Team Feuer

Sustainability Lab: A forest fire early detection system

Janek Richter

Faculty of Economic and Social Sciences

Department of Information Systems

University of Cologne

GitHub Repository:

https://github.com/innovationlab-fire/innovationlab-fire

Website:

https://innovationlab-fire.netlify.app

YouTube:

https://www.youtube.com/channel/UCS5Bbf_3bhYVp7_8QDcPbxg

Authors: Tim Mayer, Nathalie Spellerberg, Lazar Milosevic, Henning Schultz, Moritz Müller

Cologne, 26.01.2023

Table of Contents

List of figures

1 Introduction

Climate change has increased the risk of increased temperature and droughts all around Europe and the world.[1] The impacts of droughts can be seen especially in an increase of forest fires in high-risk areas for forest fires such as Brandenburg in Germany, in the Mediterranean area of Europe, Russia or Canada.[2] The number of years with fire risk, length of fire risk season and the increase of extreme fire events are direct consequences of drought and climate change.[3] The number and intensity of forest fires around the globe have increased thus far, and according to most scientific predictions, we can expect a dramatical increase of forest fires and their intensity in the future.[4] For example, in the Campania region in Italy 80% of the registered forest fires (3400) between 1989 and 2019 occurred between 2016 and 2019.[5] This is also due to the increase in extreme heat waves caused by climate change and its correlation with a higher risk of forest fires (e.g., 97% of forest fires in Portugal occur during heat waves.[6]

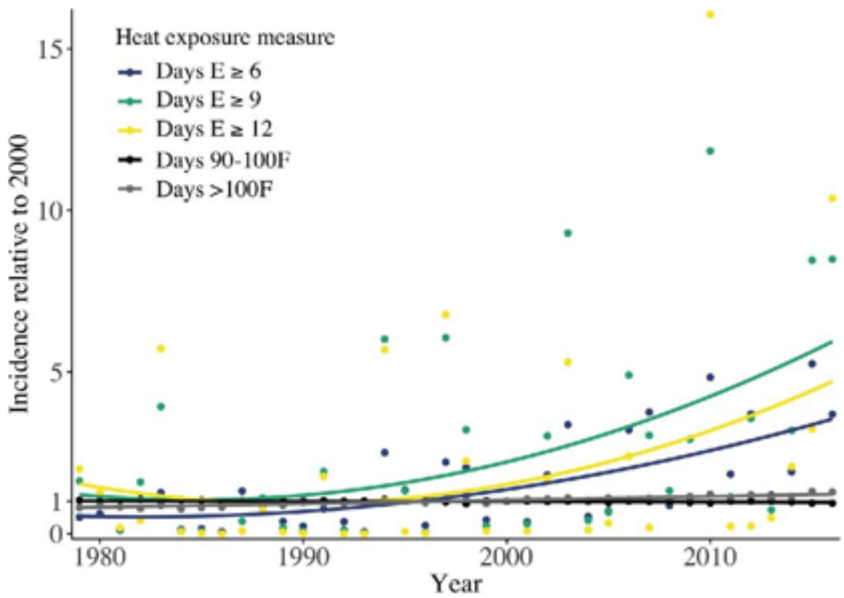

Figure 1: Global Trends in Heat-Wave Incidence[7]

---

[1] Alcamo et al 2006, p. 273
[2] Bindi et al 2006, p. 85 / Fosberg et al 1998, p. 1
[3] Bindi et al 2006, p. 85 / Fosberg et al 1998, p.1
[4] Vgl. Busico et al 2019, pp. 16
[5] Busico 2019 et al, p. 16
[6] Amraoui et al, p. 539
[7] Chua et al 2021, p. 2659

Figure 1 shows the heat wave incidence around the world. It is easy to recognize that heat waves strongly increased since 1980. This development greatly contributes to forest fires, as forest dry out faster and fires spread and behave more aggressively if they occur.[8] Figure 2 illustrates the fires and climate feedback loop.

,

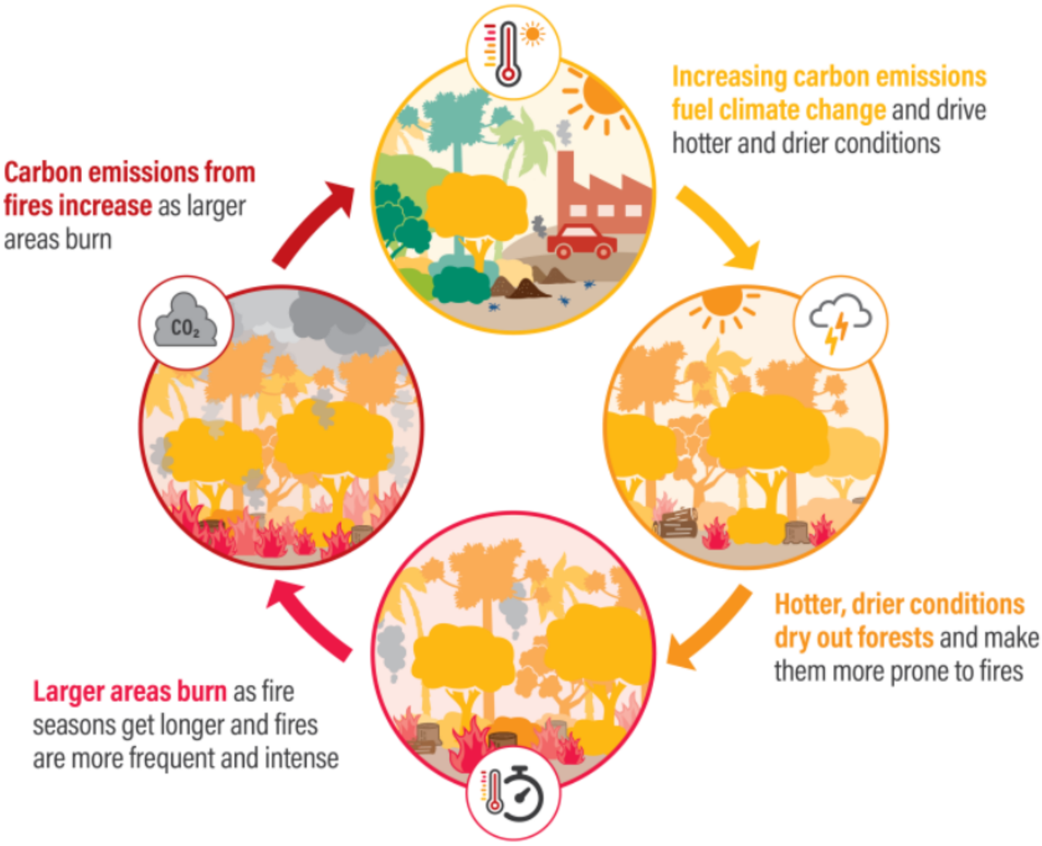

Figure 2: Fires and Climate Feedback Loop[9]

The increase of carbon emissions contribute to hotter weather conditions and extreme weather waves caused by climate change. These drier conditions contribute to more frequent and intense forest fires, which in turn contribute worsen climate change by releasing large amounts of CO2 as they burn.

