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# Modelling the Potential Size of Swedish 2022 Forest Fire Areas

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Bachelor thesis, 15 credits, in Physical Geography and Ecosystem Analysis

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Abstract

Forest fires are a danger both to society and to the climate. The forestry sector is an important and large element of Sweden's economy, nature and landscape. Forest fires directly impact the economic viability of the forest industry and the people dependant on it. Forest fires also impact society, by necessitating measures to combat and prevent forest fires, and endangering human lives. A key part of effective forest fire response is the ability to comprehend the behaviour and spread of fires, thus being able to predict and prepare for potential fires. This is mostly done by implementation of predictive models that consider different variables, like weather, topography and fuel availability, to estimate the possible fire behaviour. This study attempts to model the potential area that selected Swedish forest fires could have achieved were they to have been undisturbed. This is done by selecting eight forest fire sites from 2022 and using the historical Fire Weather Index (FWI) precent for these sites to estimate the possible direction of forest fire spread. This is combined with a Land Cover dataset to dictate which areas could host a forest fire and which could not. Six different sensitivity assumptions were made for how the FWI would impact the forest fire spread as well as three assumptions for how far the forest fire would be able to spread. All the modelling was carried out in a GIS program. In total 144 different forest fire areas were estimated. The modelling approach used has some virtue, particularly due to easily accessible data, but would need to be further developed and compared to other model outputs to be able to give an indicator of effectiveness.

**Keywords: GIS, Fire Weather Index (FWI), Forest Fire, Sweden, 2022.**

# Contents

# 1 Introduction:

Sweden is a northern European country located on the Scandinavian Peninsula which extends about 1600 km to the north and about 500 km east to west with about 15% of the land area within the Arctic Circle (Weibull, 2024). Sweden is traditionally divided into three main regions, those being Norrland making up the northernmost part of the country, Svealand being the heartland and Götaland in the south. Most of the population is focused in Svea- and Götaland with most of Norrland sparsely populated. According to the Köppen-Geiger climate classification scheme Sweden falls within two different classes, Dfb: Cold without a dry season with a warm summer and Dfc: Cold without a dry season and with a cold summer (Beck et al., 2018). Sweden is mainly exposed to south-western or western winds coming in from the north Atlantic, creating for the latitude mild winter conditions (*Sveriges klimat (Swedens Climate)*, 2009). Forests and forestry take up large amounts of Sweden's landcover, with forested land making up 69% of the total Land Cover (Petersson., 2023). In total 58 % of Sweden's land is classed as productive land, pliable for forestry, of which 82 percent is coniferous (Petersson., 2023). Conifers are more prone to forest fires compared to deciduous forest types (Parviainen, 1996; Päätalo, 1998). As such forest fires, their regularity and spread, are important to Sweden both economically and socially.

The occurrence of forest fires is based on climate and modified by patterns of ignition, topography and fuel availability (Pinto et al., 2020). As a result of human activity, both via climate change and fire suppression, forest fires are directly affected in their behaviour and occurrence (Drobyshev et al., 2012). A way to measure the impact had by weather on the ability of forest fires to break out and start is a Fire Weather Index (FWI). Sweden, specifically the Myndigheten för samhällsskydd och beredskap (ENG: The Swedish civil contingences agency), shortened to MSB, uses the Canadian Forest Weather Index to predict the prevailing weather conditions and how well they allow for forest fire spread ((MSB), 2024; Van Wagner, 1987). The Canadian FWI encompasses the amount of fine fuel able to burn, the moisture and saturation of the material and the wind speed and direction ((MSB), 2024; Van Wagner, 1987). The FWI value gives a general description of the fire behaviour in regards to the prevailing dryness and weather conditions ((MSB), 2024)

Differences between tree species have an impact on the possibility and ability of forest fires to start. The rate of decomposition within the understories of coniferous stands are more prone to fire both as a result of present natural vegetation, lichen and mosses, and of a slower rate of decomposition (Johnson, 1992). This is in addition to the lower ability of deciduous species to support crown fires, as the moisture of deciduous leaves make up 150% of the dry weight contra the 100% of dry weight for the coniferous needles (Johnson, 1992). Overall, the more deciduous trees precent within a stand the lower the rate of fire spread.

It is interesting, both from an ecological and economical perspective, to see whether it is possible to predict the potential sizes of forest fires using easily and readily available spatial data.

## 1.1 Study Aim and Research Questions:

As the ability to predict the spread of a forest fire would be beneficial in both preventing and combating possible fires. The simplest way to do this is to investigate historic forest fires and how much they spread. The goal of this study is to see the effect of using FWI as an input proxy for modelling the possible spread of selected Swedish forest fires of 2022. Different assumptions of how fire could spread based on the prevailing historic FWI values are to work as a form of sensitivity analysis.

### 1.1.1 Research Questions:

- Will there be a large variation in the amount of land burned depending on the FWI based assumption?
- Is there a noticeable difference between the historical fires and the potential fire areas?

The expected outputs are forest fire areas of variating size and spread. It is interesting to see whether there are any noticeable patterns of variation between the selected sites and between the different assumptions made.

# 2 Method:

## 2.1 Site Selection and Description:

First the locations and times of the fires were investigated and the year 2022 was selected. This was due to 2022 allowing the best possible crossover with the Fire Weather Index (FWI) data, as the current FWI data collection was started first in 2021. Therefore, the year of 2022 was selected as it was a year with FWI data coverage and had recorded forest fires in the Skogsstyrelsen (ENG: Swedish Forestry Agency) data (Skogsstyrelsen, 2023). It was of interest to compare the historically large and small fires to each other. Thus, three largest fires of 2022 and the three fires closest to one hectare were selected. The small fires were in southern Sweden and the large fires in northern Sweden. The reason for choosing three locations for large and small fires was to have a better ability to compare the results based on size. The choice of one hectare as the basis for small fires was to provide with fires that should be somewhat sizable and be seen relatively easily form satellite imagery. These locations can be seen in Table 1 with the historic extent of the fire and the given dates for the fire. The locations can be seen on a national map of Sweden in Figure 1.

*Table 1. Study sites, their historic fire area extent and the dates they are believed to have been burning. For the sites of Matts myra and Kalmar two days are shown as it was not possible to eliminate any of the days further.*

| Name: | Area Hectares: | Dates: |
|---|---|---|
| Mörtatjärnarna | 94.77 | 08-15/22 |
| Honkavaara | 40.58 | 06-28/22 |
| Matts myra | 30.96 | 06-26/22, 06-27/22 |
| Kalmar | 1.12 | 05-01/22, 05-02/22 |
| Valdermansvik | 1.01 | 07-31/22 |
| Kullevik | 1.06 | 05-09/22 |

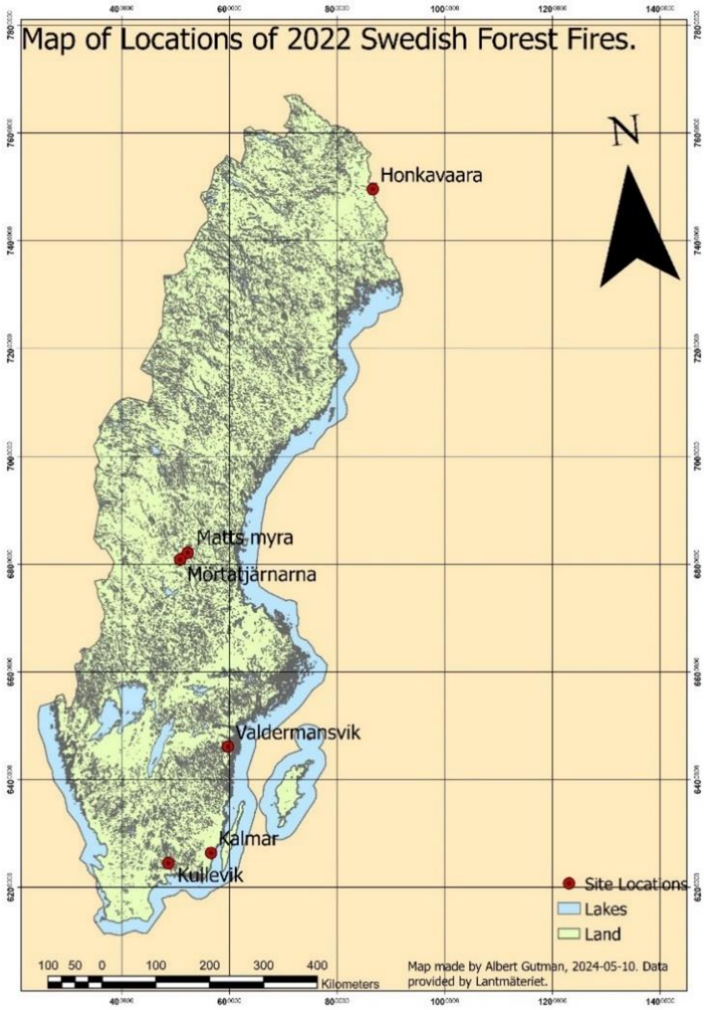


*Figure 1. Map of selected forest fire site locations for 2022, Sweden.*

### 2.1.1 Mörtatjärnarna:

The site for the largest single fire of 2022, located in northeast of the town of Mora in the province of Dalarna in northern central Sweden. Figure 3 in Appendix 1 illustrates the local landscape features for the area, including the extent of the historic fire. The site has a large lake complex bordering it to the east and south and few roads in the area. Most of the landcover is forest peppered with wetlands.

### 2.1.2 Honkavaara:

The northernmost of the selected sites for 2022, and the second largest for the year. Figure 3 in Appendix 1 shows the local landscape and Land Cover of the site along with the historic fire area. The site is bordered by a road in the west and south and by open wetlands in the north and east. A lot of the local Land Cover is classed as open wetlands with multiple rivers flowing west to east.

### 2.1.3 Matts myra:

The third largest forest fire site for 2022 is located not far away from the Dalarna-Gävleborg border, on the Gävleborg side. The site is almost fully enclosed either by lakes to the north, west and east or rivers to the south and east. Placing the historic fire area almost on an island., as can be seen in Figure 1 in Appendix 1.

### 2.1.4 Kalmar:

This site is in Kalmar County, in southern Sweden. The site itself can be seen in Figure 1 in Appendix 1, where it is located a bit to the side of a road. Most of the site is forested with some wetlands and fields adjoining.

### 2.1.5 Valdermansvik:

Located in southern central Sweden the Valdermansvik site is located north of the actual city of Valdermansvik. The historic fire site is in a large forest section surrounded by roads, as can be seen in Figure 2 in Appendix 1.

### 2.1.6 Kullevik:

This is the southernmost forest fire site selected, located in Blekinge county. The historic fire area is located close to two roads, one in the west and one in the south, and has further roads and powerlines creating a section of unified forest, as can be seen in Figure

2 in Appendix 1. Most of the local landcover is different forms of mixed forest with recurring wetlands.

## 2.2 Data Acquisition and Preparation:

The first part of the workflow was the finding and requisitioning of data (see Table 2). The landcover and Fire Weather Index data was freely available, but the forest fire locations both from Skogsstyrelsen and MSB (MSB, n.d) were acquired by email communication with the respective parties.

The FWI is obtained from SMHI and is a modelled product (*Brandrisk skog och mark – Fakta och modeller*, 2024). It provides point values covering all of Sweden in a 2.8 km spaced grid. The model uses past precipitation (24 h), temperature, wind direction and relative humidity. Of interest is the produced FWI values and their spatial coordinates.  A secondary value of interest for simplification of analysis is the FWI-Index which is a classification scheme implemented in Sweden to simplify comprehension. The FWI-Index has 6 values ranging from low to high fire chance, more details can be found in “Brandrisk skog och mark-Fakta och Modeller” from 2024 which is a more extensive documentation of the FWI. The FWI-Index was used only to determine what FWI values would result in what type and severity of fire.

The polygon fire locations were gained from interpersonal communication with the Swedish Forestry Agency, although the data is publicly available it is not easily downloadable. The polygon layer consists of a recorded fire, the year of its happening and in some cases the day and month. Some fires also have a given name, cause of ignition and how it was recoded (Skogsstyrelsen, 2023). The point layer for fire instances was provided by MSB after interpersonal communication. It is an Excel sheet which has a lot of different information recorded, of note is the coordinates for a recorded fire and the day of callout. This allows for dating the fire instances to determine which days of FWI is necessary. The data itself is available to the public at request but not easily obtained without intrapersonal communication.

*Table 2. Showing the type of data used, its name and the source of origin.*

| Data Name: | Data Type: | Source: | Reference: |
|---|---|---|---|
| Landcover. | Raster-Geo TIFF, 10 m. | Naturvårdsverket. | (Naturvårdsverket, 2022) |
| Fire Weather Index (FWI). | Excel workbook | SMHI. | (SMHI, 2021) |
| Forest fires 2018 to 2023. | Shapefile, Fires > 0.5 ha. | Skogsstyrelsen. (ENG: Swedish Forestry Agency) | (Skogsstyrelsen, 2023) |

| | | | |
|---|---|---|---|
| Forest fires 2018 to 2023. | Excel workbook, Fires > 0.5 ha. | Myndigheten för Samhällsskydd och Beredskap (MSB). | (MSB, n.d) |

The dates of the fires were based on a few different factors. First, the forest fires 2018 to 2022 data set provided by MSB was consulted. The Excel sheet was turned into a point layer that recorded the location and time of a reported fire to MSB. These points did not give a clear day of fire for all the selected fire areas. Mörtatjärnarna, Matts myra, Kullavik and Kalmar all had some number of discrepancies. The selected Kalmar site had no point recorded exactly on the area of fire, but it had two points recorded close to the burned area. This was seen by comparing the location of reported forest fires (MSB, n.d) to the location of reported polygons (Skogsstyrelsen, 2023). These points provided dates of 05-01 and 05-02. These days were investigated using the Copernicus browser (*Copernicus Data Space Ecosystem*, 2024) which could confirm that the fire occurred one of those days but could not specify further.

Kullevik was also missing a point for fire location, but it was possible to determine the day to being the 05-09 based on a newspaper article ("Flera styrkor bekämpade skogsbrand," 2022). This day was verified using the Copernicus browser, but a precise estimation was not possible to attain due to heavy cloud cover over the area of interest. For the sites of Matts myra and Mörtatjärnarna there were no point provided by MSB in the vicinity, so they were investigated using the Copernicus browser to create a range of days where the fire could occur. To further eliminate possible days the FWI values with the areas were investigated for each range of days. Those days with a lower FWI value than 10 were discarded. This resulted in one day with high values for Mörtatjärnarna (Figure 3) and two days of relatively similar FWI values for Matts Myra (Figure 2 and 3). For the sites of Valdermansvik and Honkavaara the MSB points corresponded well with the fire area polygons and with the observed Copernicus satellite images.

The overall use of the Copernicus Browser (*Copernicus Data Space Ecosystem*, 2024) is to visually verify the times of fire for each location. Each location was investigated by first looking at the days of fire, if those were provided, or the closest days without cloud cover. For locations with no known date the first day with a visibly burned area was found and thereafter the first day without. This crated a range of days where a fire could have occurred, thus narrowing the window of opportunity.

