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Containing Wildfires with Satellites

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Contents

1 Introduction

1.1 Background and overview of the problem

Wildfires are a main cause of environmental, social and economical problems, destroying millions of hectares of forests and causing loss of biodiversity and human lives.

They contribute severely to the destruction of wildlife habitats and to an increase in the levels of CO_2, all around the globe. Apart from the environmental consequences, they pose a threat to millions of people, whose lives and houses are put at risk every year. In the European Union alone, between 2000 and 2017, 611 people lost their lives directly because of a wildfire and 8.5 millions of hectares have burnt [6]. Globally, between 1998 and 2017, around 2400 people died, according to a UNISDR report, and 6.2 million people were injured or displaced from home, for example [28]. In Figure 1, we present a graph showing the total amount of burnt area in the European Union between 1998 and 2013, which added up to the amount of about 6.8 million hectares [14].

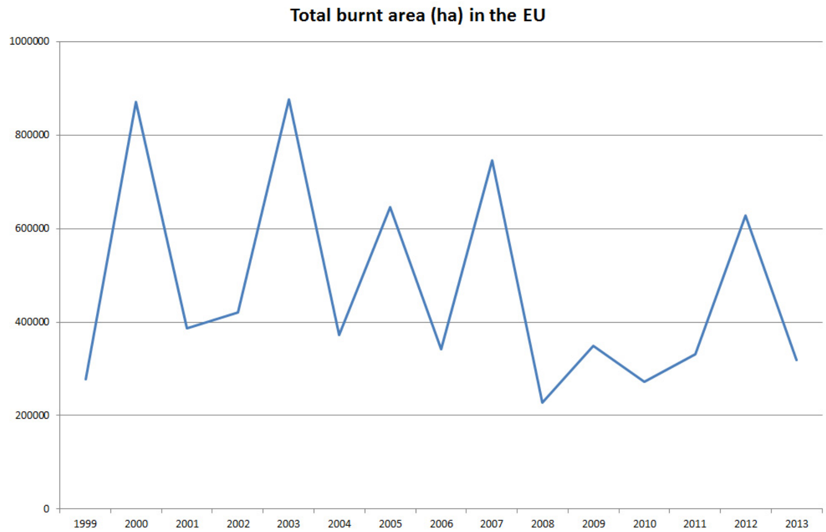

Figure 1: Total burnt area in the EU between 1998 and 2013 [14]

It is important to state that, nowadays, 96% of forest fires in Europe are human-induced, according to the European Forest Fire Information System (EFFIS), a component of the EU Copernicus programme [25]. In a WWF study released in late 2016, the author presents a similar number: 95% worldwide [20]. These studies indicate that currently, only 4-5% of forest fires are natural occurrences.

Moreover, global efforts to combat wildfires and minimise its side-effects carry a significant cost of economic funds. According to a report elaborated by the European Comission, between 2000 and 2017, in the EU, the total amount of economic losses exceeded €54 billion (approximately, €3 billion each year) and this value is expected to increase in the next years [6].

1.2 Health risks and benefits for nature

Additionally, wildfires also constitute a health risk for populations, due to the emission of smoke, which is constituted by gases and fine particles. Studies addressing short-term effects of smoke exposure have concluded that these particles worsen chronic heart and lung diseases, which can lead to premature death. Other less severe consequences include eye and respiratory tract irritations. This is an important issue due to the increasing number of wildfires in recent years [27, 7, 23].

Nonetheless, wildfires have benefits too and it is important to state that they have always been a naturally occurring phenomenon. By burning down vegetation and dead organic matter, they increase the nutrients available in the soil, which is an important advantage to a large amount of plant and animal species. For example, by eliminating weaker trees, stronger and younger ones have more space and nutrients to grow and develop, contributing to a process of forest regeneration [22]. However, due to the substantial number of total wildfires all around the globe, their consequences outweigh their benefits.

1.3 Relationship with climate change

This increase in wildfires is partially attributed to climate change. Variations in temperature, humidity and other environmental factors are turning European land drier, by decreasing the fuel moisture levels of soil and organic matter. Therefore, fire seasons are becoming progressively longer and more intense. Although it is believed that the Mediterranean region will be the first to suffer the consequences in the upcoming years, the areas with low fuel moisture levels will expand progressively towards Northern Europe, making most of Europe more susceptible to a large amount of intense wildfires [4, 10, 23, 24].