There are several reasons why the world as a community must highly focus the protection of forests and therefor prevent forest fires. Forests act as a CO2 saver which means that healthy forest can be an impactful method to fight climate change. In

---

[8] Hudson/Kuhn/Smoyer-Tomic 2003, pp. 468 and 473
[9] World Research Institute 2022

addition to providing a habitat for many animals and plants, forests also release large amounts of oxygen, which helps counteract air pollution and improves human health. It is also worth noting that forests contribute to a society's economy through the resources they provide, which can use responsibly for their benefit. Worldwide, forests contribute 1% of GDP, and especially in developing countries, they are a crucial economic driver.[10] Immediate consequences of a forest fire can also negatively impact human health through inhalation of wildfire smoke, the cost of rebuilding areas affected by fires, and degradation of watersheds by wildfire pollutants.[11] There are several levels on which the global society can counterpart the development of forest fires and its consequences. Obviously, the general prevention of CO_2 emissions will contribute to a better health of forests and reduce droughts. Still, we need to develop strategies and techniques for the case, a fire emerges. A part of that is the recognition of emerging forest fires. As a forest fire gets harder to control when it spreads and gets larger it is essential to recognize forest fires as early as possible. With effective early warning systems, the dramatic consequences of forest fires can be prevented. In this work we will present a lightweight solution to recognize forest fires at an early stage. A main goal of this solution is the ubiquitous applicability due to a design which is cheap, small, and easy to use and install for everyone. With our solution, we particularly aim to contribute to United Nations Sustainable Development Goals (SDG) 13 (Climate Action) and 15 (Life on Land). We want to contribute to SDG 15 by addressing the protection and restoration of forest ecosystems and halt biodiversity loss of forests.[12] SDG 13 is addressed by developing and providing a technique to take urgent action to combat climate change and its impact referred to the role of CO_2 in interplay with forests.[13]

[10] Berry/Nautiyal 1996, p. 31 / Worldbank 2022
[11] UN Environment Programme 2022
[12] United Nations
[13] United Nations

2 Problem Description

Depending on which scale we're looking for a solution, there exist different approaches to prevent forest fires from spreading which are applied today. In Germany, measures such as reconnaissance flights, watchtowers, forest fire patrols and an automatic forest fire early detection system (FireWatch) are used.[14] These methods can be costly and ineffective. Forest fire patrols may be useful in smaller forests, but in larger forests, they may seem like searching for the needle in a haystack. Watchtowers can recognize forest fires from a long distance, but only at a later stage of the fire when it's hard to stop and much damage may be caused. Reconnaissance flights also have this problem, as they can easily observe a large distance, but are not able to recognize forest fires in their early stages. Additionally, reconnaissance flights are costly both financial and environmental. The automatic early warning system FireWatch which is particularly used in high-risk areas in Germany (e.g., Berlin and Brandenburg) is a heavyweight camera-based system which can automatically observe and analyze the state of a forest through a range of 20km. While these solutions may have their place in preventing the spread of a forest fire, there are few approaches for reliable early warning systems on a smaller scale (i.e., easy and cheap to install for everyone and recognition at a very early stage of the fire).

Figure 3: Stages of a Wildfire[15]

Figure 3 shows generalized wildfire stages/ranks. The time in which the stages are reached is highly influenced by factors such as the forest type, existing heat waves, soil quality, and wind.[16] It is obvious that recognizing a fire at ranks 1-2 would significantly minimize damage and effort compared to ranks 4-6. In this work, we want to fill this gap. The goal of our solution is to recognize fires at a rank between 1 or 2.

---

[14] Bundesministerium für Ernährung und Landwirtschaft 2022
[15] Government of British Colombia
[16]DWD / Colorado Forest Restoration Institute 2021

The underlying idea is to use the main pattern of forest fires: They are typically caused by humans. In 2021, out of 259 forest fires with known cause 252 are human induced.[17] This fact has led us to the conclusion that it's particularly reasonable to look for fires in their early stages. Especially in areas, which are frequently contacted by humans.

2.1.1 Dryad

Another solution is offered by the German start-up Dryad. Dryad aims to achieve a similar goal as our project, that is, ultra-early detection of forest fires. Dryad is available on the market with 10 deployment locations all around the world.

Dryad developed a device which is equipped with solar powered sensors. The sensors can measure different gasses, temperature, humidity, and air pressure. The devices are systematically interconnected over a network named Silvanet. Each device is connected to a gateway which are connected to the main server which processes the data. The threshold values of the sensors are determined by a machine learning approach. Both the technology behind the devices and the network and server infrastructure are quite complex and costly. Therefore, Dryad targets customer groups which can afford the expense of the sophisticated and complex system, such as governmental institutions.

In contrast, our solution approach aims to be lightweight and keep costs and complexity as low as possible to target both concerned individuals (e.g., the owner of a camping resort) and larger customers (e.g., governmental institutions).

[17] Waldbrandstatistik der Bundesrepublik Deutschland 2021

3 Stakeholders

There are several stakeholders which might profit from our solution. First to mention is the society itself. Fewer forest fires lead to better health since the air is cleaner. Additionally, society is indirectly positively impacted by having less costs which must be paid as a common society. These costs can occur due to the uncertain impacts of climate change or the high effort required to extinguish a forest fire and restore the environment. It also must be considered the forest as a place for human beings itself: If a forest burns, it will be taken away from many people who use it for various activities. Resources which could have gained financial benefit for the society are vanished in the thin air. Because of all that direct and indirect influences of forest fires on society, the society is the biggest stakeholder of all.

When it comes to a fire, the fire department gets alarmed by our device and must fight the fire afterwards. If a fire gets larger the fire department needs more resources to fight the fire. Therefore, it’s in the best will of fire departments to have our solution in practical application. Also concerning eventual health risks of the fire fighters when inhaling the polluted air or bringing themselves into danger because of the flames, it’s in the best will of fire departments to stop forest fires as soon as possible.