Having selected the fire locations and the days the fires occurred the FWI values were turned into raster layers. First by turning the Excel records to a point layer, each point being 2.8 km apart. These points were then used to interpolate a 10 m raster layer using a first-degree polynomial interpolation function present within Arc GIS Pro 2.7 (ESRI, 2020).

As part of raster generation, the FWI raster(s) were snapped to the Land Cover raster to make sure they corresponded to each other spatially. Figures 4 and 5 in Appendix 1 illustrate the total interpolated area, whilst Figures 2 and 3 show the local FWI close to the burned areas.

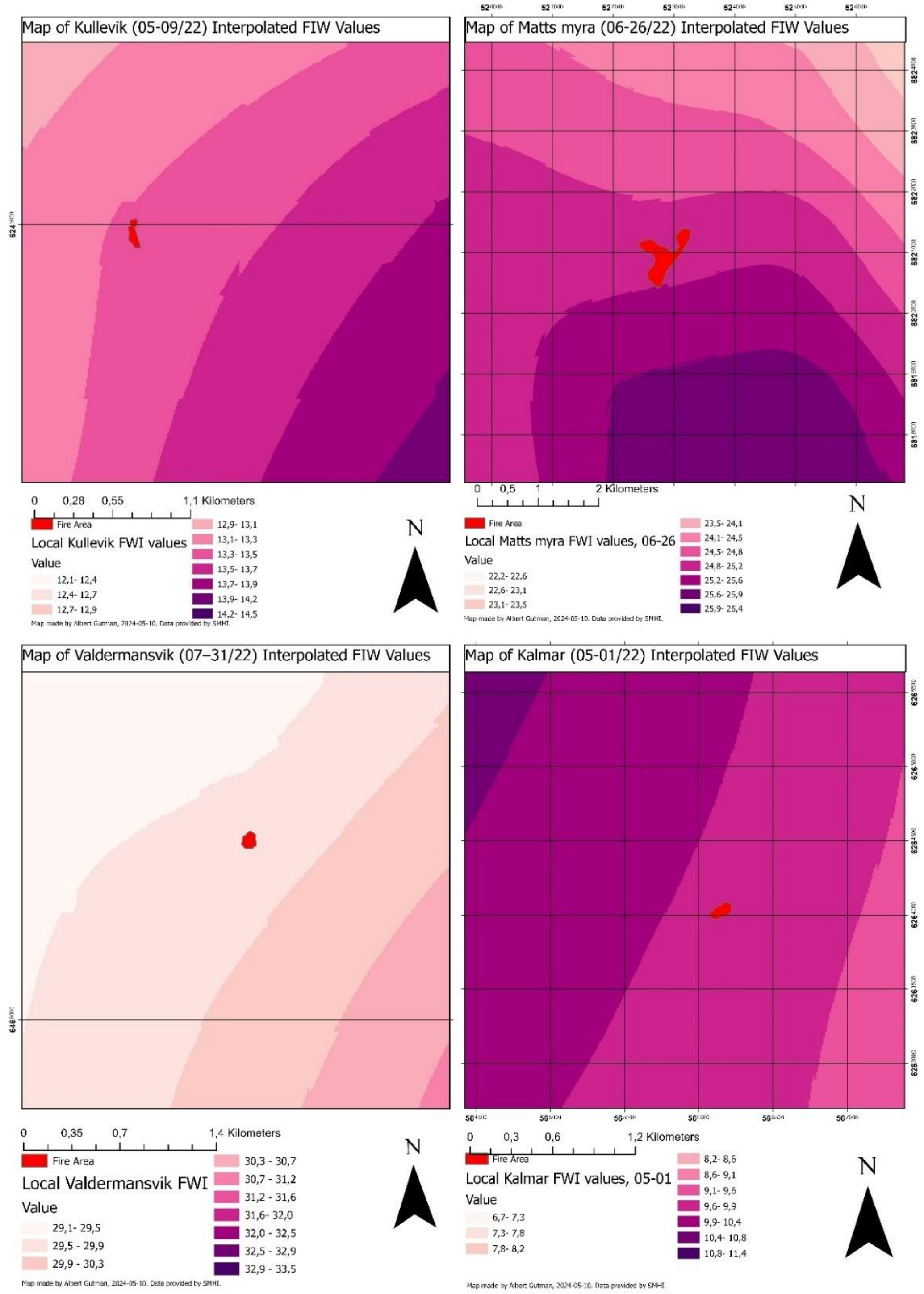


*Figure 2. Map of interpolated Local FWI values for Valdermansvik, Kalmar 05-01, Matts myra 06-26 and Kullevik.*

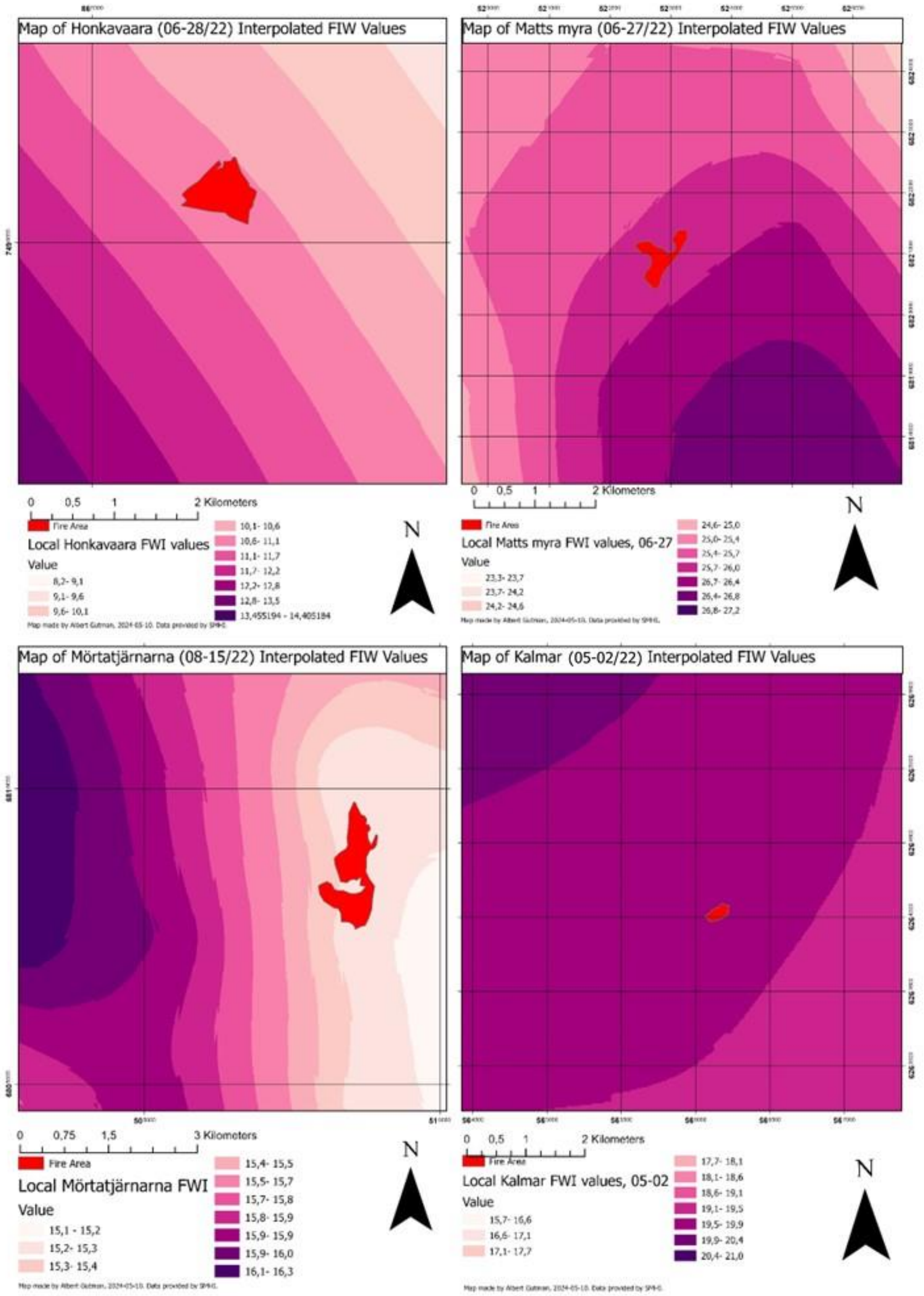


*Figure 3. Map shoving the local interpolated FWI values for Kalmar 05-02, Mörtatjärnarna, Matts myra 06-27 and Honkavaara.*

## 2.3 Geoprocessing:

The selected 2022 fire areas were extracted from the Forest fires 2018 to 2023 Shapefile. These polygons were turned into 10 m Raster(s) and snapped to the Land Cover layer to ensure minimal spatial deviation. The Land Cover raster was reclassified to gain the possible burnable areas and non-burnable areas. Forests that were not located on wetlands were given a value of 1, thus allowing fire to spread and areas that were deemed to not spread fire were assigned with the value of 0. Roads, water, open land and forests within wetlands were the main forms of Land Cover to not be able to spread the fire. Roads and water because they would have little to no ability to burn whilst open land would no longer be a forest, therefore not a forest fire. For wetland forests it was deemed that they would be more difficult to ignite due to their higher moisture content and therefore excluded as directly burnable areas. This was done using the "Reclassify raster" tool in Arc GIS and completed according to the scheme present in Appendix 1, Table 1, the classes having a full description in Naturvårdsverket (2022) (ENG: The Swedish Environmental Protection Agency). As a result of this classification all roads, electrical lines and waters become a hard limit for the possibility of the fire to spread, effectively stopping the fire no matter what. This means that a small forest road would be equally as hard a stop as a major highway. The with or area of generally open land would play no relevancy for its ability to burn, rather any amount of open land would be seen as inflammable.

The reclassified Land Cover raster(s) were turned to polygons, where the burnable area overlapping the historic area was selected and buffered. This was done to increase the potential area that could burn, effectively creating two further boarders for the burnable area.  This was done as it was reasoned that a forest fire would be able to spread beyond the hard boarders set for it by the burn classification. It was also thought that an isolated stand of wetland trees would eventually be able to burn given enough fire surrounding the stand.

The buffer distances used were 20 and 30 meters. These distances were chosen as a decent estimation of the average tree height, as when a burning tree falls it would be bringing with it burning material that could continue the spread of the fire. The buffered polygons were then rasterized creating three raster(s) per fire site. One with the potential burn area, called the 00 buffer as it had no buffer applied, it was simply the largest fire extent before reaching a natural limit. Then there were the 20 m and the 30 m buffer. The use of buffers was intended to work as a measure of sensitivity, particularly when it comes to the classification of burnable and non-burnable Land Cover. As the buffers will surpass the hard borders set for the potential fire spread.

The raster's containing the historic fire areas were multiplied with the FWI layers. This produced a layer with FWI values only within the areas of the historic fires. These historical FWI values were used to determine the minimum, maximum and mean values for FWI present within the burned areas at the time of them burning. These values were used to calculate the FWI at 25%, 50% and 75% of mean. This can be seen in Table 4.

*Table 3. Showing the derived FWI values for each day of fire for the historic fire areas. The M1 scenario is the FWI value that is Equal or higher than mean value in the original fire area. The M2 scenario is the FWI value that is Equal or higher than the highest value in the original area. The M3 scenario is the FWI value that is Equal or higher than the lowest value in the original area. The M4, M5 and M6 scenarios show the FWI value that is 75%, 50% and 25% less than the mean. The different derived numerical values were used as the cutoff point where all cells with a higher FWI value than*

| Locations | Matts myra 26 | Matts myra27 | Honka-vaara | Mörtat-järnarna | Valder-mansvik | Kalmar 01 | Kalmar 02 | Kullavik |
|---|---|---|---|---|---|---|---|---|
| Mean | 25.077 | 25.854 | 10.825 | 15.290 | 29.702 | 9.881 | 19.614 | 13.372 |
| Maximum | 25.218 | 25.942 | 11.079 | 15.387 | 29.724 | 9.900 | 19.622 | 13.387 |
| Minimum | 24.964 | 25.747 | 10.624 | 15.250 | 29.681 | 9.862 | 19.604 | 13.359 |
| Standard Deviation | 0.0591 | 0.0395 | 0.0992 | 0.0288 | 0.0109 | 0.0092 | 0.0046 | 0.0071 |
| M1 | 25.077 | 25.854 | 10.825 | 15.290 | 29.702 | 9.881 | 19.614 | 13.372 |
| M2 | 25.218 | 25.942 | 11.079 | 15.387 | 29.724 | 9.900 | 19.622 | 13.387 |
| M3 | 24.964 | 25.747 | 10.624 | 15.250 | 29.681 | 9.862 | 19.604 | 13.359 |
| M4 | 6.269 | 6.464 | 2.706 | 3.823 | 7.426 | 2.470 | 4.904 | 3.343 |
| M5 | 12.539 | 12.927 | 5.413 | 7.645 | 14.851 | 4.941 | 9.807 | 6.686 |
| M6 | 18.808 | 19.391 | 8.119 | 11.468 | 22.277 | 7.411 | 14.711 | 10.029 |

These scenarios were created so that it would be possible to simulate different types of forest fire spread. The assumptions were: Fire spreads to values equal to or greater than the mean FWI value present within the historic fire area (M1). Fire spreads to values equal to or greater to the highest FWI value present in the historic fire area (M2). Fire spreads to FWI values equal to or lower than the minimum value in the historic area (M3). Fire can spread to FWI values equal to or lower than 75%, 50% or 25% of the mean (M4, M5 and M6 respectively). The reason for these assumptions was the uncertainty of how fire spread would behave regarding the FWI index. It was reasoned that the fire would most likely be able to spread in relatively complex patterns and not necessarily in a predictable way. Therefore, multiple fire spread scenarios were proposed, see Table 3, depending on the FWI values present within the historic fire area. Since the area did burn historically the FWI values present within it would be sufficient to support a fire. So, to better simulate the way a fire could spread based on conditions known to facilitate forest fire the different M scenarios were decided upon.

The buffered and rasterized Land Cover layers were multiplied with the FWI index for the respective day to create the potential FWI ranges. These layers were then reclassified in accordance with the classifications presented in Table 3, where the different M values were set the value above which fire could spread. The product of this operation were layers with the potential burnable areas classed as a 1 and non-burnable areas classed as a 0.

These areas were then multiplied with the Land Cover layers, then subtracted with layers containing the Land Cover present in the historic areas. Creating layers containing only Land Cover that could potentially burn per scenario. This was done to ensure that the potential fire areas did not in any way overlap with the historic data, thus confusing the results by creating double values. The full simplified workflow can be seen in Figure 4 below.