2 The Project Idea

2.1 Methodology

The development of our project idea comprises two stages.

Our project idea is to develop an application in which the estimated progression of a wildfire is easily visible and understood, by displaying the area affected on a map.

In order to track the progression of a wildfire, it is first necessary to detect its existence, in an early phase. Furthermore, it is fundamental to have real-time observation of the fire's progression. We aim to do this based on data collected by SAR satellites. This will consist on the first stage of our application (subsection 2.3).

On a second stage, the application will provide the most likely evolution of a wildfire, by showing a map which indicates its probable progression (subsection 2.4).

Due to the vast consequences of forest fires, this project encompasses UN Sustainable Development Goals 1, 2, 3, 5, 6, 9, 12, 13 and 15.

2.2 Integration with other programs

Nowadays, there are several governmental programmes worldwide which are focused on wildfires. For example, EFFIS has multiple applications concerning wildfires. The system gathers vital near real-time data, relating to fire danger, active fire detection, and fire damage assessment, therefore targeting three crucial points for minimising the risks and consequences of these occurrences. Annual fire reports and other publications can also be accessed on the EFFIS website [12, 13].

To support prevention, EFFIS uses satellite imagery and meteorological data to establish weather maps and forecast possible wildfires [25]. Even though we consider that preventive measures and the development of weather forecast maps are important, we do not believe it is enough, especially because the vast majority of wildfires is human-induced, as we stated in section 1. For this reason, our focus will be on the fire detection and tracking platforms it presents.

Ever since the programme began, the systems used for fire detection and monitoring have undergone various modifications in order to achieve more accurate results. Currently, active fire detection by EFFIS is based on the NASA FIRMS (Fire Information for Resource Management System) [13]. The data is collected from the MODIS and VIIRS satellite-based sensors, which look for thermal anomalies. These technologies rely on the emission of mid-infrared light from the blaze, displaying the active fire as a pixel on a global map, which is presented on the FIRMS online platform [1]. An example of an image seen on the NASA FIRMS online platform can be found on Figure 2.

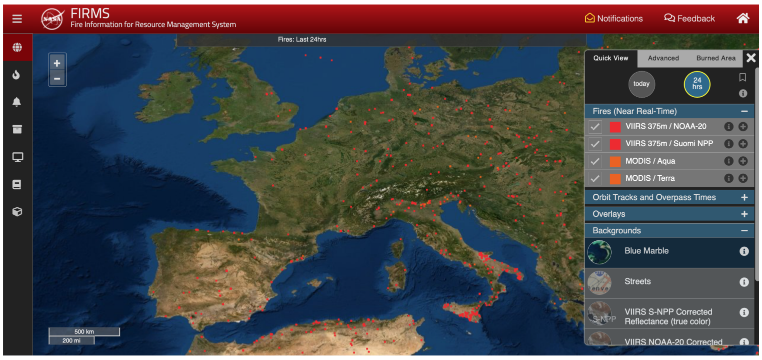

Figure 2: FIRMS online platform displaying active fires on June 28th 2020 [15].

Even though this application allows us to monitor wildfires worldwide, it still lacks accuracy and is affected by weather conditions. Under multiple circumstances, the satellite-based sensors mentioned above are subject to failure. The presence of cloud or smoke over the area under surveillance is one of the primary difficulties in detecting or monitoring an active wildfire through satellite imagery. Moreover, technical difficulties may also result in missing data [1].

On a practical level, the platform exhibits numerous limitations, as the actual fire may be smaller than the pixel displayed, or there may be more than one active fire corresponding to the same pixel. The system is also unable to distinguish between different types of thermal anomalies based only on information gathered by MODIS and VIIRS, just as some fires are not detected nor shown on the map [1].

In addition to this, the information is only updated a few times a day, and therefore cannot be used for rigorous fire tracking. Consequently, following the fire's progression using this platform is still insufficient [13, 1].