Property owners are direct stakeholders of our solution because they are a large user group. Since our device is designed to fit both individuals and institutions/organizations property owner is a wide ranging term. On a smaller scale a property owner might be the owner of a camping site, adventure locations (e.g., the owner of a climbing park) or a farmer operating or living next to a forest. On a larger scale property owners can be governmental institutions or companies operating in the forest. It’s in the best interest for a farmer or company to prevent a fire just to save their economic base. In this way, agricultural companies which aren’t operating in the forest can also benefit from our solution. On large agricultural fields a fire (which can be caused by anything) can ruin the whole harvest, since farms can burn heavy and fast while drought. A fast early warning system would decrease the amount of lost crops after a fire. A governmental institution can apply our solution as a cheap method particularly in areas that are not defined as high risk. For example, the federal state

Baden-Württemberg don’t use early warning systems at all.[18] The area has low risk for forest fires, but low risk does not mean no risk (consider: 10% of the forests in Germany are located in Baden-Württemberg). It is conceivable that a case like Baden-Württemberg requires early warning systems, but the existing ones are just to heavyweight and expensive. We can scale that example to governmental institutions all around the world, also considering developing countries and societies which can’t afford heavyweight solutions.

Similar to property owners, hunters can be considered as relevant stakeholders. They are responsible for a certain area in the forest and may encounter the devices. It’s conceivable that hunters act as information providers since they are aware of human frequented forest areas or particularly vulnerable areas in the forest.

Journalists and news in general must also be considered as relevant stakeholders as they play a key role in reporting and promoting the solution. With news, potential users get aware about the existence of our solution and the benefits of its application.

For our information gain we interviewed and contacted several stakeholders and experts. First, we had a Zoom session with the founder of Dryad who gave us both information about their product and hints and tips for our solution. Additionally, we interviewed the head of the fire department of Cologne, who gave us worthful information about the behavior of fire itself and supported the inherent need of a solution for forest fire early warning systems.

[18] Bundesministerium für Ernährung und Landwirtschaft

4 Solution Description

Our solution is an Arduino based device which is equipped with several sensors. The device is designed to be waterproof and can be placed everywhere its use seems reasonable. The core functionality is to detect a fire through certain threshold values of CO2 and then automatically send an alert SMS to the responsible instance (typically a fire department).

4.1 Prototype

To reconstruct the prototype, you need the materials listed in the following table. In addition, for the installation you need jumper wires, resistors (330 Ohm) and a soldering device. All in all, you should expect spending approximately 60 to 70 euros for the purchase of all materials for one device (as of January 2023) as it can be seen in figure 4.

Name	Price in EUR
Arduino R3 incl. USB-cabel	~ 10
MQ-2 Gas Sensor	~ 6
SPI Reader Micro Memory SD TF Card Memory Card Shield Module	~ 5
SIM800L GPRS GSM Module incl. antenna	~ 9
SD-Card	~ 5-10 (depending on memory)
Lithium Polymer Battery 3.7 V 2000 mAh	~ 15
Breadboard with 830 or 400 pins	~ 4
Sim-Card	~ 5-10 (depending on provider)
A Case for the hardware	~ 10 (depending on material)

Figure 4:Cost calculation

After collecting all needed materials, you have to download the Arduino IDE. You can do that directly on the Arduino website. After successfully downloading the IDE you should also download the required library “Adafruit BusIO” by Adafruit via the integrated library manager on your Arduino IDE. Then, you can download the project code from our Github Repository.

After downloading the code, start your Arduino IDE and click on „File“ in the top left corner of the Arduino IDE and click on „Open…“. Then, you need to select the previously downloaded code and it will be opened in the IDE. Now, you only have to make a small alteration to the code, in order to send the SMS to the right phone number regarding your respective use case (we have made a comment like “XXXXX” to indicate where you have to change the number). After that, the code is ready to use.

Before starting with the hardware, create an empty csv file called "test.csv" on your SD card. This will be used later in order to save the measured gas values including the respective timestamps.

Regarding the hardware, you need to wire up the Arduino uno and the modules like shown in figure 5.

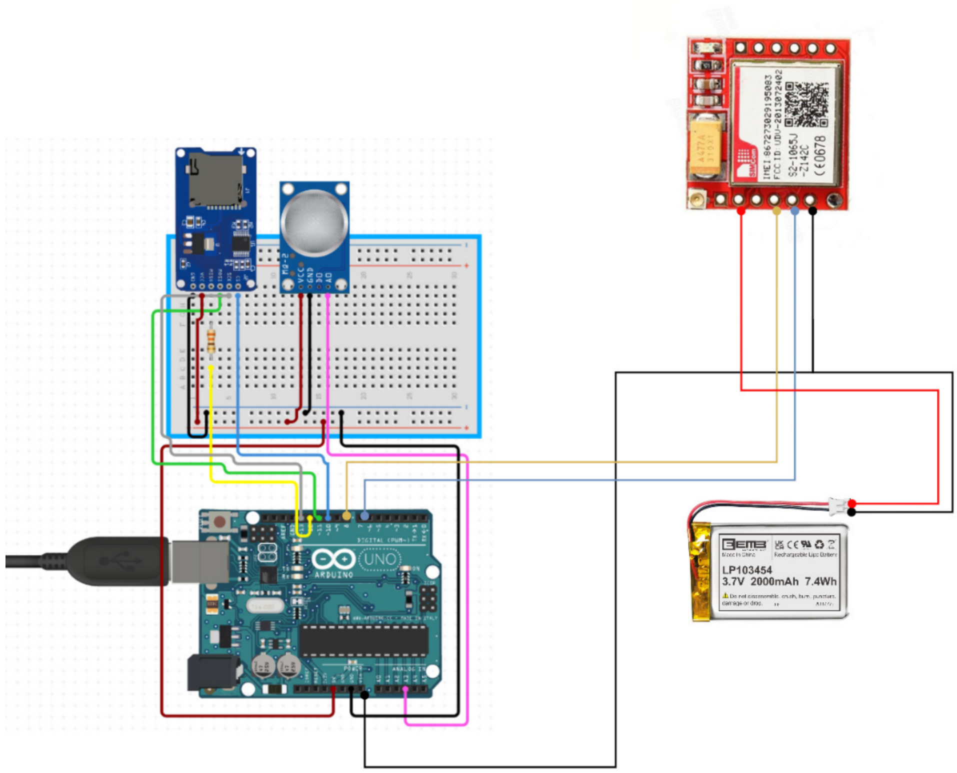

Figure 5: Arduino Modular Architecture

You also need to solder the sim module correctly, connect it to the separate LiPo battery and clip on the green antenna. After you have done this, see if the sim module is working correctly if it flashes every 3 seconds. If it only flashes at 1 second intervals, the sim module is still searching for the available network. Please note that the Arduino requires a constant power supply for smooth operation (5V), which can be connected via the power supply unit. Please bear in mind that we only describe the start-up via a computer, which, however, is not a realistic option for the desired application in a forest. Therefore, please inquire about alternative power supply options.