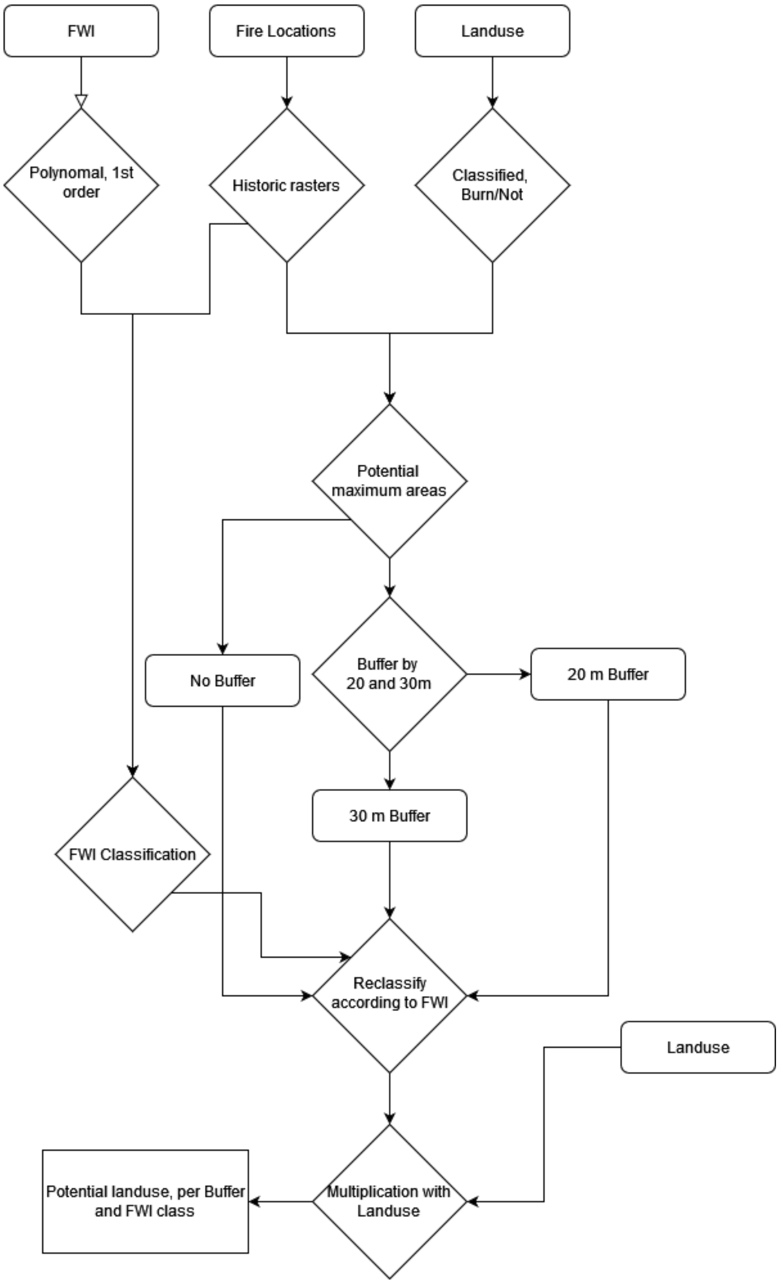


*Figure 4. Work flowchart showing the general steps taken in geoprocessing the acquired data to a potential burned Land Cover area per estimation of fire spread and buffer conditions.*

The resulting raster values were exported to Excel where they were grouped based on their area, buffer and fire spread scenario. The data was processed to remove Land Cover areas which could not have burned, like roads and water, which were added to the potential fire areas because of the buffers. Thereafter it was analysed and visualised to show the differences between the fire spread scenarios, buffers and the locations.

# 3 Results:

Figure 5 shows how the different buffer areas interact with each other for the site of Kullavik and the M2 condition. Particularly it shows how areas which would be excluded by the potential fire area, like forests on wetlands, would get burned by either the 20 or the 30 m fire area buffers. It also shows how the buffer areas can overcome the width of the roads and boarders surrounding the potential fire area thus being able to spread across the set boarders.

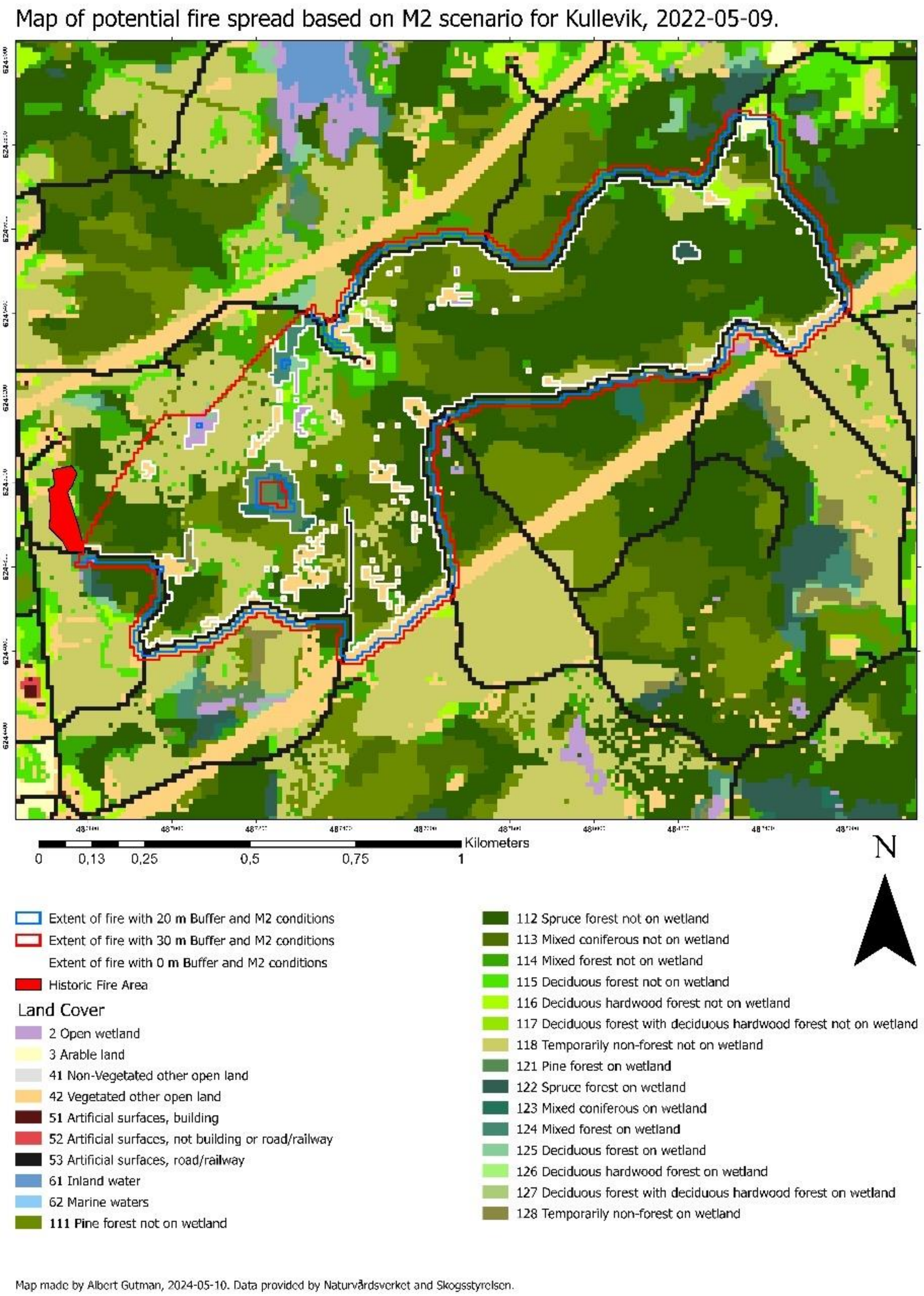


*Figure 5. Map showing an example output with the historic fire area and three different potential areas, white denoting no buffer, blue a 20m buffer and read a 30m buffer. With each buffer distance the size and number of enclaves, caused by forests growing on wetlands. The extension of the potential fire area past hard boarders, like roads, is also caused by the buffer zones.*

## 3.1 Burned area Graphs:

The resulting burned areas per M scenario is shown first as a comparison of total areas burned in Figures 6 to 13. The internal variation in percent can be seen in Figures 14 to 21. Here the amount of land burned is stacked, so whilst the potential area would as an example be showing 50 hectares of land burned and the historic fire showing 40 hectares burned the total would be 90 hectares burned for the potential area. The buffer areas show only those values that increase the burned areas, so the total burned area of the 30 m buffer is the sum of the shown 20 and 30 m buffers.

The main results are the prediction and projection of possible burned land area based on predetermined fire spread scenarios. Originally 6 total scenarios were conceived of to simulate different forms of fire spread see Table 4. The use of a percentile value of the mean was problematic approach as the result in all cases was a lower FWI value than the lowest value within the burned area.

Effectively this meant that scenario M4, M5 and M6 would produce the same burned area as they all allow for more fire to spread to lower FWI values than those present within the area of study. Therefore, scenario M5 and M6 are not shown in the results as they would have an identical range of values as M4.

The M4 scenario also has a different impact than what it was originally conceived to have. Instead of showing a fraction of burned area it is instead an indicator for the maximal burnable area. Therefore, the M4 scenario should be seen as the full potential burn area. An example of this would be Kalmar 05-01 and 02 (Figures 11 and 12) where the M1 to M3 scenarios predict a rather low amount of burnable land whilst the M4 scenario is noticeably higher.

Kullevik (Figure 6) has a potential area which variates between 73 and 84 hectares, M2 and M4 respectively. Depending on the possible buffer to that is added 17.5 hectares for the 20 m, and 7 hectares more for the 30 m buffer.

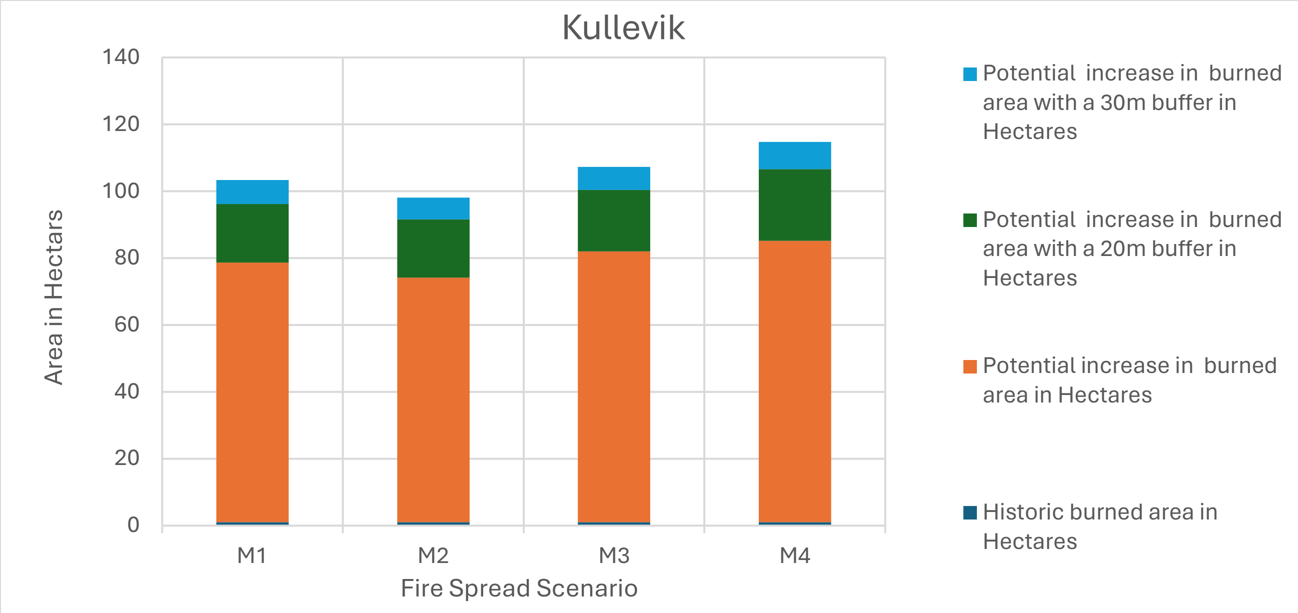


*Figure 6. Showing the amount of historic and potential burned area in Hectares for the area of Kullevik. The historical fire covered an area of 1.8 Hectares with the potential fire area between 73 and 84 Hectares. The potential buffer extends increase the burned area with about 17.5 Hectares for the 20 m buffer and a further increase 7 Hectares for the 30 m buffer.*

Matts myra 06-27 and 06-26, Figures 7 and 8 respectively, have the second largest historical fire area at 31 hectares. Matts myra (Figure 7) 06-27 has a potential fire area between 7.48 (M1 scenario) and 21 (M4). Depending on the buffer length the burned area increases by an average of 2 hectares (for the 20 m buffer) and roughly an additional 2 hectares for the 30 m buffer. For the M2 scenario the 20 m buffer increase is 0.8 hectares, and the 30 m buffer is 1.6 hectares.

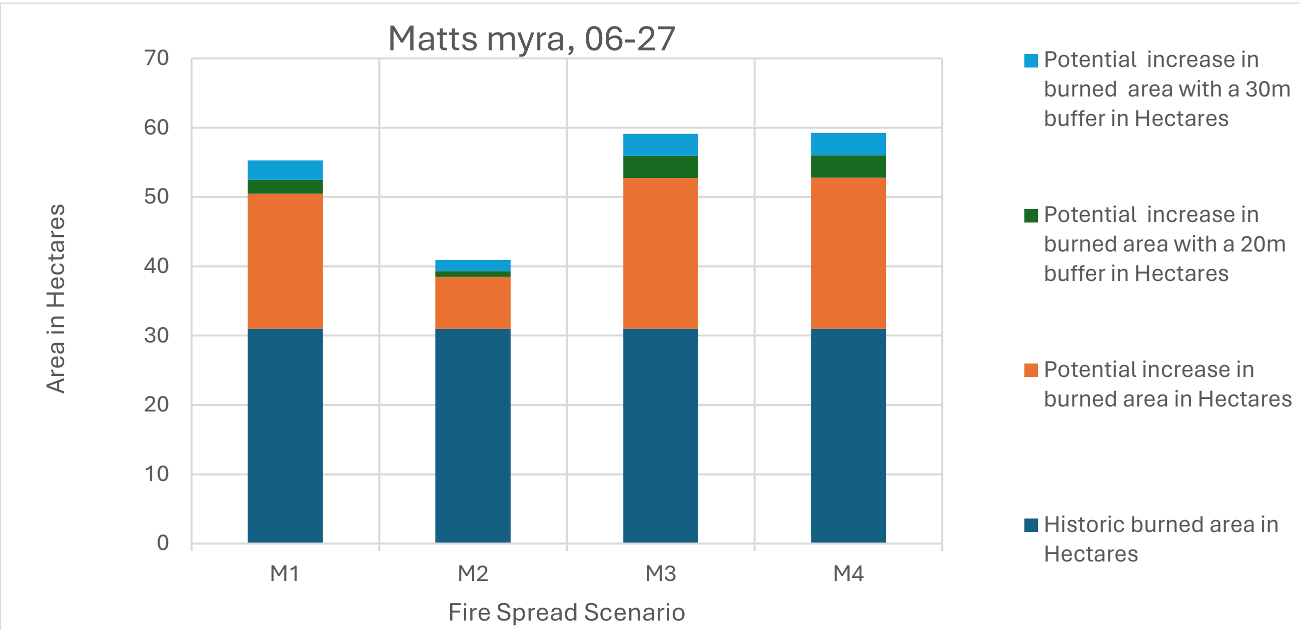


*Figure 7. Showing the amount of historic and potential burned area in Hectares for the area of Matts myra, 06-27. The historical fire covered an area of 31 Hectares with the potential fire area of between*

*7.48 and 21 Hectares. The potential buffer increases the burned area with about 2 Hectares for the 20 m buffer and roughly 2 Hectares for the 30 m buffer.*

Matts myra 06-26 (Figure 8) has somewhat higher overall values for the potential fire area variating between 11.8 to 21.8 between M2 and M4 scenarios. The fire areas increase by an average of 2.6 for the 20 m buffer and 2.8 hectares more for the 30 m buffer.