2.3 SAR satellites for fire detection

The possibility of using SAR (Synthetic Aperture Radars) to solve the problems stated above is emerging. These satellites emit their own light and therefore do not rely on external sources, such as sunlight, to obtain visual data. Furthermore, they operate on wavelengths which are able to penetrate through clouds, making data acquisition possible under any atmospheric conditions. SAR systems obtain data by emitting microwave radiation, which is not affected by atmospheric phenomenons. After it reaches the surface, the radiation is then reflected back to the original source, a phenomenon called backscatter, which is explored in SAR satellites in order to obtain data [8]. Their ability to generate high resolution images is yet another factor which underlines its determinant role in Earth observation [18, 3].

The Sentinel-1 constellation, part of the ESA Copernicus programme, includes two polar-orbiting satellites, Sentinel-1A and Sentinel-1B [18]. These are an example of SAR satellites which have produced consistent results in fire tracking, as demonstrated in multiple studies [3, 15].

A successful case was observed in Australia, where a research team was able to determine the evolution of wildfires with great accuracy, demonstrating the system's reliability for producing change maps of the occurrences. In comparison to the NASA FIRMS, the Sentinel-1 series present the advantage of allowing the fire's progress determination independently of weather circumstances. The change map produced between 18 and 30 November 2019 is represented in Figure 3 [15].

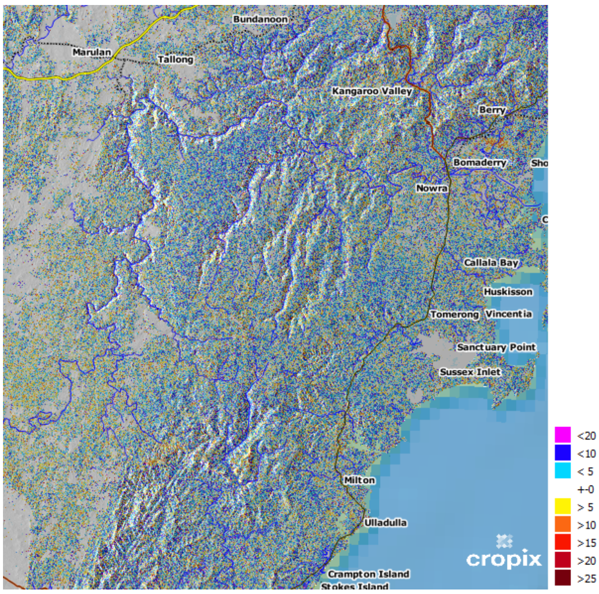

Figure 3: Change of Copernicus Sentinel-1 ESVI between 18 and 30 November 2019. The values are Enhanced SAR Vegetation Index (ESVI) units. This map allows for the detection of the burnt area. No change is represented in white, whereas blue to purple signifies a reduction and yellow to red an increase of ESVI values [15].

According to another study, based on Sentinel-1 data from three different fire occurrences, two in Canada and one in the USA, the system was able to detect and follow the wildfire's progressions by processing backscatter variations through time. Combined with deep learning models, the researchers were able to accurately distinguish burnt areas from the surroundings, demonstrating the relevance of SAR systems for future near real-time fire detection and tracking applications [3].

As a result, following the progress of wildfires is not only possible, but also brings the advantages cited above. However, the information provided by Sentinel-1 is only available for use at much lower frequencies than desirable, as these satellites present a revisit period of 6 days in Europe, which means that it takes 6 days to obtain observations from exactly the same spot, and data access implies previously requesting the necessary information. For other parts of the world, data may only be accessed on a 12 day period. Nonetheless, it could initially serve as a model for studying how to detect and follow a fire through data obtained from SAR satellites [17].

Aside from the Sentinel-1 mission, other SAR satellites have been launched in recent years, which make way for new possibilities, such as the usage of data collected by these systems to provide near real-time fire tracking and detection technologies. The RADARSAT Constellation, as well as the Capella X-SAR Constellation, have lower revisit periods, making it possible to access new information within daily and hourly intervals, respectively [3, 5, 11].

We consider relying on SAR satellite data to be a key step in monitoring wildfire progression across Europe. By developing an application which relies on data obtained from SAR satellites in order to detect and observe a wildfire's progression, we aim to achieve an improved method which will allow firefighting entities to accompany the situation with greater precision and under any atmospheric conditions. The launch of both the RADARSAT Constellation and the Capella X-SAR Constellation, bringing significant improvement on data availability frequency, will be crucial for the development of this project, serving a global purpose [5, 11].