Once the hardware is wired and soldered correctly, you can connect the Arduino with the USB cable to the computer. Click on the „Upload“ button in the toolbar of the IDE and the code will be uploaded to the Arduino. The code will then start running and you can open the serial monitor to track the process.

After the code was once uploaded to the Arduino through the IDE, the Arduino will always start running the code once it has a power supply. Therefore, you can choose alternative power supply methods other than plugging it into the computer as described above.

In case of high gas values in the air, the device sends an SMS to the phone number you have specified. In addition, the measured values are stored on the SD card and you can visualize them by inserting the SD card into your computer via Excel according to your wishes.

4.2 Simulation

In order to learn more about our product and get an idea about it works on a larger scale, we conducted a simulation of multiple of the boxes in a finite area. For simulation purposes we took the area of the Kölner Stadtwald which is approximately 2.053km^2. The simulation works by first distributing a set number of Boxes N. The distribution of those boxes is done on a grid regarding the x axis and then slightly moved to simulate semi-unstructured spreading. Regarding the y axis and in order to simulate the crowding of boxes near civilization, boxes are distributed on a grid and then moved with a normally distributed probability towards the x-Axis. This means that on the x-y-plain the boxes spawn more frequently near the x-Axis, but otherwise “grid-like”. Note that especially the x-axis is modeled to simulate the length of the edges of the “kölner Stadtwald”, thereby putting civilization near the x-axis.

After all boxes have been distributed, a fire is spawned in the x-y-plain with the same probability constraints as the boxes, taking the fact into account, that about 85% of forest fires are caused by human error and thereby making it more likely that a fire may break out near civilization.

Depicting the distribution of boxes and the fire gives us the following diagram:

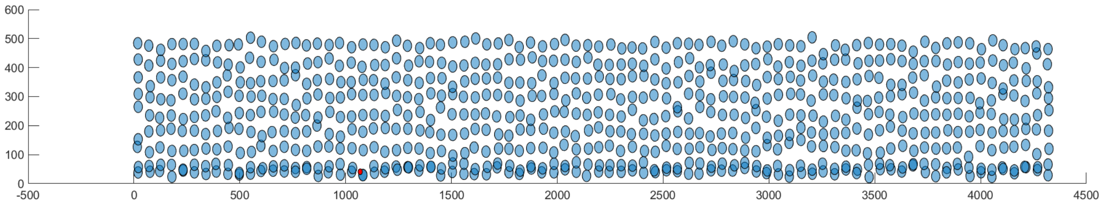

Figure 6: Distribution of Boxes

The boxes and their range are portrayed by the blue circles and the fire is the red dot. If the fire intersects with one of the blue circles, the fire is detected. This is repeated 5000 times giving us a detection probability, which is dependent on: The number of boxes N, the detection radius of a box r_Box and the radius of a forest fire r_fire. Changing these values and trying different combination gave us the following results:

From testing the product, we have determined that the Boxes can detect fires in a range of about r_Box = 20m. Moreover, we tested 3 different radii r_fire of the fire. These were 2m, 5m, and 10m. These fires are small and may not have escalated further than rank 3 (Figure 15) yet. We kept the number of boxes N variable to directly determine how many boxes would need to be distributed in the "kölner Stadtwald" to achieve different detection probabilities.

From testing the simulation with different values for N we found that 52% of fires at 2m radius are detected if about 750 Boxes are distributed around the "Stadtwald". That corresponds with about 1 box for each 2700m^2 area (note that more of them are near the edge of the forest) or about 45000€, because the price of one box is roughly 60€. With the same input 86% of fires with a radius of 10m are detected. Testing with 1000 boxes pushes the detection rate of a fire with 2m radius up to 70% and a fire of radius 10m is discovered 95% of the time. This would cost around 60000€

Even though the simulation is rather rudimentary, not taking sensor values into account for example, it still provided us with insight into the functionality of our product on a larger scale. Here are some key takeaways:

1. Sensor range is a big factor: While 20m of sensor range is higher than we initially expected, we could greatly improve our products coverage with higher sensor range. For the "Stadtwald" a distribution 300 instead of 750 boxes are necessary to achieve roughly the same results with just 10m of additional sensor range, although this would drive up the cost.

2. Distribution is most sensible in areas where a lot of humans dwell, as these are the areas where forest fires most likely start. Especially the deployment near paths in the forest and near the edge of the forest is most sensible.
3. The best way to spatially disperse our product, if full coverage of an area is desired, is to space it evenly about 50 meters apart and getting coarser the further you get away from civilization (e.g., paths and structures).
4. Our product is technically able to cover a large area of forest completely. As the cost of an average forest fire consuming an area of forest as large as the "Kölner Stadtwald" ranges from 697000$ - 3567000$[16] in addition to immeasurable cost considering the forest fire's impact on human life and the ecosystem, the estimated price of 45000€ - 60000€ for coverage is low.

