skogsbrandbevakning med flyg.'' Website. https://www.msb.se/sv/amnesomraden/skydd-mot-olyckor-och-farliga-amnen/naturolyckor-och-klimat/skogsbrand-och-vegetationsbrand/skogsbrandbevakning-med-flyg/. Accessed 13.3.2024.

OECD- 2018. National Risk Assessments: A Cross Country Perspective. OECD Publishing, Paris, https://doi.org/10.1787/9789264287532-en.

Pelastuslaki 29.4.2011/379. Available at: https://finlex.fi/fi/laki/ajantasa/2011/20110379.

Puustinen, A. (ed.), 2022. ''Kalajoen Raution metsäpalo 2021. Kokemuksia ja oppeja metsäpalo-osaamisen kehittämiseen.'' Pelastusopiston julkaisu, D-sarja, 3. http://info.smedu.fi/kirjasto/Sarja_D/D3_2022.pdf.

Ribeiro-Kumara, C., Köster, E., Aaltonen, H., & Köster, K., 2020. ''How do forest fires affect soil greenhouse gas emissions in upland boreal forests? A review.'' Environmental Research, 184. https://doi.org/10.1016/j.envres.2020.109328

Ruuska, R., 2020. ''Suomen maasto- ja metsäpalojen torjuntamenetelmän kehittäminen. Case vertailu Suomen ja Ruotsin järjestelmistä.'' Master's Thesis. Lappeenranta-Lahti University of Technology LUT.

Salis, M., Ager, A., Finney, M., Arca, B. and Spano, D., 2014. ''Analyzing spatiotemporal changes in wildfire regime and exposure across a Mediterranean fire-prone area.'' Natural Hazards, 71(3), 1389–1418.

San-Miguel-Ayanz, J., Schulte, E., Schmuck, G., Camia, A., Strobl, P., Libertà, G., Giovando, C., Boca, R., Whitmore, C. & Loffler, P., 2013. ''Comprehensive monitoring of wildfires in Europe: the European Forest Fire Information System.'' Journal of Applied Remote Sensing, 7(1), 0751012

Saydirasulovich, S. N., Mukhiddinov, M., Djuraev, O., Abdusalomov, A., & Cho, Y. I., 2023. ''An improved wildfire smoke detection based on YOLOv8 and UAV images.'' Sensors, 23(20), 8374.

Sifakis, N. I., Iossifidis, C., Kontoes, C., & Keramitsoglou, I., 2011. ''Wildfire detection and tracking over Greece using MSGSEVIRI satellite data.'' Remote sensing, 3(3), 524–538.

Silvast, A., Kongsager R., Lehtonen, T., Lundgren, M., & Virtanen, M., 2021. '' Critical infrastructure vulnerability: a research note on adaptation to climate change in the Nordic countries.'' Geografisk Tidsskrift-Danish Journal of Geography, 121(1), 79–90. DOI: 10.1080/00167223.2020.1851609

Sjökvist, A. & Strömberg, I., 2015. ''Rapport från Skogsbrandsutredningen.'' Justitiedepartementent. https://www.regeringen.se/rapporter/2015/03/rapport-fran-skogsbrandsutredningen/.

Soisalo, J., 2021. ''Metsäpalojen tähystystoiminnan arviointi ja kehittäminen.'' Master's Thesis, University of Oulu.

Staiger, S., 2020. ''Climate forecast points to an active fire season in the Western Amazon – interactive fire forecast tool now available.'' Servir-Amazonia. Available at: https://servir.ciat.cgiar.org/climate-forecast-points-to-an-active-fire-season-in-the-western-amazon/.

Thangavel, K., Spiller, D., Sabatini, R., Amici, S., Sasidharan, S. T., Fayek, H., & Marzocca, P., 2023. ''Autonomous Satellite Wildfire Detection Using Hyperspectral Imagery and Neural Networks: A Case Study on Australian Wildfire.'' Remote Sensing, 15(3), 720.

The European Commission, 2021. ''Commission Implementing Regulation (EU) 2021/965 of 9 June 2021 amending Implementing Regulation (EU) 2020/194 as regards the exchange of records held by taxable persons or their intermediaries and the designation of competent authorities responsible for coordinating administrative enquiries.'' Official Journal of the European Union 214/1. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021R0965.

The European Parliament and The Council of the European Union, 2018. "Regulation (EU) 2018/1139 of the European Parliament and of the Council." Official Journal of the European Union, 212/1. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1139.

The European Parliament and The Council of the European Union, 2014. "DIRECTIVE 2014/24/EU of the European Parliament and of the Council on Public Procurement." Official Journal of the European Union, 94/65. https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32014L0024.