2.4 Predicting wildfire progression

Following the previous stage (subsection 2.3) is the development of a fire modelling system, capable of generating the most probable burning route. Due to its complexity, prediction of fire progression would necessarily comprise a second stage of this project. Yet, the beneficial outcomes make it a decisive step in order to tackle the problem.

For firefighters on the front line, being able to anticipate the probable evolution of a wildfire may be vital, enabling the teams to adopt strategic positions, preventing millions of hectares from burning. On another side, it would also warn authorities of important places to evacuate, such as villages.

Therefore, there is a need to combine a wide range of data from multiple sources and use them as input to a sophisticated algorithm, such as: types of vegetation on the area, fuel moisture content, topography, wind speed, direction and specific wind phenomenons and other meteorological factors [2].

To further extend the application's capacity, an interesting option would be to combine this data with information regarding protected and populated areas, such as natural reserves and villages, warning firefighters of the risk of the flames reaching a certain location. This could consist of a third step to this project, in order to make information even more explicit for firefighters.

2.4.1 Relevance of vegetation, topography and SMA

In a study published in 2018, scientists investigated the importance of vegetation, topography and surface moisture availability (SMA) prior to a fire [19]. Applying boosted regression tree (BRT) modelling to data from Eurasian boreal forests, they concluded that these three environmental factors were responsible for more than 70% of variations in fire severity. Another finding was that the most severe fires occur on well-drained slopes at high altitudes, showing the influence of topography.

Consequently, it is important to obtain accurate data regarding these factors.

With the Sentinel-2 satellites from ESA, it is possible to obtain vegetation data, such as the Leaf Area Index (LAI) and the Normalised Difference Vegetation Index (NDVI), both of which can be important to track the progression of a wildfire, depending on the construction of the algorithm [9, 21]. It is also already possible to measure soil moisture from space, using Sentinel-1 [26]. These are examples of vegetation information which can be obtained from satellites and be further combined with other ground-based data (e.g. species of vegetation which are known to be present at certain locations).

Using other SAR satellites, as it was explained in subsection 2.3, near real-time information could be obtained regarding these factors, in the near future (e.g. Capella X-SAR Constellation is predicted to have all their 36 microsatellites launched in 2021, including the 6 already launched).

2.4.2 Importance of wind

Wind is of upmost relevance to predict the progression of flames in a wildfire.

By using Aeolus data, a satellite launched by ESA in 2018, we would be able to have significant near real-time measures of wind globally, which could be incorporated in the algorithm to predict the pathway of a wildfire [16].

This data could be further combined with ground-based meteorological stations, for example, depending on the location and circumstances.

3 Feasibility

The evaluation of the project's feasibility by means of a SWOT analysis is presented in Figure 4.

As mentioned in previous sections, acquiring SAR satellite data for fire detection and tracking is possible under any atmospheric conditions, allowing us to obtain accurate results, after improving the observation models using available data. However, observing the fire's evolution at hourly intervals is only conceivable with the launch of the remaining Capella X-SAR satellites.

Estimating the wildfire's expansion route would also be possible by combining multiple data sources and training a model to forecast the fire's progression, at last presenting a useful and easy to interpret visual map.

Yet, this project's development time, along with the high computational power necessary for the implementation of such algorithms and technical issues which sometimes affect satellite

Figure 4: SWOT analysis of our project idea assessing the overall feasibility

data acquisition constitute the major obstacles for this project. Therefore, it is mandatory to divide its implementation in stages, creating successive versions of our application.

Nonetheless, we consider this idea to be viable, within the referred constraints. By combining currently available ground-based and satellite-based information with satellite data attainable in the near future, this system will be able to estimate the pathway of a wildfire, allowing us to save hundreds of lives, millions of hectares and megatonnes of CO_2.

4 Conclusion

Wildfires cause irreparable damage to fauna and flora communities, representing a health hazard and endangering human lives, while resulting in enormous economic prejudice for the affected regions. The increasing number of such events is a worrying tendency, which requires adequate measures.

Consequently, this idea's purpose is to aid in wildfire combat, providing firefighters with an application that allows for near real-time fire monitoring and also displays the fire's probable evolution route on a map.

Overall, we believe this project will represent an improvement on the resources available for fighting active wildfires, aiding firefighters on the field and local authorities.

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