4.3 Use Case and Fire Alert Modelling

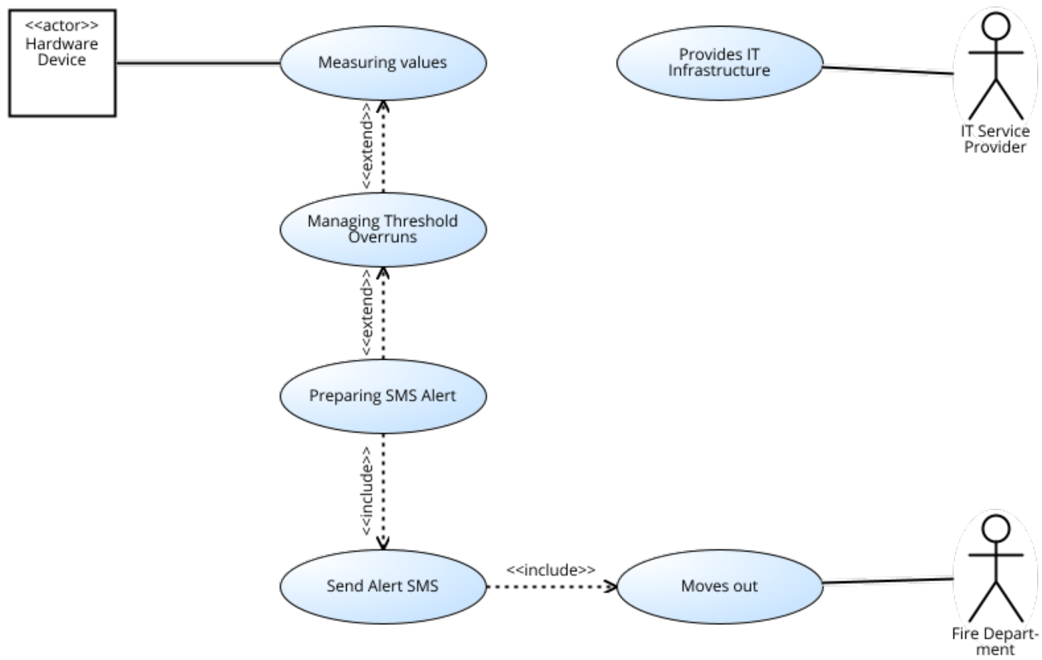

Figure 7: Use Case Diagram of our solution concept

Figure 7 shows the Use Case Diagram for our solution. The device is continuously measuring the CO2 values. Besides that, the device has an integrated threshold management feature. If a certain threshold is overcome, the device registers this exception and immediately prepares an alert SMS. The alert SMS simply contains the device ID to identify its location (devices are saved in a database table with their individual coordinates) and the recorded gas values. After receiving an alert, the fire department moves out towards the given coordinates which is offered in the SMS. The IT-service provider is responsible for providing the IT Infrastructure (such as mobile network provider and GPS service provider) and maintaining it.

Figure 8 shows the process after a gas threshold was overcome. The device then prepares an alert SMS for the fire department. The fire department estimates the situation and the operations size. They move out and attempt to extinguish the fire. Alternatively, the device sends an SMS to the owner of the device who then takes action (informing the fire department by himself).

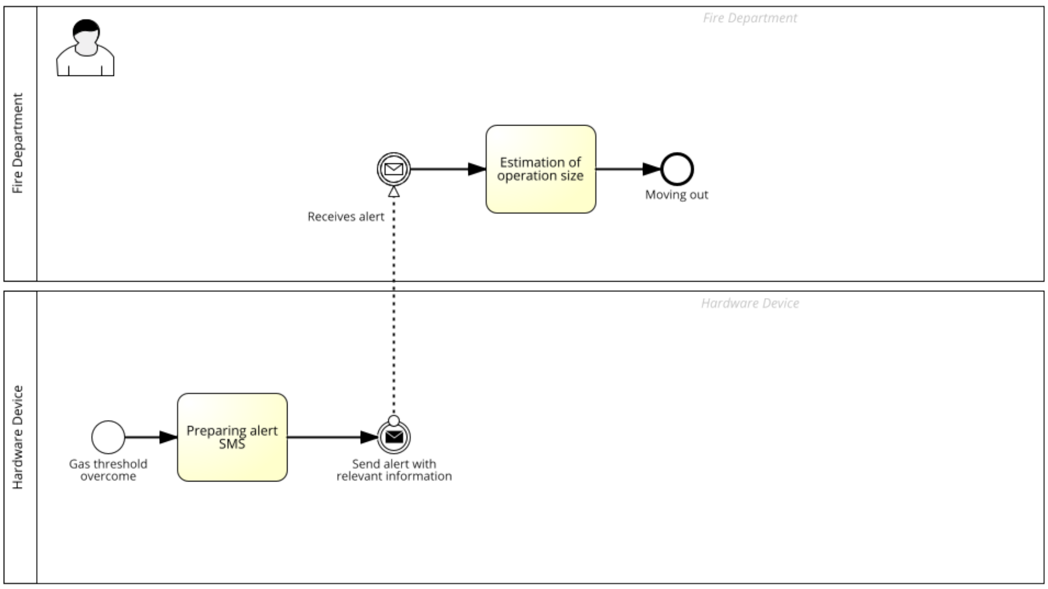

Figure 8: Fire Alert Process Diagram

5 Testing and Data

We tested the device in a safe test environment provided and controlled by the fire department of Cologne. The purpose of the tests was both finding reasonable thresholds and check the general functionality of the device. On two separate days, we evaluated the device's functionality in different scenarios. The first scenario was a grease fire environment; however, the results were not satisfying. We expected that was caused by the suboptimal fire type. We did not voluntary decided to test our device within the setting of a grease fire. However, we just had to take whatever the fire department could offer us as a test setting. Since the results were not satisfying, we decided to take another test in a more realistic environment using wood pallets, branches, and leaves on the next day. The results in the second test were well acceptable and seemed realistic. We looked at the change of the gas values with different distances to the fire. We compared the values while being directly next to the fire (1 meter distance) to being more far away (20 m) distance. The results can be seen in Figure 9. Furthermore, we looked at how the values change when we make only small differences in the distance. In doing so, we alternated between a distance of 1 m and 3 meters. These measurements are provided in figure 10. We observed that the device delivered consistent increased gas concentration during the fire. This is why it is reasonable in practice, to send the alert SMS after a certain period with consistently increased gas concentration to avoid erroneous alerts. Additionally, we noticed a potential measurement-range between about 20 meters for each device (test values about 800ppm/10).