Valtioneuvosto, 2015. Valtioneuvoston asetus aluehallintovirastoista annetun valtioneuvoston asetuksen 12 ja 13 §:n muuttamisesta. Available at: https://finlex.fi/fi/laki/alkup/2015/20151742.

van Wagtendonk, J., Moore, P., Yee, J. and Lutz, J., 2020. "The distribution of woody species in relation to climate and fire in Yosemite National Park, California, USA." Fire Ecology, 16(1), pp.1-23.

Venäläinen, A., Lehtonen, I., & Mäkelä, A., 2016. "Laaja-alaisia metsäpaloja mahdollistavat säätilanteet Suomen ilmastossa." Finnish Meteorological Institute Reports 2016: 3.

Venäläinen, A., Lehtonen, I., Laapas, M., Ruosteenoja, K., Tikkanen, O., Viiri, H. & Peltola, H., 2020. "Climate change induces multiple risks to boreal forests and forestry in Finland: A literature review." Global change biology, 26(8), 4178–4196.

Vitikka, A. No date. "Map of Bioclimatic Subzones & Boreal Forests." University of Lapland, Arctic Centre. https://www.arcticcentre.org/EN/arcticregion/Maps/bioclimatic_subzones. Accessed 9.4.2024

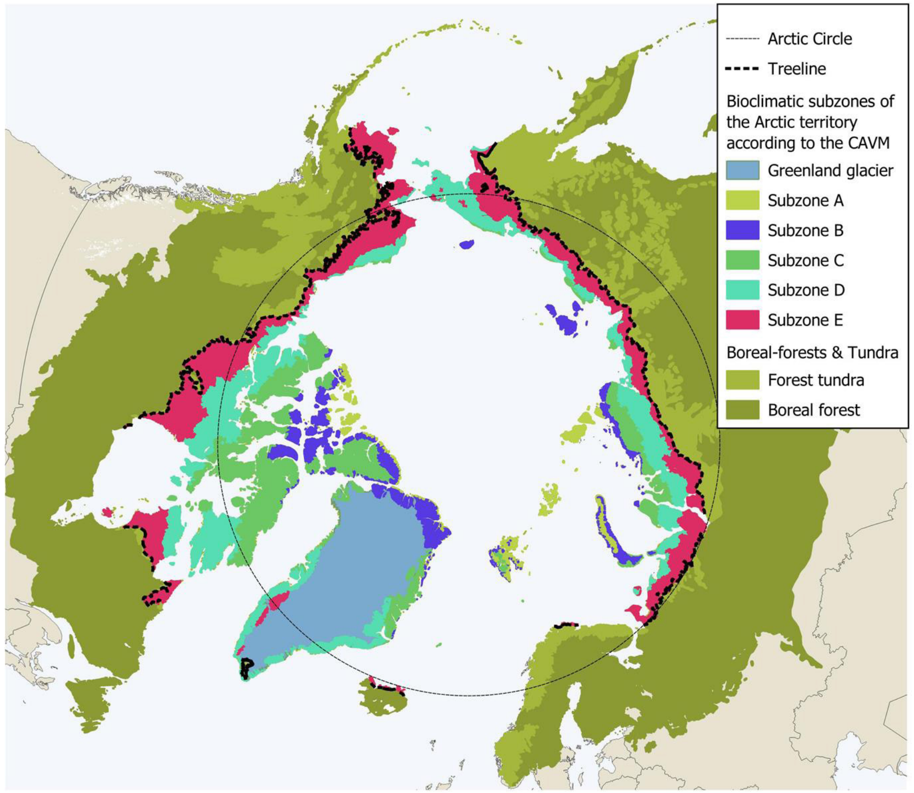
Westerling, A., Hidalgo, H., Cayan, D. and Swetnam, T., 2006. "Warming and earlier spring increase western US forest wildfire activity." Science, 313(5789), pp. 940–943.

Yang, X., Tang, L., Wang, H., & He, X., 2019. "Early detection of forest fire based on unmaned aerial vehicle platform." In 2019 IEEE International Conference on Signal, Information and Data Processing (ICSIDP), 1–4. IEEE.