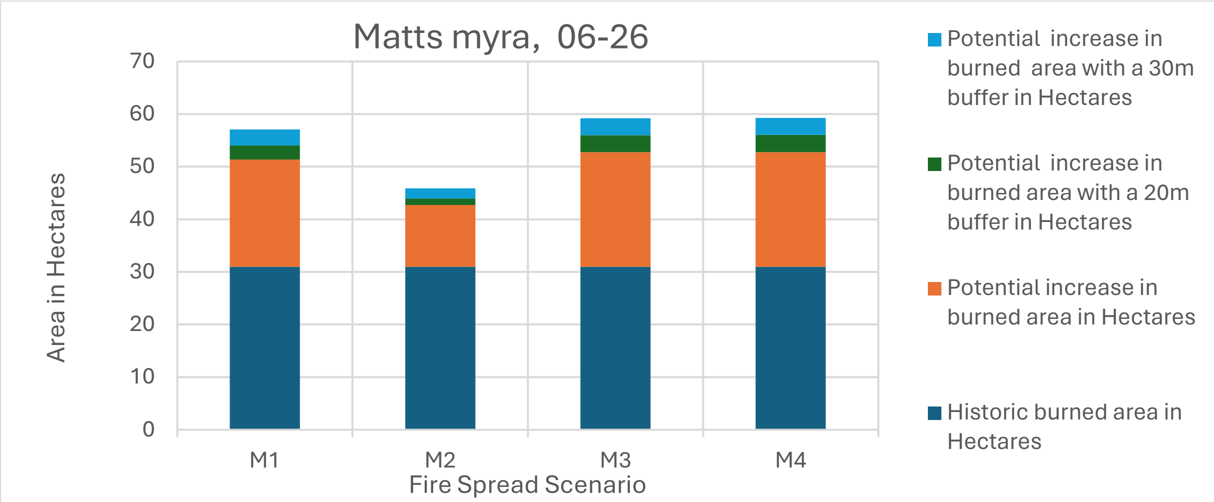


*Figure 8. Showing the amount of historic and potential burned area in Hectares for the area of Matts myra, 06-26. The historical fire covered an area of 31 Hectares with the potential fire area between 11.8 to 21.8 Hectares. The potential buffer increases the burned area with about 2.5 Hectares for the 20 m buffer and a further increase 3 Hectares for the 30 m buffer.*

Honkavaara (Figure 9) has a large numerical variation between the M2 fire spread scenario and M4. The potential fire area ranges between 0.03 to 157.7 hectares between the two scenarios. The 20 m buffer has a range between 0.18 to 28.8 hectares whilst the 30 m buffer variates between 0.16 and 14.1 hectares. The M2 scenario barley exceeds the historical fire area for neither the potential nor the buffered areas.

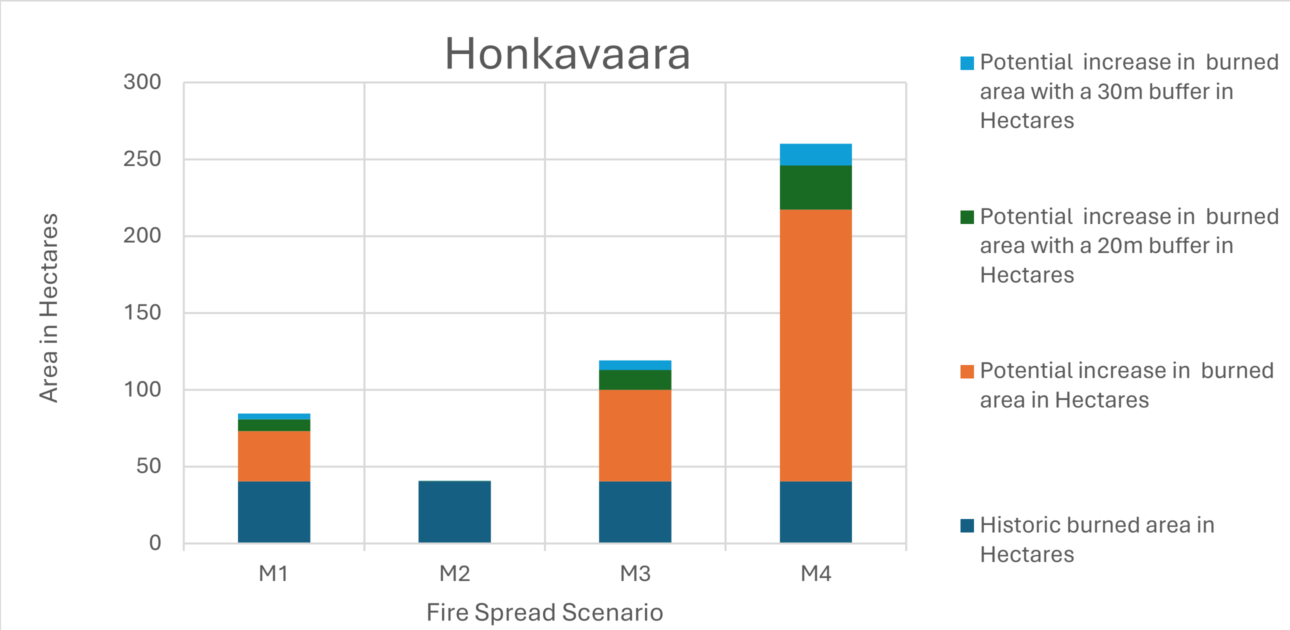


*Figure 9. Showing the amount of historic and potential burned area in Hectares for the area of Honkavaara. The historical fire covered an area of 40.7 Hectares with the potential fire area increasing between 0.3 to 157.7 Hectares depending on the fire spread scenario. The potential buffer extends increase the burned area between 0.18 and 29 Hectares for the 20 m buffer. It also increases between 0.16 and 14 Hectares for the 30 m buffer.*

Figure 10 describes the potential fire area spread in Valdermansvik. The size of the historic fire is at 1.1 hectares whilst the potential fire ranges between 226 and 274 hectares. The 20 m buffer allows for an average are increase of 38.2 hectares and the 30 m buffer adds 10.6 hectares on average.

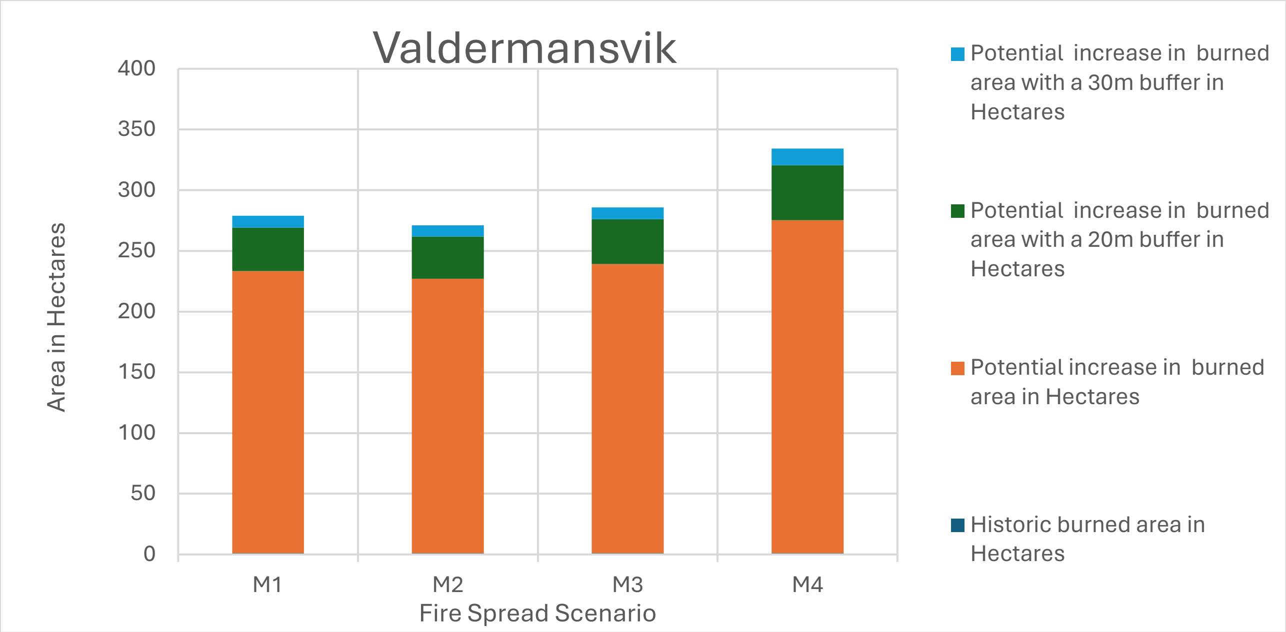


*Figure 10. Showing the amount of historic and potential burned area in Hectares for the area of Valdermansvik. The historical fire covered an area of 1.1 Hectares with the potential fire area is between 226 and 274 Hectares. The potential buffer extends increase the burned area with about 35 Hectares for the 20 m buffer and a further increase 10 Hectares for the 30 m buffer.*

Kalmar 05-01 and 02 can be seen in Figures 11 and 12 respectively. The historical fire size is 1.1 hectares whilst the potential fire area variates. For Kalmar 05-01 (Figure 11) the potential fire area fluctuates between 50 and 170 hectares between M2 and M4. The 20 m buffer provide an increase between 10 and 30 hectares and the 30 m with an additional 5 to 10. The variation between the M1, M2, M3 and M4 scenarios crate a fishhook like graph with higher values for M4 than the other M scenarios.

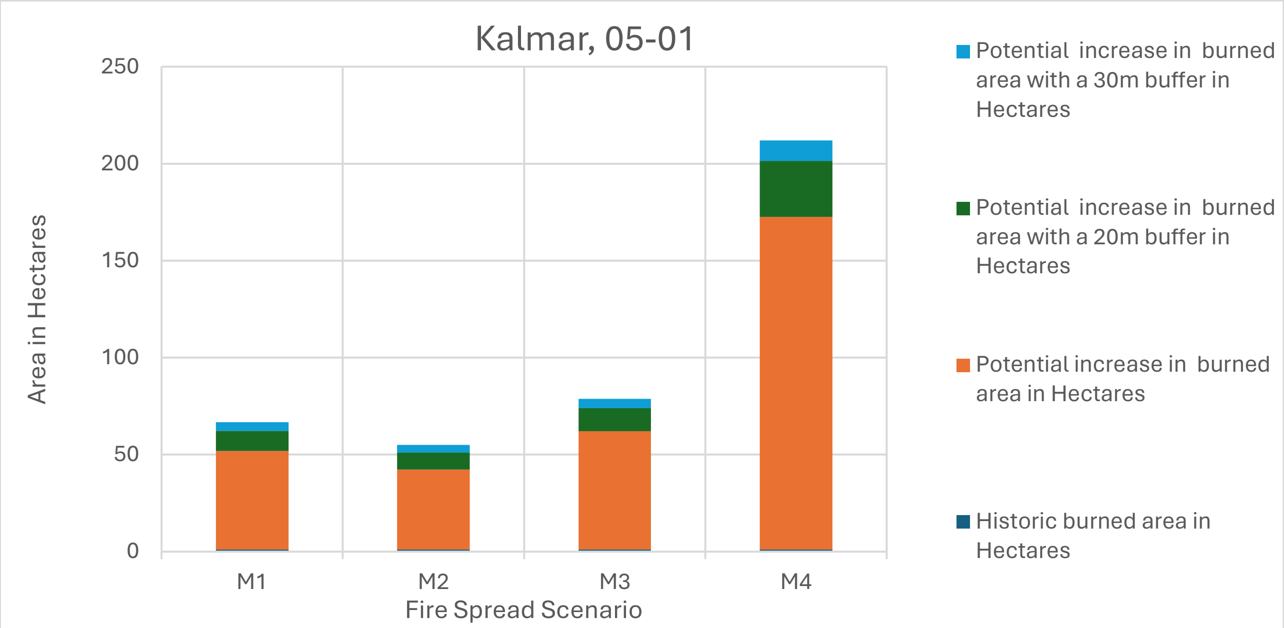


*Figure 11. Showing the amount of historic and potential burned area in Hectares for the area of Kalmar, 05-01. The historical fire covered an area of 1.1 Hectares with the potential fire area increasing to values between 50 and 170 Hectares depending on the fire spread scenario. The potential buffer extends increase the burned area with 10 to 30 Hectares for the 20 m buffer. And an increase of 5 to 10 Hectares for the 30 m buffer.*

Kalmar 05-02 (Figure 12) has a similar form of a graph to Kalmar 05-01 but lower values for scenarios M1 to M3. The potential fire area variates between 20 and 170 hectares, M2 and M4 respectively. The 20 m buffer gives a range of 10 to 30 whilst the 30 m buffer adds 5 to 10 hectares. The variation between the M1, M2, M3 and M4 scenarios crate a fishhook like graph with much higher values for M4 than the other M scenarios.