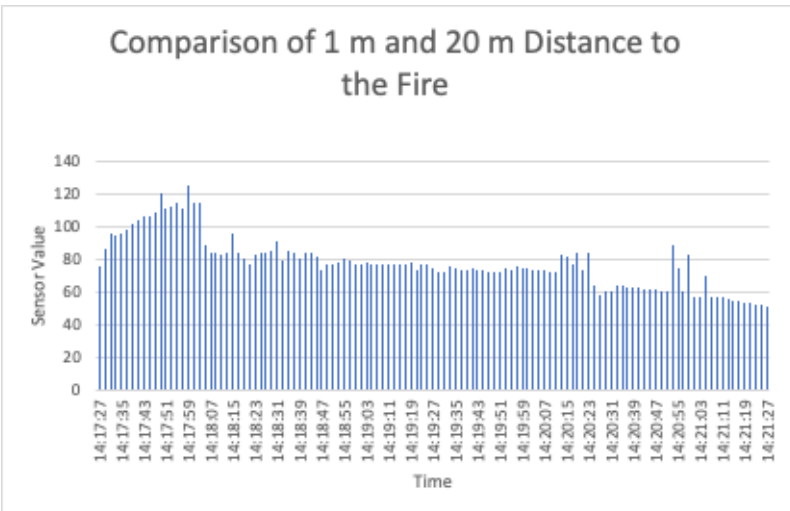

Figure 9: Measurement of 1m vs. 20m distance to the fire

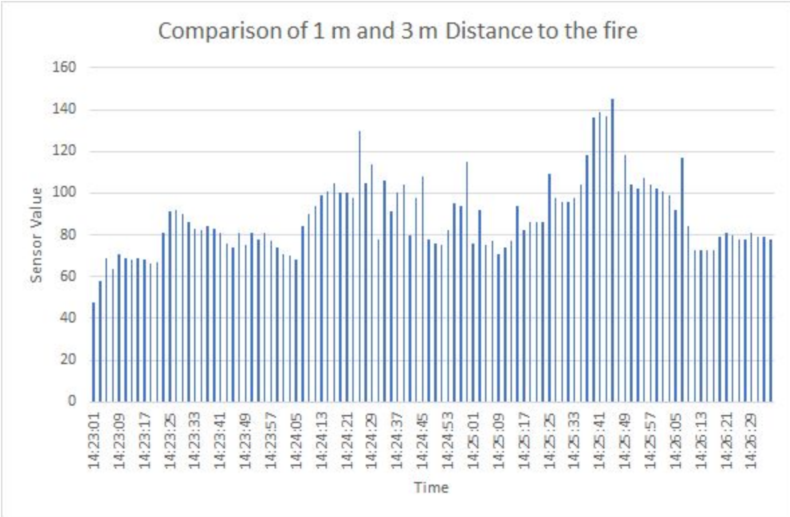

Figure 10: Measurements of 1 m vs. 3 m Distance to the fire

To achieve a certain baseline to reliably classify the gas values we also test-measured in the forest. The values we obtained in the forest serve as reference values for the future deployment in the forest since there may be different gas concentrations in forests than in a city. We measured gas values around 300ppm/10. This is further shown in the Figure 11 where the measure values are plotted. On this basis we ensured that a threshold of 800ppm/10 is a reasonable value to detect a forest fire. This is equal to a measurement range of 20 meters which we determined within the tests at the fire department.

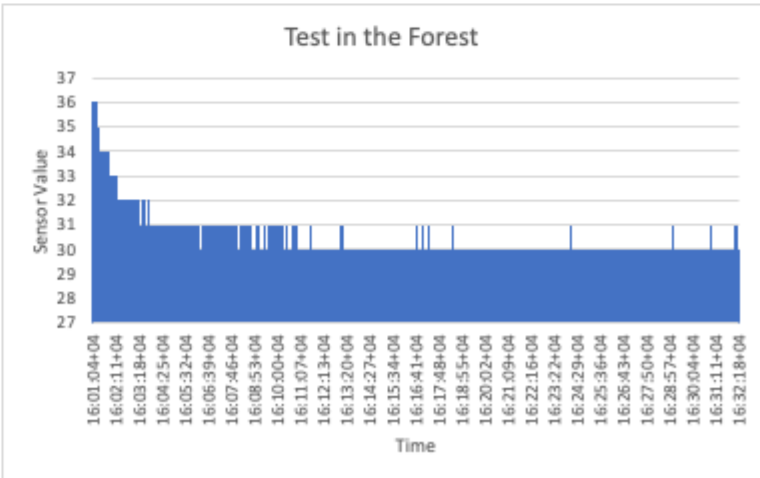

Figure 11: Diagram of Values Measured in the Forest

Figure 12: Test setting 1

Figure 13: Test environment 2

Figure 14: Test Environment Forest

6 Future Potential

Our solution concept is not fully matured yet. There are several ideas which can be potentially implemented one day. The reasons we didn't implement these ideas is based on a deficiency of time, budget and data of the applied device.

First, it can be reasonable to create a Dashboard which visualizes the data generated by the devices. These data can be sent through SMS. The dashboard should include the values recorded by the device and external data. External data may be useful to estimate the risk of a fast-spreading forest fire. For example, it could visualize the wind speed and direction, the soil-quality, and its likelihood to support a fire or indices (e.g., the "Waldbrandgefahrenindex WBI" calculated by Deutscher Wetterdienst). It is also reasonable to show the current weather conditions and forecasts particularly if heat waves are expected or present. Internal data that can be visualized may be the gas concentration and temperature of a given area or of a certain device. The number of false alerts and devices which are not forwarding data anymore may be also interesting. It is also useful to access the GPS location of a certain device fast through the dashboard. In case of an alert, the dashboard should promptly provide all necessary information such as GPS location or gas concentration of both the alert device and its neighbor devices.

In future scenarios it can be useful to implement a network design of the devices. Particularly if the applied area is larger, it may be important that the devices can reliably communicate with a main server. A disadvantage of the current SMS approach is the availability of the cellular network in a forest. Since cellular network is not available everywhere, it limits the possible locations a device can be installed. This problem may be solved through a network of devices which transmit their data to a main server e.g., by using LoRaWAN network. It is also worth noting that SMS costs may increase linearly with increasing data amount. We can assume that from a certain number of devices it will be cheaper to use a network approach. Particularly in combination with a dashboard that need a lot of real time data, costs of SMS may increase dramatically.

Our prototype solution is battery based. For the sake of both sustainability and ease of maintenance a solar power approach may be a better solution in the future.

Another potential modification in the future may be the implementation of a WIFI transmitter. Particularly for special use cases, such as a camping site, WIFI technology is typically available and could be used for fast, easy and reliable data transmission.

It is also conceivable to offer different solutions for different use cases in future. For larger applications we could offer a solution with the LoRaWAN network, for applications with consistent access to WIFI we could offer a WIFI transmitter and for smaller applications in a forest we could keep the actual solution.

7 Conclusion

As we mentioned earlier, our innovation mainly contributes to SDG 13 and SDG 15. The SDG 13 ("Take urgent action to combat climate change and its impact" [19]) is addressed since our innovation contributes to CO2 savings. Forests play a crucial role in absorbing CO2 and preventing its release in the atmosphere. Additionally, forest fires release a significant amount of CO2 through the combustion process. Our device can help reduce the intensity of forest fires, thereby reducing CO2 emissions and combating climate change. SDG 15 ("Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" [20]) is supported as our innovation contributes to the protection of forests and therefore protects terrestrial ecosystems of forests. These ecosystems include all animals and plants in a forest which must be commonly protected from both perspectives ethical and for human value (economic value, leisure time, agricultural value etc.).

Speaking about sustainability we also must mention the sustainability of our device itself. Our device utilizes an Arduino mini-computer, a battery-based power source, sensors, and a SIM module. However, the production of these components requires critical resources such as lithium. It is worth noting that the device has a low but continuous power consumption. In larger applications, the limited range of each device (between 10-20 meters) may make it impractical to install multiple devices. An alternative would be to use more expensive sensors with a wider range of measurement to reduce the number of required devices.

We consider our solution as innovative since it fills an existing gap of forest fire early warning systems. Our solution is innovative as it addresses the underlying problem in a unique way. The innovational degree depends on Dryad. At the beginning of our project, we were not aware of the existence of Dryad and its innovation. However, our solution has a lot of similarities to Dryad's since the concept itself is the same. The main difference between our solution and Dryad's is that we (partly) address another user group due to the lightweight character of our solution. The lightweight character is the second differentiation to Dryad: we used different technologies on which other

[19] United Nations
[20] United Nations

possibilities and disadvantages resulted. This leads to the conclusion, that our solution is an architectural innovation that addresses different user groups (e.g., the owner of a camping site or governmental institutions which need an inexpensive solution) and incrementally changed the technical foundation of Dryads solution.