10. Annex

10.1. Annex 1. Map of Bioclimatic Subzones & Boreal Forests

Vitikka, A. No date. “Map of Bioclimatic Subzones & Boreal Forests.” University of Lapland, Arctic Centre Website. https://www.arcticcentre.org/EN/arcticregion/Maps/bioclimatic_subzones. Accessed 25.4.2024



10.2. Annex 2. Project FIREBAR, networking events

Date	Organisor	Topic	Location
January 2023	CTIF Nordic	Introduction of the project FIREBAR	MS Teams
May 2023	Jämijärvi Aerial Fire Fighting Training	Introduction of the project FIREBAR	Jämijärvi, Finland
September 2023	CBSS, Finnish Ministry of Interior	Aerial Wildfire Monitoring Workshop	Helsinki, Finland
September 2023	Finnish Assocation of Fire Officers	Future of the fire and rescue services in the Arctic region seminar	Rovaniemi, Finland
January 2024	Finnish National Rescue Assocation	Barents Region Aerial Forest Fire Surveillance Workshop	Oulu, Finland
March 2024	MSB	Skogsbrand 2024 conference participation	Östersund, Sweden

10.3. Annex 3. Project FIREBAR Interviews

Date	Organisation	Organisation type	Location
August 2023	Royal Swedish Aeroclub KSAK	Non-governmental organisation	Stockholm, Sweden
October 2023	Swedish Civil Contingencies Agency MSB	Authority	Karlstad, Sweden
October 2023	Regional State Administrative Agency of North Finland PSAVI	Authority	MS Teams
November 2023	County Administrative Board Västerbotten	Authority	Umeå, Sweden
November 2023	Umeå Flygklubb (Flight club)	Flight club	Umeå, Sweden
November 2023	Norwegian Directorate for Civil Protection DSB	Authority	Tønsberg, Norway
November 2023	Grenland Fire and Rescue Department	Authority	Skien, Norway
November 2023	Norwegian Air Sports Federation NLF	Non-governmental organisation	Oslo, Norway
February 2024	Finnish Air Rescue Association SLPS	Non-governmental organisation	Helsinki, Finland
February 2024	Lapin Ilmailuyhdistys (Flight club)	Flight club	MS Teams
February 2024	Hedmarken Fire Service & Midt-Hedmark Fire and Rescue Service	Authority	MS Teams
February 2024	Sandefjord Flyklubb (Flight club)	Flight club	MS Teams

10.4. Annex 4. Data of the Swedish and Finnish forest fire surveillance between 2018–2023

Sweden	Flight time in hours**	Flight time training flights	Detected fires *	Costs in € (converted with the average yearly exchange rate from Crowns to Euros)	Number of flights **	Number of training flights	Total amount of wildfires ***
2018	11008	145	688	2 910 483 €	5064	146	4572
2019	3252	165	151	1 024 881 €	1612	155	2805
2020	5014	166	160	1 473 644 €	2238	182	2651
2021	3296	156	114	1 071 094 €	1415	151	1815
2022	3294	147	133	1 079 465 €	1531	156	3043
2023	5054	132	163	1 610 937 €	2309	173	2831

* Total amount of fires detected (incl. Fires detected during the surveillance flight, training flights and fires detected by verifying external observations.)
**excluding training flights
***Fires labeled as incident in productive forest land or other land with tree cover, from national statistics based on incident reports

Finland	Flight time in hours	Flight time training flights	Detected fires *	Costs in €	Number of flights	Number of training flights	Total amount of wildfires
2018	3304	N/A	281	N/A	1286	N/A	4412
2019	1780	N/A	177	785 801 €	699	N/A	3046
2020	1646	N/A	192	724 824 €	639	N/A	2780
2021	2356	N/A	234	1 098 357 €	891	N/A	2450
2022	1021	N/A	95	482 673 €	392	N/A	2370
2023	1155	N/A	113	596 397 €	446	N/A	2571

* Total amount of fires detected (incl. Fires detected during the surveillance flight and fires detected by verifying external observations)

10.5. Annex 5. Barents Region Aerial Forest Fire Surveillance Workshop, Brainstorming questions

Topic: Organising international cooperation in forest fire surveillance

Questions from groups:

- How can we share information and experiences?
- How can we find new ways to cooperate?
- How often do responsible parties meet?
- How should we organise international cooperation?
- How should we proceed in cooperation?
- How can we get more people together?
- How to measure the benefits?

- What are the benefits?
- What are the highest barriers to get over?
- What are the levels of cooperation?
- What are the limits/restrictions?
- What are the organisational levels/action groups?
- What can we share in terms of experiences and information?
- What expectations do we have for cooperation?
- What groups are involved in international cooperation?
- What is the main topic?
- What platforms can be used for it?
- What techniques are on the market?

- When should we start cooperation?

- Where could we find the best practices?
- Where does the cooperation happen geographically?
- Where would the database be located at?

- Who belongs to the network?
- Who coordinates co-operation?
- Who gets the knowledge of the aerial surveillance?
- Who is involved?
- Who is responsible for organising?
- Who maintains the networks?
- Who pays?

- Why should we have international cooperation?
- Why haven’t we got to cooperate already?

The Finnish National Rescue Association

SPEK