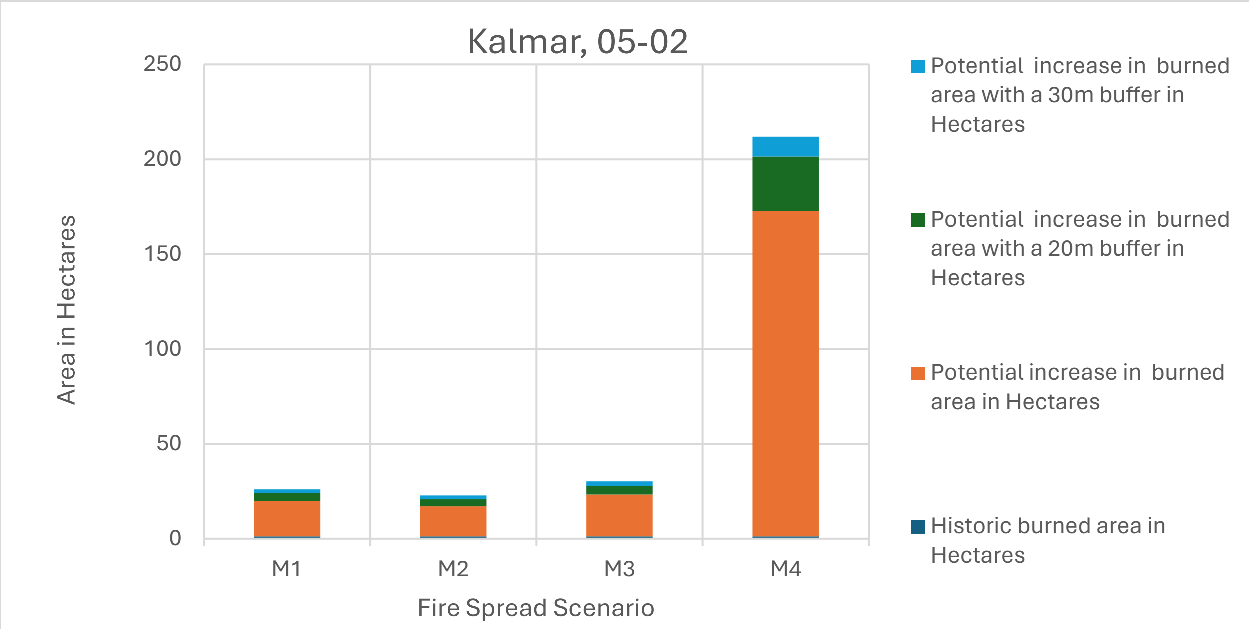


*Figure 12. Showing the amount of historic and potential burned area in Hectares for the area of Kalmar, 05-02. The historical fire covered an area of 1.1 Hectares with the potential fire area increasing to values between 20 and 170 Hectares depending on the fire spread scenario. The potential buffer extends increase the burned area with 10 to 30 Hectares for the 20 m buffer. And an increase of 5 to 10 Hectares for the 30 m buffer.*

Mörtatjärnarna (Figure 13) has the largest historical fire area for 2022 at 94.8 hectares. The potential dire area is in the ranges of 380 hectares for M2 and 621 hectares for M4. The 20 m buffer results in an increase between 75 and 107 and buffer 30 m increases it by 22 to 32 hectares for the same conditions.

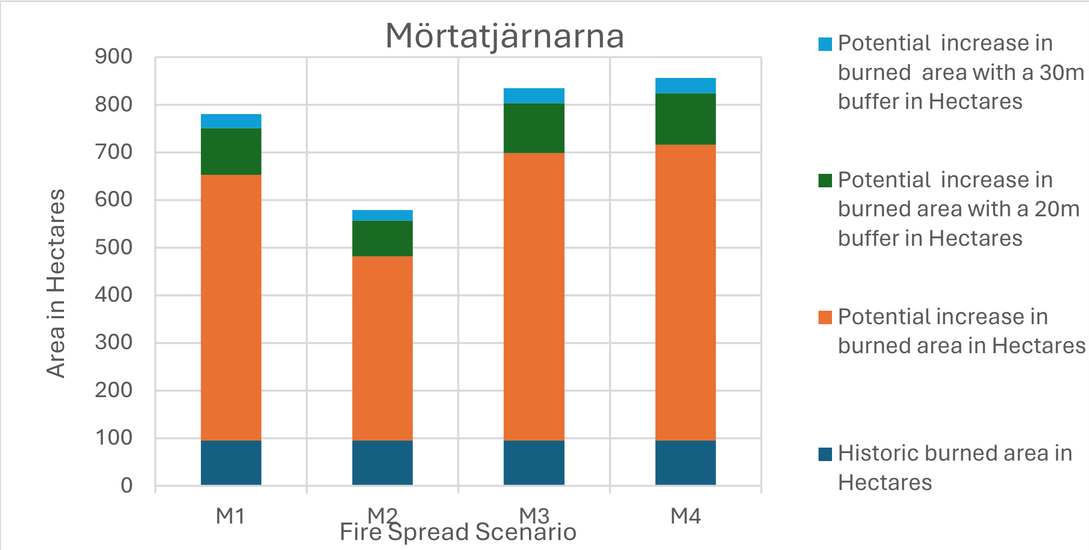


*Figure 13. Showing the amount of historic and potential burned area in Hectares for the area of Mörtatjärnarna. The historical fire covered an area of 94.8 Hectares with the potential fire area ranges between 380 to 621 Hectares. The potential buffers extend the burned area between 75 and 107 Hectares for the 20 m buffer and 22 to 32 Hectares for the 30 m buffer.*

## 3.2 Burn percentage Graphs:

Figure 14 shows the relative amount of land burned for each fire spread scenario. It also illustrated what share of land was burned by which fire area estimation. The historic burn area makes out 1 % of the total fire area with the potential burn area making up about 75 % across the board. The 20 m buffer area makes up some 17% and the 30 m buffer about 7%.

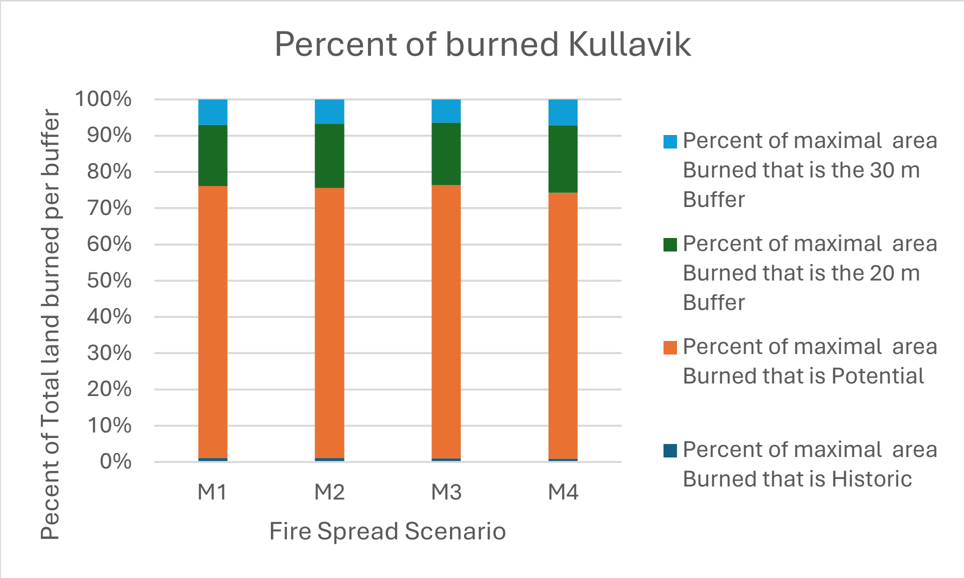


*Figure 14. Showing the amount of percent each potential and historic area makes up each fire burned scenario for the area of Kullavik. The historic burned area makes up 1% in all M scenarios whilst the potential burned area is about 75%. The 20 m buffer accounts for about 17% for all the scenarios and the 30 m buffer for 7%.*

Matts myra. 06-27 has a more noticeable variation between the percentile distribution of the different fire spread scenarios (Figure 15). The M1, M3 and M4 historic fire areas make up about 53 percent of the total burned area whilst the M2 historic area makes up 76%. The potential fire area counts for about 36% for M1, M3 and M4 and 18% for M2. The 20 m buffer is responsible for 2% of the total area for the M2 scenario and about 5% for the remaining scenarios. When it comes to the 30 m buffer it makes up 4% of the M2 total area and 5% of the total area for the remaining scenarios.

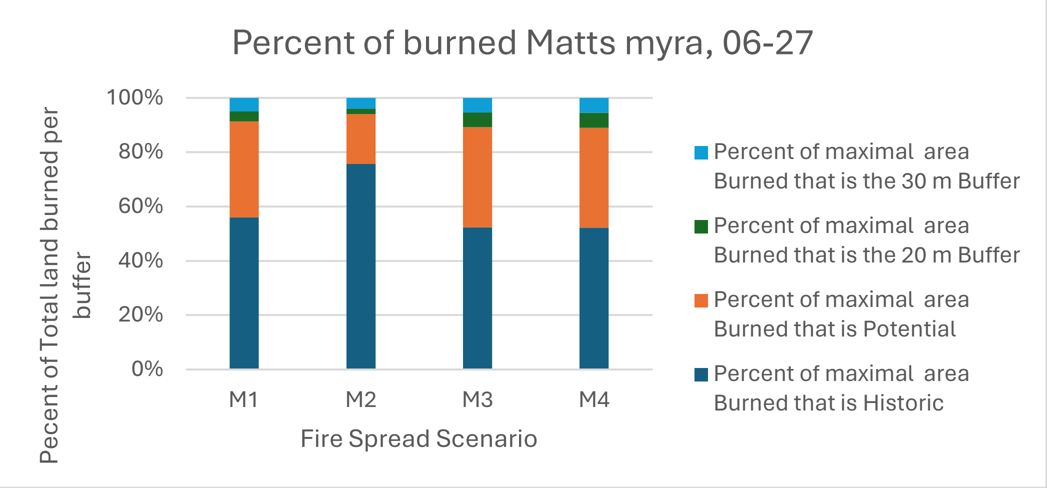


*Figure 15. Showing the amount of percent each potential and historic area makes up each fire burned scenario for the area of Matts myra 06-27. The percentile distributions of the historic area are as follows: 56% for M1, 76% for M2, 52% for M3 and M4. The potential area makes up 35% of M1, 18% of M2 and 37% of both M3 and M4. The 20 m buffer accounts for 4% of M1, 2% of M2, 5% of M3 and 6% of M4. The 30 m buffer accounts for 5% of M1, M3 and M4 and 4% of M2.*

Matts myra. 06-26 (Figure 16) also has a variation between the percentile distribution of the different fire spread scenarios. The M1, M3 and M4 historic fire areas make up about 53 percent of the total burned area whilst the M2 historic area makes up 68%. The potential fire area counts for about 37% for M1, M3 and M4 and 26% for M2. The 20 m buffer is responsible for 3% of the total area for the M2 scenario and about 6% for the remaining scenarios. When it comes to the 30 m buffer it makes up 4% of the M2 total area and 5% of the total area for the remaining scenarios.

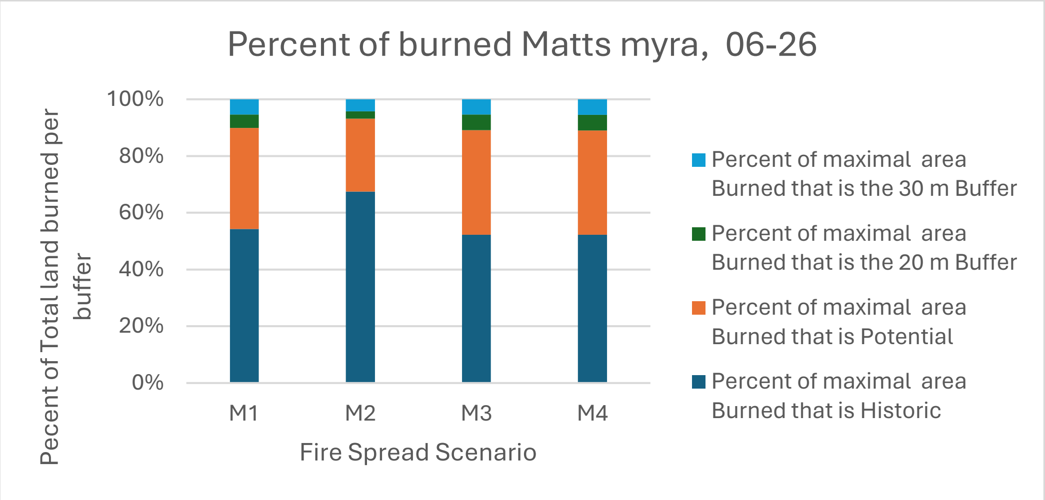


*Figure 16. Showing the amount of percent each potential and historic area makes up each fire burned scenario for the area of Matts myra 06-26. The percentile distributions of the historic area are as follows: 54% for M1, 68% for M2, 52% for M3 and M4. The potential area makes up 36% of M1, 26% of M2 and 37% of both M3 and M4. The 20 m buffer accounts for 5% of M1, 3% of M2, 6% of M3 and M4. The 30 m buffer accounts for 5% of M1, M3 and M4 and 4% of M2.*

The M2 scenario stands out for the Honkavaara (Figure 17) site as it makes up roughly 99% of the burned land for that scenario. For M1 the historic land area makes up 48 % whilst making up 34% and 16% for M3 and M4 respectively. The potential burned land for M2 is close to 0% (0.073%) whilst being 39% for M1, 50% for M3 and 68% for M4. The 20 m buffer makes up 11 % of M3 and M4, 9 % of M1 and close to 0% for M2 (0.0441%). The 30 m buffer makes up 5 % of M3 and M4 and 4% of M1 whilst M2 is close to 0% (0.392%).

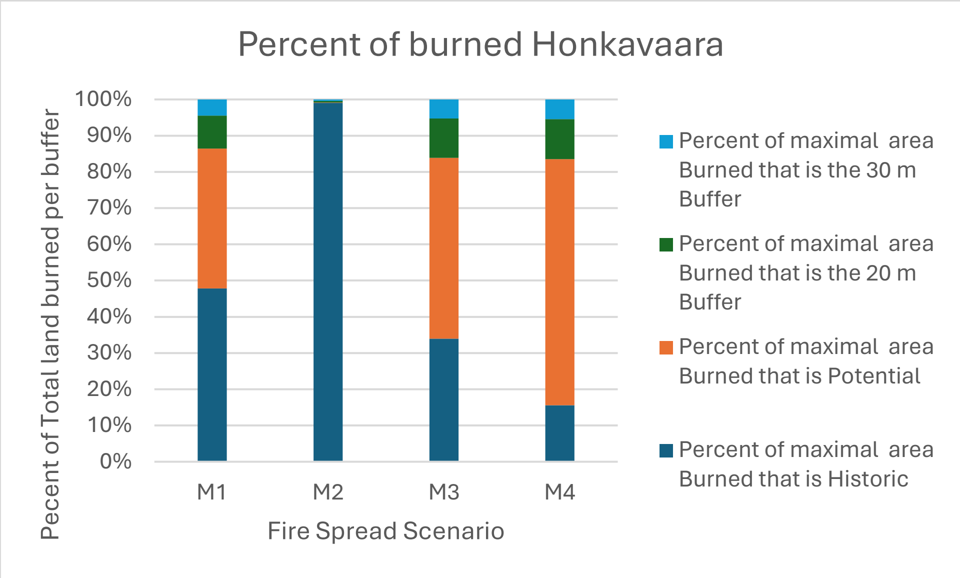


*Figure 17. Showing the amount of percent each potential and historic area makes up each fire burned scenario for the area of Honkavaara. The M2 historic burn area makes up 99% of its total burned area. For M1 the historic land area makes up 48 % whilst making up 34% and 16% for M3 and M4 respectively. The potential burned land for M2 is 0.073% whilst being 39% for M1, 50% for M3 and 68% for M4. The 20 m buffer makes up 11 % of M3 and M4, 9 % of M1 and for M2 0.0441%. The 30 m buffer makes up 5 % of M3 and M4 and 4% of M1 whilst M2 is 0.392%.*

For Valdermansvik the amount of total burned area made up by the historical fire is in all M scenarios close to 0% (Figure 18). The amount of potential burned area for M1, M2 and M3 is 83 % and 82% for M4. The 20 m buffer provides a percentile value of 13 for

M1, M2 and M3 and 14% for M4. Buffer 30 m makes up 3% of the total area burned for M1, M2 and M3 and 4 % for M4. Valdermansvik has overall a very even distribution of values.