8 Appendix

8.1 Interview with Dryad

09.12.2022 um 10:30

1. Wann löst der Waldbrandmelder von Silvanet Alarm aus?
    - Schwellenwert reicht nicht, zu viel Fehl Alarme
    - Die haben: Kombination aus schwellenwert und machine learning zur Muster Erkennung
    - Gas Scans sehr Energie intensiv, schwellenwert
    - ->Air Quality Index: sagt erstmal es „stinkt“
    - Air Quality einmal pro Minute, erst wenn die schlecht ist, dann gas Messung
    - Für Prototypen reicht ein Air Quality Sensor
        - → air Quality ist ein Draht der erhitzt wird, wenn Draht erhitzt gehen da gas Moleküle dran die die Spannung ändern
    - Prototyp nicht mit machine learning
2. Welche Schwellenwerte bei der CO- oder CO2-Konzentration in der Luft sind ein gutes Indiz für einen sich entwickelnden Waldbrand?
    - CO2 bei Schwelbrand noch nicht so stark
    - Co2 ist erst bei richtigem Brand und hohen Temperaturen (800)
3. Würden Sie bei einem rudimentären Prototyp, wie unserem, eher die Messung von CO oder CO2 verfolgen?
    - Lieber Air Quality Index (auch andere Gase, auch Wasserstoff etc)
    - An co2 ist die false positive Erkennung schwierig, weil viele false positive und es ist nicht (immer) zu erkennen warum →Bodenfeuchte, Tiere im Wald, Vrkehr
    - Wichtig zu wissen ist: Was ist die Quelle von co2, wind trägt gas Konzentrationen weiter aber schwierig im Wald
    - Es gibt unternehmen die das kommerziell mit CO2 machen
4. Was für einen Messbereich sollten die Sensoren haben? Reicht z.B. für CO2 ein Messbereich von 0-5000 ppm?
5. Gibt es noch andere Indikatoren, die mitgemessen werden sollten (wie z.B. Temperatur, Jahres-/Tageszeit)?
    - Beziehen die nicht mit ein
    - Nur Luft Qualität und Gas Scan
    - Wind nicht, für Erkennung nicht relevant

- Im Wald ist kein konstanter wind, starke Verwirbelungen von Luftströmen.
- H würde sich mehr eignen, Konzentration ist sehr stabil in der Luft

6. Wem kommuniziert Silvanet ein auftretendes Feuer? Nur den Waldbesitzern, oder sogar der Feuerwehr?
    - Kommt drauf an wer der Kunde ist
    - Waldbesitzer bekommt es als erstes
    - Wenn kommune-> dann die Feuerwehr direkt
    - Bei Strom Betreibern dann die werksfeuerwehr
7. Wie weit sind Ihre Sensoren im Wald voneinander entfernt?
    - Alle 100 Meter einen Sensor (wenn man in 5 min einen Waldbrand erkennen will, dann natürlich kleinerer Radius
    - 100 Meter 60 min
8. Haben Sie Vorschläge welche weiteren Stakeholder wir ansprechen könnten im Kontext des Prototypens zur frühen Waldbranderkennung?
9. Haben Sie Studien oder Tests durchgeführt, die sie mit uns teilen könnten?
    - Privatbesitz Wald getestet in einer Feuerschale
    - Barbecue genommen und Schachbrett Muster gemacht und geschaut welche Sensoren anschlagen
    - Nur möglich, wenn geringe warnstufe
10. Haben Sie weitere Empfehlungen zur Erstellung des Prototyps? Tipps zur Gestaltung und zum Material des Gehäuses/der Hülle? Mögliche Fehler, die wir bei der Entwicklung oder dem Testen vermeiden sollten?
11. Weitere Stakeholder
    - Feuerwehren und Waldbesitzer
12. Sein Use-Case Vorschlag für uns:
    - Campingplatz als use Case
13. Dryads Ansatz:
    - Air Quality ist Schätz Eisen, der sagt da ist was in der Luft aber wissen noch nicht was
    - Mems technologie, draht der heiß gemacht wird und widerstand gemessen
    - Je nach Temperatur kann man dann Rückschlüsse auf die gas Zusammensetzung finden
    - Mit mehreren Temperaturen dann Fingerabdruck von gasen
    - Air Quality über einen schwellenwert, dann gas Messung
    - Energieverbrauch ist ein großer Aspekt
14. Hat Dryad schon einen Brand entdeckt? Wie oft wird Dryad schon verwendet?

    - In Nürnberg war ein kontrollierter Brand und am nächsten Tag hat es dort wieder angefangen (weil nicht richtig gelöscht) und das haben sie detected
    - 12 Anwendungsgebiete, decken Flächen bis zu 50 ha ab
    - Fürs nächste Jahr 230.000 ha geplant (haben 10.000 Sensoren bestellt)
15. Wie sollte die Box/der Prototyp aussehen?
    - Gehäuse muss wasserdicht sein, outdoor Tauglichkeit
16. Wo sollten die Geräte hängen, wieso hängen die von Dryad auf 3 Meter Höhe?
    - Auf drei Meter Höhe, damit nicht geklaut
    - Tiere interessieren sich nicht dafür, hatten die noch nicht Probleme mit
    - ➔ Hängt von den Gasen ab, manche sind schwerer oder leichter als Luft
    - ➔ CO ist schwerer und ist eher unten am Boden
    - ➔ Wasserstoff geht schnell nach oben

8.2 Interview Fire Department

Interview mit Stefan Martini, Leiter der Stabsstelle 37/6

Testmöglichkeiten

- Gasflutung von Übungshaus bzw. Container
- Feuerschale auf dem Übungsplatz
- Düren Feuerwehr macht täglich Feststoffbrände
- Next Steps: Kontaktherstellung mit Übungsleiter Daniel Heu

Infos

- Use cases
    - Campingplatz
    - Nordfriedhof Abschnittlager brennt ab und an
    - Privatgrund in Waldregion
    - 2x pro Monat Feuer in Wäldern in Kölner Region
    - Szenario Buschfeuer Australien, nicht relevant wenn bisschen was brennt ABER Frühwarnung zur Evakuierung
- Feuer in Stadtgebieten schneller erkennen (1h sehr sehr langsam) hier höhere Konzentration von Sensoren
- Europäisches Forschungsprojekt zur Simulation von Rauchverbreitung / Gasverbreitung in Umgebung
    - Aktuell extrem schwierig, da Rechenleistung auf Teilchenebene zu gering
    - Rauigkeit des Bodens erzeugt Verwirbelungen -> schwierig zu simulieren (zu viele einzelne Einflüsse)
    - Aktuell nur „ideale Luftströme“ simulierbar
- Verantwortung Nutzflächen in Stadt Köln = Ordnungsamt