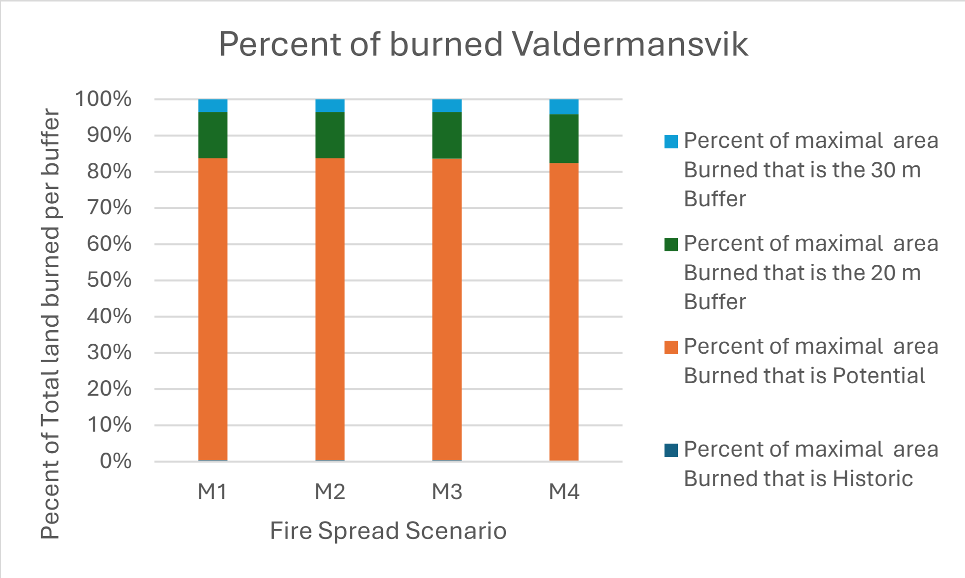


*Figure 18. Showing the amount of percent each potential and historic area makes up each fire burned scenario for the area of Valdermansvik. The historic area for Valdermasnsvik make up on average 0.35% of the total burned area. The amount of potential burned area for M1, M2 and M3 is 83 % and 82% for M4. The 20 m buffer provides a percentile value of 13 for M1, M2 and M3 and 14% for M4. Buffer 30 m makes up 3% of the total area burned for M1, M2 and M3 and 4 % for M4.*

Figure 19 shows the percentile distribution of burned land for the site of Kalmar, 05-01. The historical fire area makes up 2% for M1 and M2 and 1% for M3 and M4. The potential burn area for M1 is 76% and 75% for M2. For M3 it is 78% and 81% for M4. The 20 m buffer accounts for roughly 15% for all scenarios and the 30 m buffer for about 6%.

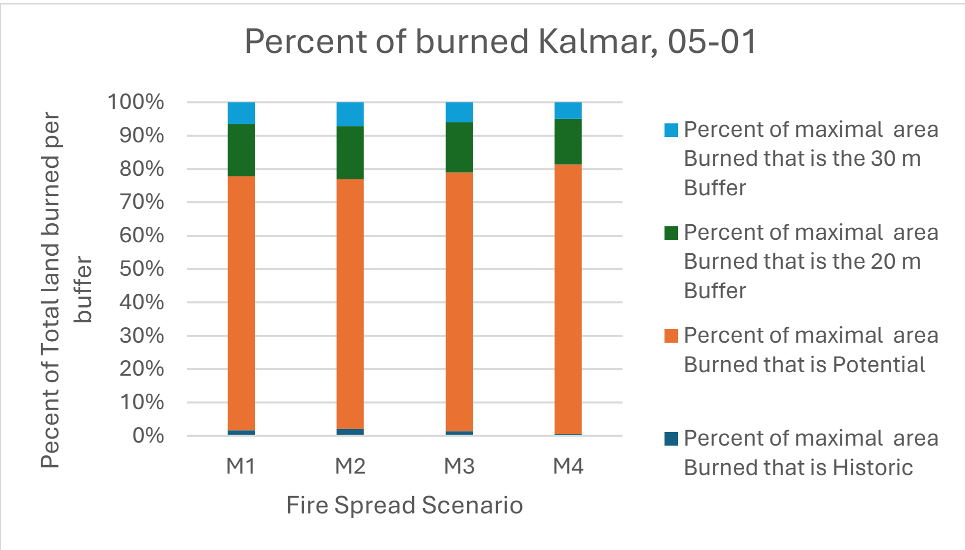


*Figure 19. Showing the amount of percent each potential and historic area makes up each fire burned scenario for the area of Kalmar, 05-01. The historical fire area makes up 2% for M1 and M2 and 1% for M3 and M4. The potential burn area for M1 is 76% and 75% for M2 whilst for M3 it is 78% and 81% for M4. The 20 m buffer accounts for 15% for M3, 16% for M1 and M2 and 14% for M4 and the 30 m buffer for 6% for M1 and M3, 7% for M2 and 5% for M4.*

Figure 20 shows the percentile distribution of burned land for the site of Kalmar, 05-02. The historical fire area makes up 4% for M1 and M3, 5% for M2, and 1% for M4. The potential burn area for M1 is 71% and 70% for M2. For M3 it is 74% and 81% for M4. The 20 m buffer accounts for roughly 15% for all scenarios and the 30 m buffer for about 7%.

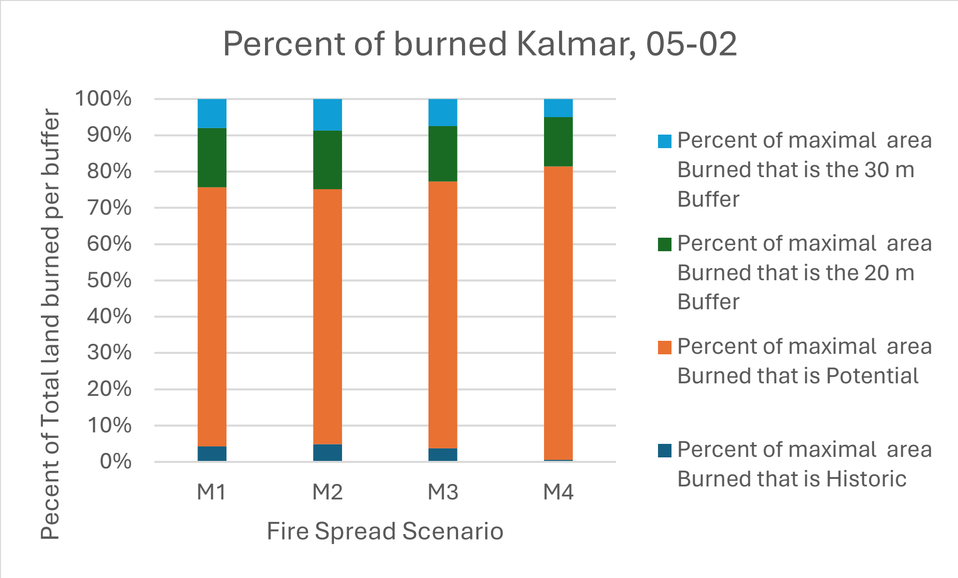


*Figure 20. Showing the amount of percent each potential and historic area makes up each fire burned scenario for the area of Kalmar, 05-02. The historical fire area makes up 4% for M1 and M3, 5% for M2, and 1% for M4. The potential burn area for M1 is 71% and 70% for M2. For M3 it is 74% and 81% for M4.* The 20 m buffer accounts for 15% for M3, 16% for M1 and M2 and 14% for M4. *The 30m buffer is responsible for 5% for M4, 7% for M3 and 9% and 8% for M2 and M1 respectively.*

Mörtatjärnarna (Figure 21) has a relatively even spread for most of the burned area percentages. The historic fire area makes up 12% of M1, 16% of M2 and 11% of both M3 and M4. The potential fire area for M1 makes up 71% of the total area. For M2 it is 67% whilst for M3 and M4 it is 72% and 73% respectively. The 20m buffer makes up 13% of the total area for all fire spread scenarios and the 30m buffer makes up 4 % of all the M scenarios.

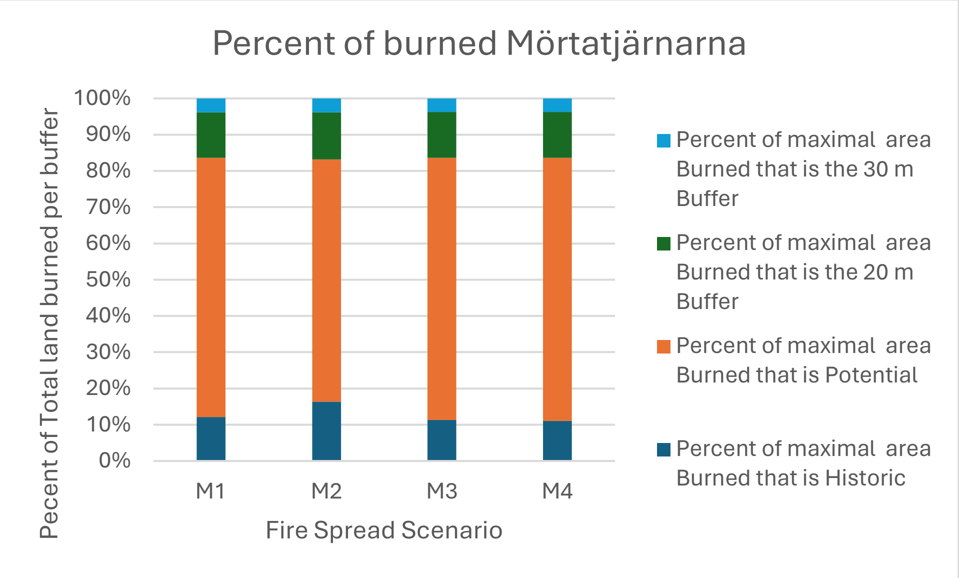


Figure 21. Showing the amount of percent each potential and historic area makes up each fire burned scenario for the area of Mörtatjärnarna. The historic fire area makes up 12% of M1, 16% of M2 and 11% of both M3 and M4. The potential fire area for M1 makes up 71% of the total area. For M2 it is 67% whilst for M3 and M4 it is 72% and 73% respectively. The 20m buffer makes up 13% of the total area for all fire spread scenarios and the 30m buffer makes up 4 % of all the M scenarios.

# 4 Discussion:

## 4.1 Interpretation of Results:

For the most part the predicted scenarios follow a similar pattern. The M2 scenario has the lowest potential burnable land increases, as it is the most conservative. The M1 and M3 scenarios have for the most part similar values, with overall somewhat higher values for M3. The M4 scenario has the highest estimations of burned land compared with the other scenarios. Variation between the scenarios indicate a possible difference in how a fire would spread. An example would be Honkavaara (Figure 9 and Figure 17) which has a very low value for the M2 scenario, and a high historical area percentage value. This is down to the higher values of FWI (Figure 3) being located right next to a crossing of two roads (Appendix 1, Figure 3), thus the more conservative fire spread scenario is quickly blocked by the presence of the roads. This is of course based on the assumption that the roads would create enough of a hindrance to stop the fire.

A similar situation can be seen in Kalmar 05-01 and 02 (Figures 11 and 12). Here the M2 scenario also indicates a fire development towards a hard border, or in a limited direction, that would prevent further spread. The difference between the M1, M2 and M3 scenarios are not particularly large but the M4 scenario is noticeably different from the rest when it comes to both Kalmar days. This difference indicates that the major direction of fire would be away from the directly connected forestland. Figures 19 and 20 show a similar pattern where the M4 condition has an overall lower percentile value for the historic fire area.

Mörtatjärnarna is the largest fire that occurred in the year 2022. Figure 13 shows the possible burned land values which don't differ to much between each other bar the M2 scenario. M1, M3 and M4 all are relatively close in predicted potential fire areas, this can also be seen in Figure 21 where the percentile values do not differ much. The M2 scenario is a more conservative estimation of fire spread so a lower value is not unexpected. Of major interest is why the potential fire area is sizable no matter which of the analysed M scenarios is considered. This is most likely a cause of the prevailing FWI values cooperating well with the local geographic layout allowing the fire to spread unhindered further for all scenarios. Figure 3, found in Appendix 1, shows that the Mörtatjärnarna site is bordered on one side by a rather large lake complex thus allowing the fire to spread predominantly in one direction.

Matts myra 06-26 and 27 is an interesting geographical site which can be seen in the potential fire area estimations (Figure 8 and 7 respectively). Figure 1 in Appendix 1 shows that the historical fire at Matts myra happened on a predominantly isolated island with limited area for fire development before reaching a natural barrier. The limited available area results in the unique situation where the historic fire area makes out more than half of the total area burned for each scenario (Figure 16 for 06-26 and Figure 15 for 06-27). There is still some increase in potential area caused by the two buffer conditions, but the potential burned area does not outweigh the historic area.

When it come to the sites of Kullevik and Valdermansvik the projected burned area behaves similarly. Neiter site has a large variation between the M scenarios (Figures 6 for Kullevik and 10 for Valdermansvik) and neither do they have a large difference in percentile distribution depending on the fire area projection (Figure 14 for Kullevik and Figure 18 for Valdermansvik). This is most likely due to a relatively large mainly uninterrupted potential burn area that corresponds relatively well to the local FWI values. Simply put, most of the area to which the fire could spread was within reach. There is some difference between the M1, M2, M3 and the M4 values for both Kullevik and Valdermansvik, indicating that not the full potential area is being burned, but as the difference is not large it is still a major part.

Overall, there seems to be no optimal fire spread scenario. By combining and comparing the different scenarios it is more possible to comprehend the conditions present for fire areas. Whether or not they are likely to grow large before reaching some form of barrier or if there is ample room for the fire to grow. So, the best option, working from the fire spread scenarios precent in Table 4, would be to have an analysis of each.

There are some main differences between the historically large and small fires. The main one is the historically small fires have a larger ability to develop, this can be seen in the percentile graphs (Figures: 19, 20, 14 and 18). Even when the fire reaches a natural barrier, as in Kalmar 01 and 02 (Figure 19 and 20 respectively) the potential fire area is still noticeable. This is not that surprising as a small fire only needs to grow to two hectares to double in size. It is more interesting how the historically large fires are mostly, in the case of Matts myra 26 (Figure 16) and 27 (Figure 15) and Honkavaara (Figure 17), not that far away from their potential size. This could indicate that the forest fires were able to grow close to the maximal size before being stopped.

Human intervention is important to determine the extent of a forest fire, not only by actively combating it but also because of the population density. The more people live in an area, the more individuals to notice a forest fire. It also means more roads, and smaller continues forest plots. Thus, creating a more patchwork and separated forest landscape. Therefore, it is not unlikely that the forest structure itself is a contributing factor for the extent of forest fires.

## 4.2 Uncertainties and problems:

The first and most direct problem would be the dubious data sources. Skogsstyrelsen provided the Fire Area Polygon (.shp) dataset (Skogsstyrelsen, 2023) but there is no completely clear methodology nor limits provided by them. Because of this it is hard to say what exactly they consider a burned area. Presumably it is the area directly affected by the flames, charred and fire consumed trees. But it could be that the areas overlap with parts which either did not burn or possibly did not burn directly. As is the exact extent of the fires being a difficult to fully verify. As a rough visual validation with Copernicus satellite images, via the Copernicus browser, showed that the recorded areas were like the satellite images.

Additionally, the MSB point data did not always complement the data from Skogsstyrelsen. This is mainly because the MSB data not always having a point close to one of the fire locations shown by Skogsstyrelsen. This was particularly noticeable with the Kalmar, Matts myra, Mörtatjärnarna and Kullevik. This difficulty with finding exact dates for some of the fires makes it difficult to ensure that the FIW values used for analysis is truly accurate.

In the case of Kalmar, it is reasonable to assume that one of the days is the "true" time of the fire. The two points could be a result of confusion, miss input or multiple callouts and the MSB records are based on the recorded callout instances. So, if a fire was reported twice, it is not impossible that two points were created. It could also be a result of a reignition, although as the fire in question only reached one hectare that seems less likely.

For the sites missing a MSB point altogether, Kullevik, Matts myra and Mörtatjärnarna, this is more difficult to explain. There are no points close to the locations of the fires that state a date close to that found by newspaper or satellite. This could be down to an oversite or miscommunication. For the site of Kullevik this seems like a plausible explanation as it is a smaller fire, only slightly above one hectare in size. The Skogsstyrelsen polygon historical fire areas and the MSB fire coordinate data have been previously found to have inconsistencies and not entirely cooperative with each other (Jones, 2023).

For Matts myra and Mörtatjärnarna the situation is more difficult. These two fires cover the largest areas for 2022 and would reasonably be expected to be documented to a greater extent. As it is the lack of accompanying date is puzzling. All of this creates a degree of uncertainty, as a mistake in days may result in a wrong FWI value and thus an incorrect reclassification and area estimation.

Another possible uncertainty is the FWI values themselves. This is mainly down to them being based on modelled data ((MSB), 2024), which in turn has been interpolated to create a raster. The datapoints used for interpolation are spaced with 2.8-kilometre frequency which gives a decent data coverage, but there could still be local weather variations caused by local geography ((MSB), 2024). As the FWI data is interpolated from point to raster using a first-degree polynomial the direct effect of interpolating modelled data is hopefully diminished, as a first-degree polynomial has less of an effect on the data compared to higher degrees. This is a point of uncertainty that should be considered, particularly when it comes to the FWI values used to estimate the FWI values for the historic fires. As the larger a fire is the higher chance of it overlapping with a FWI data point it also means that the smaller a fire is the more it is reliant on wholly interpolated data.

The implemented approach is not fully without merit. Using only Land Cover and Fire Weather Index data to estimate the possible spread and direction of a fire has both its pros and cons. One of the main benefits is the relative low amount of data necessary to estimate a possible fire area. In the case of Sweden that data is also readily and freely available at a good spatial and temporal resolution. This is particularly relevant when it comes to FWI and Land Cover data which can easily be access from both SMHI and Naturvårdsverket.

When it comes to historical fire areas and fire locations this is somewhat more difficult to acquire, but not by a lot. This relative ease of data acquisition is a positive factor when it comes to the possible implementations of this approach. Land Cover data at a 10 m resolution allow for a reasonable estimation for what type of vegetation is precent within a particular area (Naturvårdsverket, 2020). The use of FWI data as a proxy of where a fire can spread is not necessarily well suited to fully simulate how fire would spread. Whilst it is an indicator of the suitability of a forest to burn it is not necessarily fully representative. Factors like local weather events and local geographical features are not well considered for by the FWI ((MSB), 2024) index and would need to be compensated for by the model.

The main assumption taken is that if a fire has been able to occur under a particular set of FWI conditions, then that fire could spread to FWI conditions of a similar type. This was the basis for the different M fire spread scenarios. Effectively they were used to give more estimations to simulate the different ways a fire can spread in relation to the prevailing FWI values. This was done to make the assumptions more solid and balanced.

A similar reasoning was used when deciding on the use of a buffer distance. Since forest fire can spread in multiple different ways, (Päätalo, 1998) it is difficult to assume a particular spread for a particular area or situation. By using buffer distances of 20 and 30 m the intention was to simulate the extra possible area to where fire could spread beyond the hard boarders set out by the given assumptions. This allowed fires to cross over roads and rivers, effectively by the fire being carried by falling trees. So, whilst there are several assumptions made as to how fire would behave both regarding the weather conditions and to the physical fire movements the multiple scenarios for this spread have been introduced to mitigate potential inaccuracies.

One point to bring up is the use of hard limits for the fire areas. This is exemplified by assuming that any road would be able to stop fire equally and fully. As an example, the fire at Kullevik (Figure 5) where most of the shown roads are minor forest service roads, and thus manly gravel. These roads would probably not truly be a full 10 m wide and are probably based on recorded road networks rather than identified the same way as the Land Cover data itself. Thus, these roads would most likely not provide a strong enough barrier to fully prevent a fire as effectively as has been modelled.

The decision to make them into hard stops is twofold. One is the need to have a point where the fire spread stops otherwise the possible area would become noticeably larger. A second reason why the roads were seen as hard stops is that they in turn allow for humans to access, supervise and modify the landscape. So, any action to combat the fire, excluding waterbombing, would most likely be delivered by the roads present. Therefore, if the roads are not in and of themselves hard limits, they could be turned into hard limits (Heinselman, 1981).

When it comes to the categorisation of which Land Cover classes could burn ad which could not the focus was on whether the Land Cover class would be counted as forest or not. An example of this would be again for Kullavik (Figure 5) which has a pair of noticeable clear lines indicating the location of electrical wires classed as Land Cover “42 Vegetated other open land” (Naturvårdsverket, 2020). This area would most likely be free of any major vegetation but not necessarily totally free of all. Shrubs and thickets could easily grow below the powerlines and the degree of this depends on how often it is cleared of vegetation. Shrubs may even contribute to the spread of fire from a ground-based fire to a crown-based fire (Päätalo, 1998).

Thus, it could also be assumed that there is vegetation that could carry a flame present within those strips of land, meaning that a fire would continue to spread further past these hard limits. The main reason for assuming that “42 Vegetated other open land” (Naturvårdsverket, 2020) would be a hard stop to a spreading forest fire is that it would no longer be a forest. So, the fire would shift its main type of fuel and the way it spreads would also be affected by this. Therefore, the assumption of no spread in “42 Vegetated other open land” (Naturvårdsverket, 2020) was made to simplify the possible scenarios. This assumption would absolutely differ from real world fire behaviours thus creating uncertainties compared to the real world.

The original intention with the M4, M5 and M6 fire spread scenarios was to create more versions of possible fire spread. So that the fire could spread to ranges between the minimum FWI and maximum FWI values within the historic area. To achieve the original idea with the M4, M5 and M6 scenarios it would have been better to use the standard deviation instead of a percentage value of the FWI. So, the M4 to M6 scenarios would indicate how many standard deviations of historic FWI values the fire could spread. This would provide the desired result instead of estimating the full fire area.

## 4.3 Further Research:

A possible further development would be to use the historic fire as a base and then create buffers directly from these shapes. This as a way of determining the full potential area rather than selecting all burnable land connected to the historical fire area. The benefit would be that more predetermined and similar ranges of burned land per fire location. These buffer ranges could then indicate what type of Land Cover would be affected on how far away from the source the fire managed to get. The main benefit of such an approach would be an ability to more simply process large quantities of data.

Another possible further development would be an incorporation with the methods used by Jones in 2023. This study already shares some data and methods as Jones, so the methods employed here could be combined with the methods disused in this thesis. The main benefit of this would be a statistically verifiable approach, particularly if further investigating the impact had on tree species.

It would also be interesting to compare the output of this model to other more complex and tested models. It could also be interesting to try a larger scale analysis with more locations selected to see how a larger model would change things. Both comparisons would allow for a sturdier understanding of the viability of this model. A further possible development is too closer investigate the Land Cover type effected by the forest fires or to incorporate the effects of topography. A way of making the Landcover more important would be by giving the Land Cover weights depending on the species of tree precent.

# 5 Conclusion:

By using a model based on Fire Weather Index (FWI) and Land Cover for Sweden it was possible to estimate potential forest fire areas based on historic cases. There were noticeable differences between the potential fire area and the historic fire area for most of the sites. The different assumptions of how FWI influences forest fire spread allows for better comprehension of the conditions precent for the historic fires. The different FWI assumptions can result in big differences in the potential burned area. There are some differences between the historically large and small fires, the main of which is that the larger fires are less likely to grow. The model approach has some benefits, mainly due to data availability, but has some issues when it comes to accuracy and how well it represents the real world. Further studies are possible, both to develop the model and to verify it to reality.

# 6 References:


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# 7 Appendix 1:

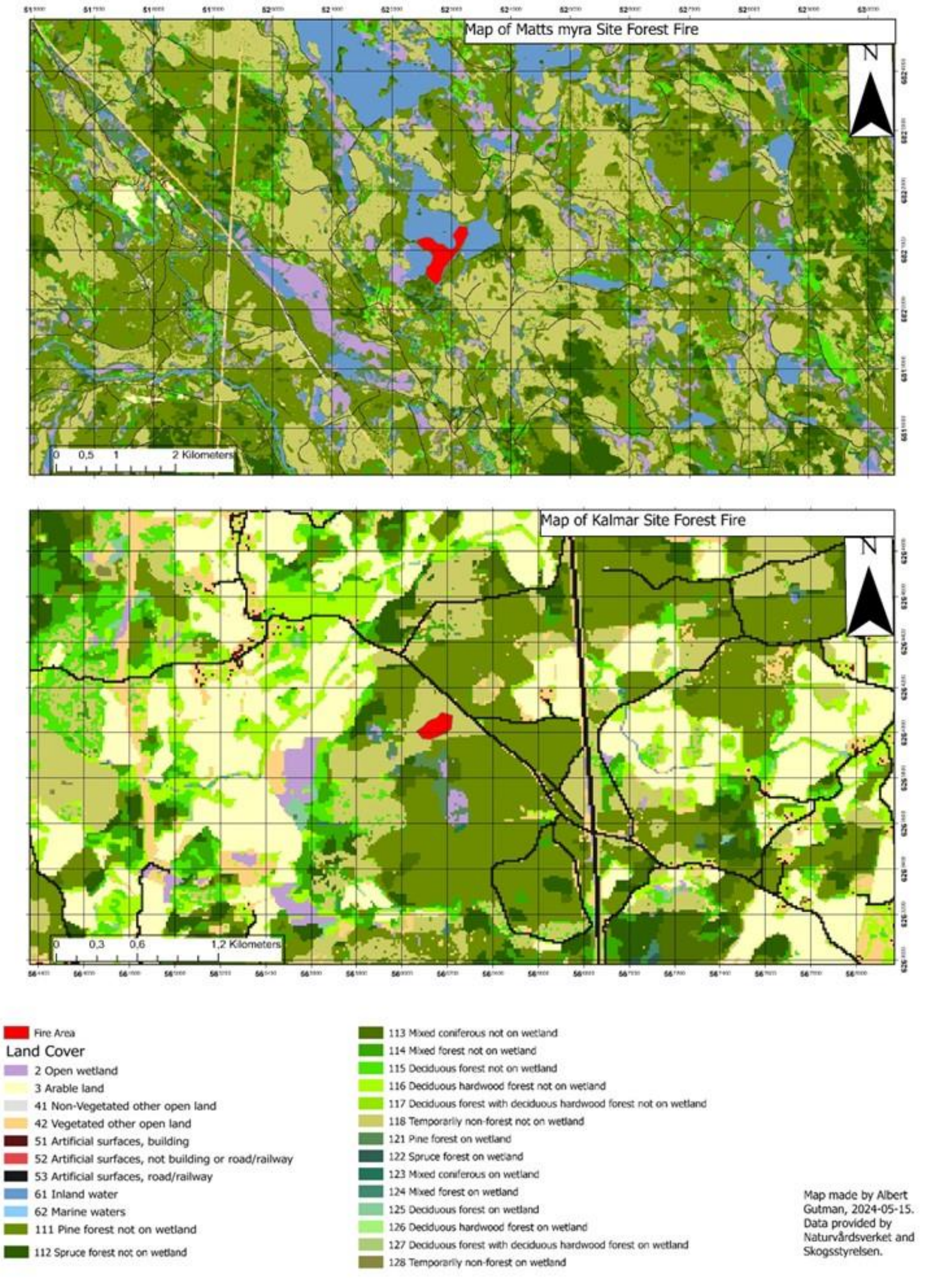


*Figure 1. Map over the historical forest fire sites of Kalmar and Matts myra with Land Cover as a background.*

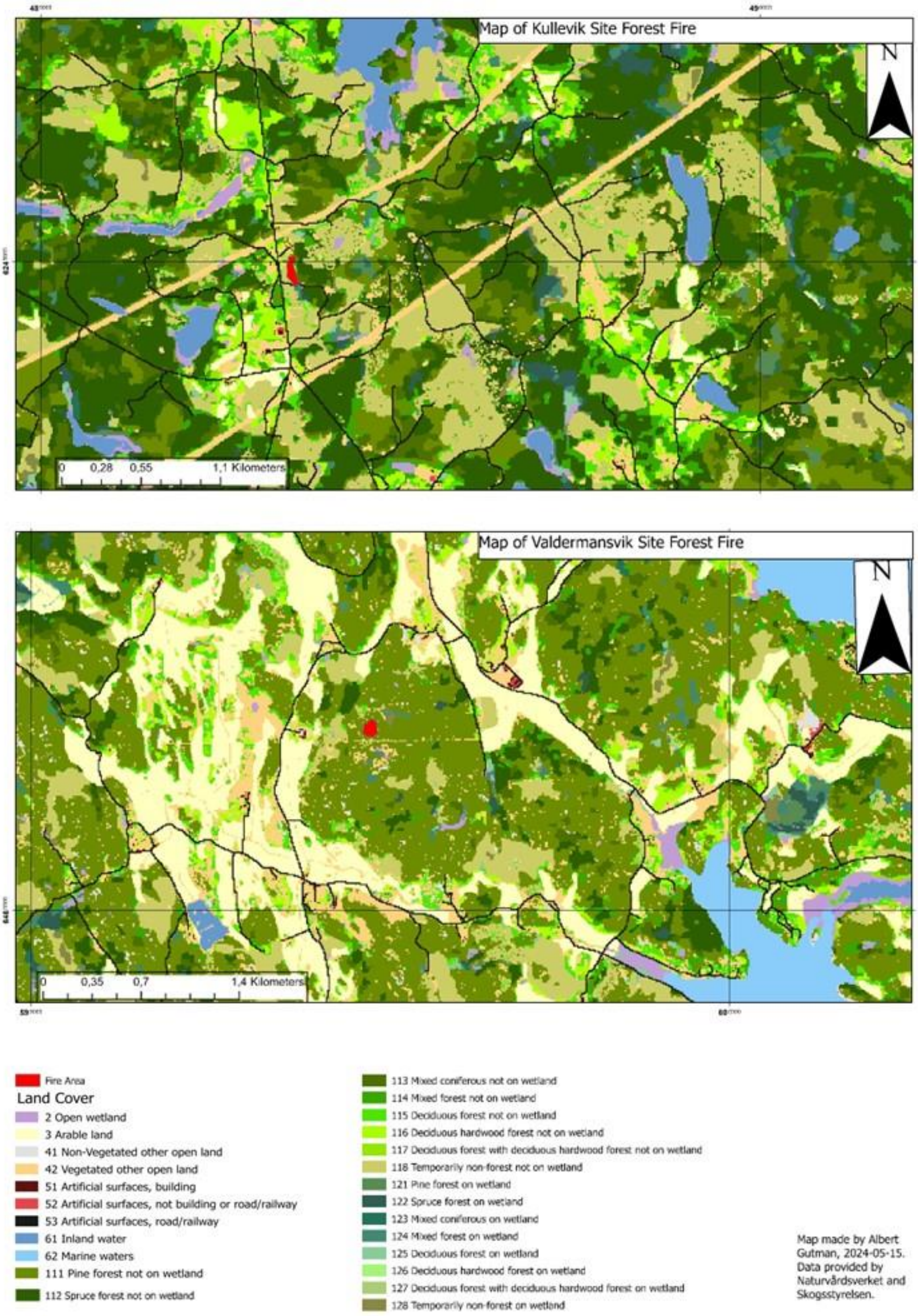


*Figure 2. Map over the historical forest fire sites of Kullevik and Valdermansvik with Land Cover as a background.*