Wichtigkeit des Themas

- Feuerwehren in D-Land bereiten sich verstärkt auf zunehmende Waldbrände vor
- Länder mit höherer Waldbrandgefähr aktiver in der Bekämpfung

Future:

- Mega spannend wäre die Kombination von diversen Datenquellen
    - DWD Wetterdaten
    - Spektrometrie an dem Sensor selbst (Farbstufen für mehrere Quellen der Feuererkennung)
    - Health Index Wald: Feuchtigkeit, Wind, Sauerstoffgehalt, CO2 Gehalt etc. -> Vorhersagen von Waldbränden + Simulation des Waldbrands -> wo geht er hin (Evakuierungen etc. nicht nur reines löschen)
    - Je gesünder der Wald, desto geringer ist die Brandgefahr
- Netzwerkmöglichkeit des Sensors (Landkarte mit Regionen mit Sensoren + Übereinanderlegen der Daten

➔ Simulationstool, das Rauchentwicklung in einem Raum simulieren kann (CAD Zeichnung benötigt)
FDS-SMV NIST (Fire dynamics simulator) -> ggf finden wir hier noch was praktisches für uns

- Richtiger Schritt laut ihm erstmal die Basis zu testen und dann darauf aufzubauen

Reference list

Berry, R.A./Kant, S./Nautiyal, J.C. (1996): Forest and economic welfare, in: Journal of Economic Studies, Vol. 23, No. 2, pp. 31-43.

Bindi, M./Corte-Real, J./Durao, R./Giannakopoulos, C./Good, P./Moriondo, M. (2006): Potential impact of climate change on fire risk in the Mediterranean are, in: Climate Research, Vol. 31, p. 85-95.

Alcamo, J./Döll, P./Henrichs, T./Kaspar, F./Lehner, B. (2006): Estimating the Impact of Global Change on Flood and Drought Risks in Europe: A Continental Integrated Analysis, in: Climate Change, Vol. 75, pp. 273-299.

Fosberg, M.A./Hartley, G.R./Jin, J.Z./Lawrence, K./Lynham, T.J./Mason, J.A./McKenney, D.W./Mearns, L./Stocks, B.J./Wotton, B.M,/Yang, Q. (1998): Climate Change and Forest Fire Potential in Russian and Canadian Boreal Forests, in: Climate Change, Vol. 38, pp. 1-13.

Bundesministerium für Ernährung und Landwirtschaft (2022): Waldbrandfrüherkennung, under:

https://www.waldkulturerbe.de/service/wissenswertes/wissenswertes-detail/waldbrand-frueherkennung, seen: 26.01.2023.

Bundesministerium für Landwirtschaft und Ernährung (2021): Waldbrandstatistik der Bundesrepublik Deutschland für das Jahr 2021, under: https://www.ble.de/SharedDocs/Downloads/DE/BZL/Daten-Berichte/Waldbrandstatistik/Waldbrandstatistik-2021.pdf?__blob=publicationFile&v=2, seen: 26.01.2023.

Busico, G./Colombani, N./Giuditta, E./Kazakis, N. (2019): A Hybrid GIS and AHP Approach for Modelling Actual and Future Fire Risk Under Climate Change Accounting Water Resources Attenuation Role, in: Sustainability, Vol. 11, No. 24 p. 1-20.

Government of British Colombia: Wildfire rank, under: https://www2.gov.bc.ca/gov/content/safety/wildfire-status/wildfire-response/about-wildfire/wildfire-rank, seen: 26.01.2023.

Colorado Forest Restoration Institute (2021): Fire behaves differently in different forest types, under: https://cfri.colostate.edu/wp-content/uploads/sites/22/2021/01/FireEd-Infographic-Web_Print-1.pdf, seen: 26.01.2023

Chua, K./Coggins, J./Miller, S./Mohtadi, H. (2021): Heat Waves, Climate Change, And Economic Output, in: Journal of the European Economic Association, Vol. 19, No. 5, pp. 2658-2694.

Hudson, A./Kuhn, R./Smoyer-Tomic, K.E. (2003): Heat Wave Hazards: An Overview of Heat Wave Impacts in Canada, in: Natural Hazards, Vol. 28, pp. 463-485.

Amraoui, M./Fischer, E.M./Parente, J./Pereira, M.G. (2018): Heat waves in Portugal: Current regime, changes in future climate and impacts on extreme wildfires, in: Science of the Total Environment, Vol. 631-632, pp. 534-549.

The World Bank (2022): Forests, under:

https://www.worldbank.org/en/topic/forests/forests-area#:~:text=Forests%20produce%20more%20than%205%2C000,%25%20of%20GDP%20in%20Cameroon, seen: 19.01.2023.

DWD: Waldbrandgefahrenindex WBI, unter:
https://www.dwd.de/DE/fachnutzer/landwirtschaft/dokumentationen/allgemein/wbi_doku.html;jsessionid=B556038ACE0C06C20848CC73E9AB5A3D.live21073?nn=16102&lsbId=344032, seen: 19.01.2023.

UN Environment Programme (2022): Number of wildfires to rise by 50% by 2100 and governments are not prepared, experts warn, under: https://www.unep.org/news-and-stories/press-release/number-wildfires-rise-50-2100-and-governments-are-not-prepared, seen: 26.01.2023.

United Nations: 15, Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss, under: https://sdgs.un.org/goals/goal15, seen: 26.01.2023.

United Nations: 13, Take urgent action to combat climate change and its impacts, under: https://sdgs.un.org/goals/goal13, seen: 26.01.2023.

World Research Institute (2022): New Data Confirms, Forest Fires Are Getting Worse, unter: https://www.wri.org/insights/global-trends-forest-fires, seen: 19.01.2023.

Work Distribution

Following table provides an overview of the work distribution and responsibilities of the project. Since many tasks have been worked out interconnected this serves more as a rough orientation rather than a detailed list.

Lazar Milosevic	Hardware, Website, Testing
Nathalie Spellerberg	Hardware, Software, YouTube
Henning Schultz	Software, Testing, Simulation
Tim Mayer	Stakeholder Communication, Project Management, Final Presentation
Moritz Müller	Stakeholder Communication, Use Case Analysis, Project Report

Declaration

We hereby certify that our project work with the topic: 'Early Fire Detection' was written independently and that we have not used any sources and aids other than those indicated.

Cologne, 26.01.2023

M. Müller Henning Schultz

N. Spellerberg

Lazar Milosevic