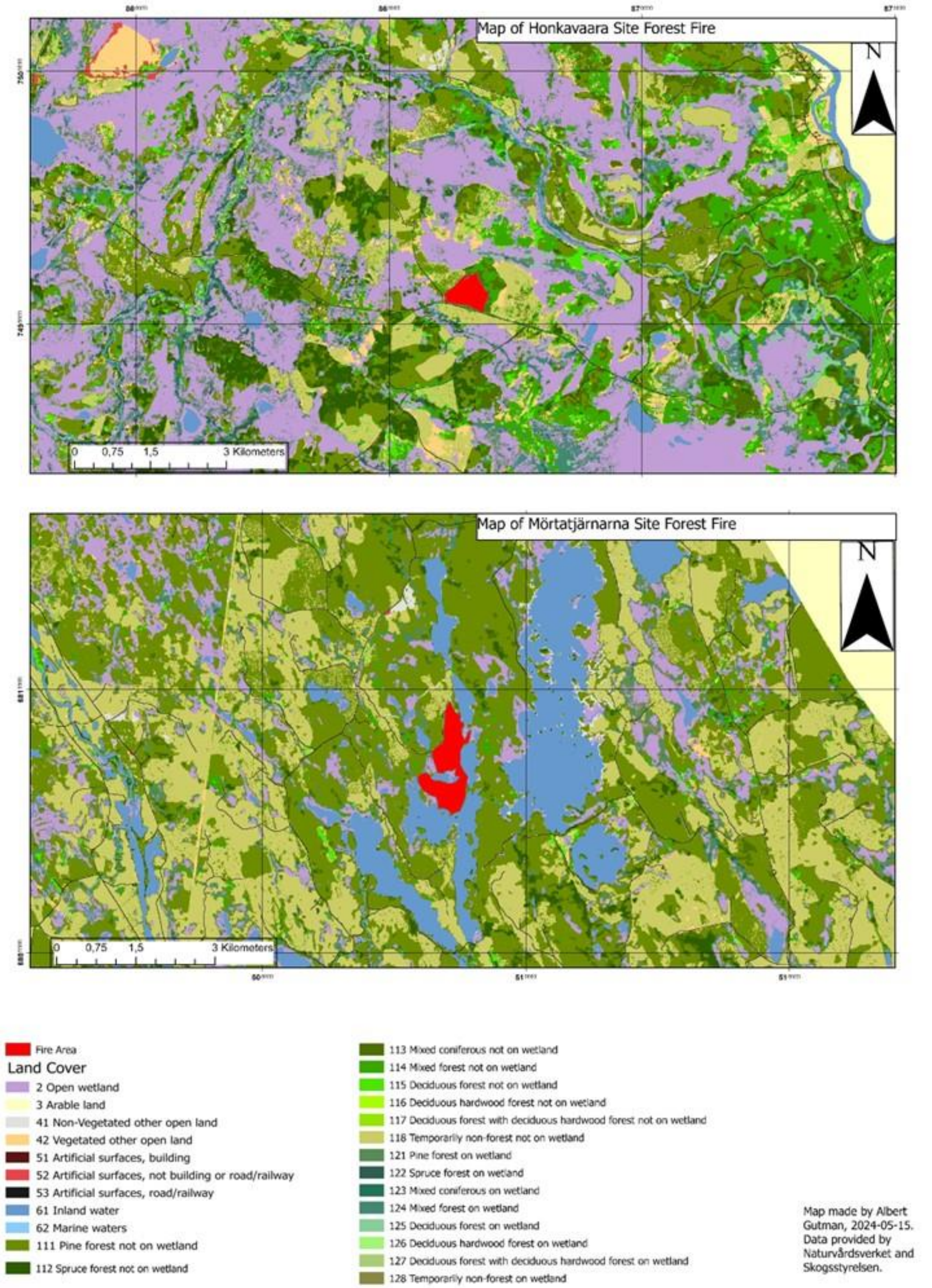


*Figure 3. Map over the historical forest fire sites of Mörtatjärnarna and Honkavaara with Land Cover as a background.*

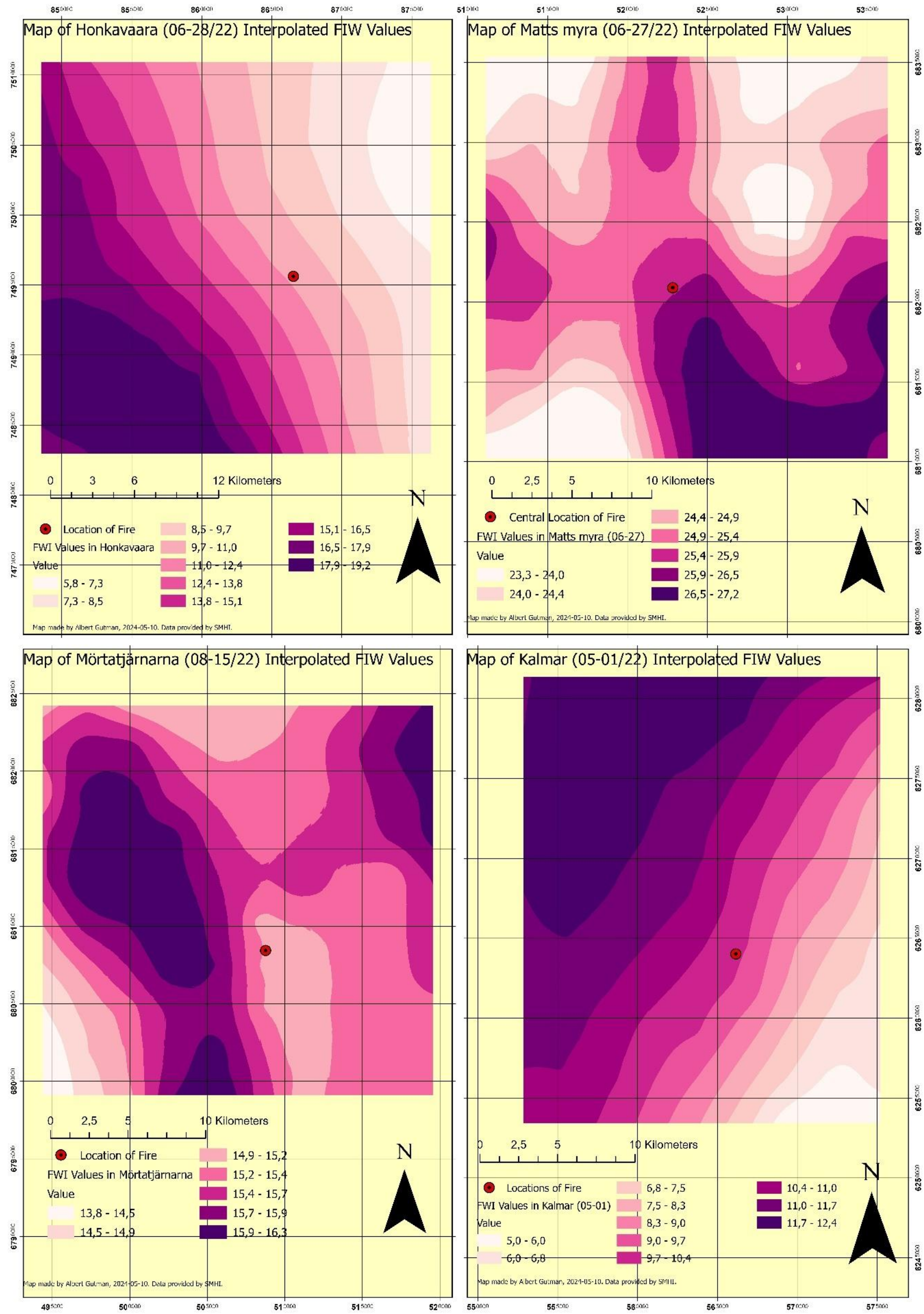


*Figure 4. The full interpolated Fire Weather Index values. Interpolated with a first-degree polynomial.*

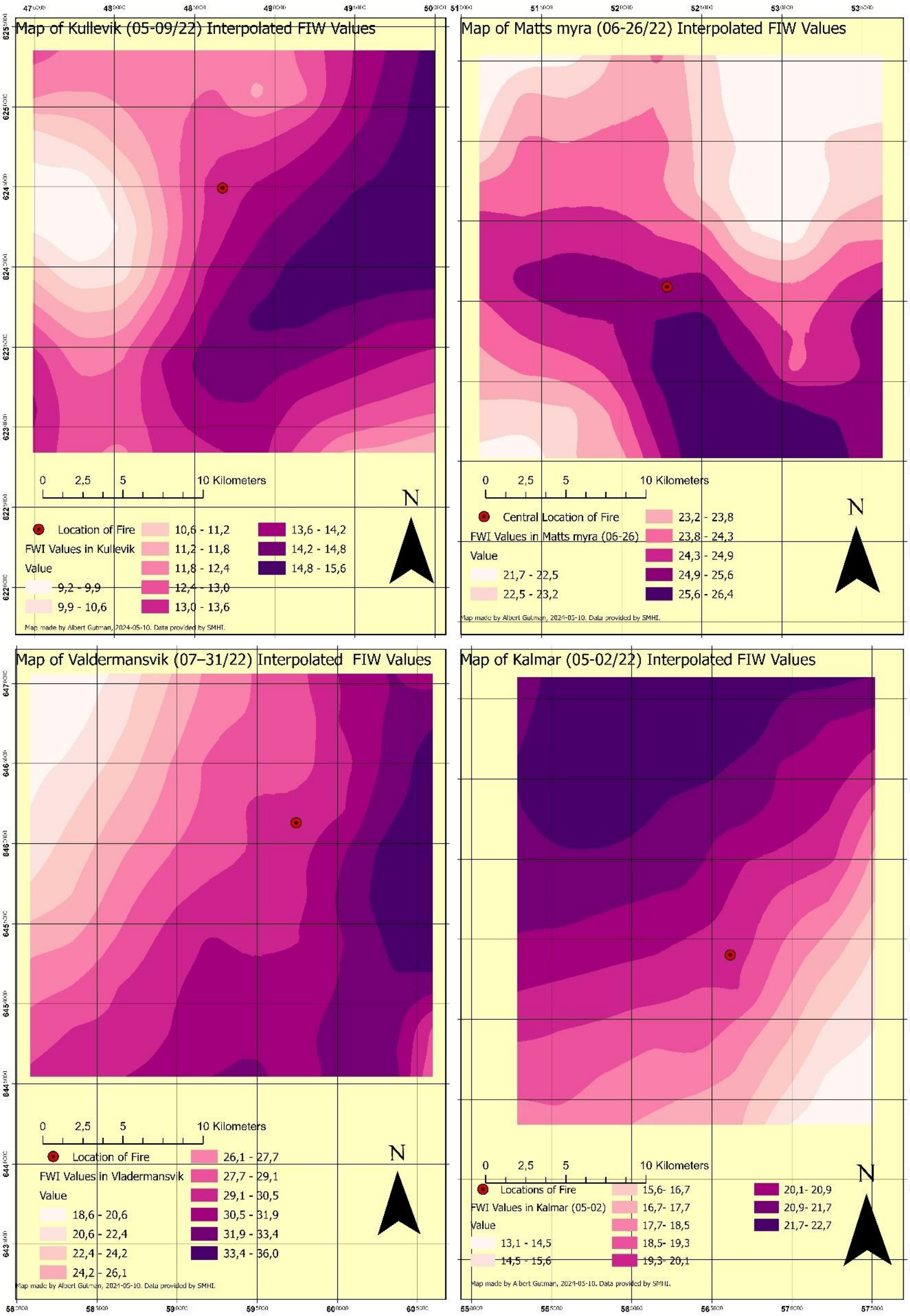


*Figure 5. The full interpolated Fire Weather Index values. Interpolated with a first-degree polynomial.*

*Table 1. Showing the reclassification scheme used to determine the burnable and non-burnable Land Cover types. Land Cover with forest, but without wetland are considered possible to burn, given the code of 1. The remaining Land Cover types are given a value of 0 to denote their inability to burn.*

| Land Cover Code | Land Cover name | Classification (1 burned, 0 not) |
|---|---|---|
| 111 | Pine forest not on wetland | 1 |
| 112 | Spruce forest not on wetland | 1 |
| 113 | Mixed coniferous not on wetland | 1 |
| 114 | Mixed forest not on wetland | 1 |
| 115 | Deciduous forest not on wetland | 1 |
| 116 | Deciduous hardwood forest not on wetland | 1 |
| 117 | Deciduous forest with deciduous hardwood forest not on wetland | 1 |
| 118 | Temporarily non-forest not on wetland | 0 |
| 121 | Pine forest on wetland | 0 |
| 122 | Spruce forest on wetland | 0 |
| 123 | Mixed coniferous on wetland | 0 |
| 124 | Mixed forest on wetland | 0 |
| 125 | Deciduous forest on wetland | 0 |
| 126 | Deciduous hardwood forest on wetland | 0 |
| 127 | Deciduous forest with deciduous hardwood forest on wetland | 0 |
| 128 | Temporarily non-forest on wetland | 0 |
| 2 | Open wetland | 0 |
| 3 | Arable land | 0 |
| 41 | Non-vegetated other open land | 0 |
| 42 | Vegetated other open land | 0 |
| 51 | Artificial surfaces, building | 0 |
| 52 | Artificial surfaces, not building or road/railway | 0 |
| 53 | Artificial surfaces, road/railway | 0 |
| 61 | Inland water | 0 |
| 62 | Marine water | 0 |
| 0 | Outside mapping area | 0 |