Team Space: https://joinlaunchpad.com/#/projects/3037/forestry-for-a-sustainable-future

FORESTREE

Team Members: Errita X., Alicja M., Hao (Lily) L., Keith D., Kirtan P., Shantanu P.
Mentor: Dr. Bharti Singal

Systems Within the Solution

**For all figures, click to enlarge!

Knowing that the functions carried out by the different technological components of our solution are critical to addressing the challenge of peatland forest fires and hydrological drought, we further researched the individual technologies and how they can be integrated to form a cohesive system.

To accurately detect a peatland fire, several **parameters**, such as soil moisture levels, temperature, humidity, gas concentration (CO2, CH4, NH3), and particulate matter concentrations, must be taken into consideration and precisely measured. This will involve combining different types of sensor nodes into a **unified Wireless Sensor Network (WSN)**. The most critical piece of data is solid water levels, as increasing soil moisture will mitigate the risk of hydrological droughts, abate fires, and support the sustainability of local ecosystems.

Further, we learned that a piezometer node could be used to measure water pressure. This will provide more accurate data in peatland environments than above-ground nodes. Data on other parameters can be generated using existing nodes, such as the **DHT11** for temperature and humidity, the **MQ2** for carbon gasses and smoke, and the **SEN54** for particulate matter. **Analog to Digital Converters (ADC)** will allow these digital circuits to interface with the real world by encoding the analog signals into binary code, which certain iterations of, can later be applied to activate an application of the **Cyber-Physical System (CPS).**

Moreover, we learned that the **LoRa system** can facilitate secure communication of data taken by the nodes, to other parts of the system. The most logical arrangement of the WSN nodes in the designated peatland area in our solution is the **star network**. In this network arrangement, a **single base station (LoRa gateway)** can send and/or receive a message to a number of different sensor nodes. An advantage of this type of network for wireless sensor networks includes low power consumption and minimal delay in nodes communicating with their respective LoRa gateways. These gateways are beneficial to use in remote environments, as they can wirelessly transmit data via a **radio frequency (RF)** module, to the LoRa network server, over distances of 20 to 30 miles. The LoRa network synchronizes the data fed in by each gateway and transmits this data to the physical process units of the **Cyber-Physical System (CPS)**.

Additionally, we studied **Machine Learning (ML) algorithms** to determine which one would suit the main criteria of our solution: the peatland environment, and the goal of fire and drought risk detection. We deemed that an **Artificial Neural Network (ANN)** would be beneficial, as it is applicable to problems rich in data but poor in models; in our solution, large volumes of data are taken by individual nodes and the ML will be used to develop a model in the form of a risk index. ANN can both learn from examples and generalize the knowledge acquired through the learning process to new and unseen examples. Through applying seen and previously unseen forest fire and drought parameter data sets, the ANN can synchronize the data taken by sensors for the parameters correlated to forest fires (soil water levels, air temperature, relative humidity, gas emissions, particulate matter concentrations, etc.) into a **Fire Weather Index (FWI) and Drought Index (DI)**. Based on water levels that attribute combinations of data to the relative risk of a fire or drought categorize them, ANN will activate and notify the CPS and IoT systems, respectively. The CPS consists of controlled, automated peatland water distribution pumps for an efficient mass release of water to specified target regions.

We also deemed that in addition to the water distribution physical process, our solution will employ a **digital process (IoT)**. According to the FWI, if there is a high fire risk, a notification will be sent to **local fire stations'** computers so that the firefighters are informed and can choose to further utilize traditional firefighting methods. Further, based on the extent and intensity of the fire, they may choose to further warn the local population or local farmers. The CPS, therefore, reinforces local/traditional firefighting methods and expedites the employment of fire management. Regular in-person checkups by **experts** and **remote tracking** will allow careful measuring and monitoring of the progress and effectiveness of the technology to mitigate fires and droughts and restore peatland ecosystems.

Figure 1: Map of Peatland regions in Indonesia

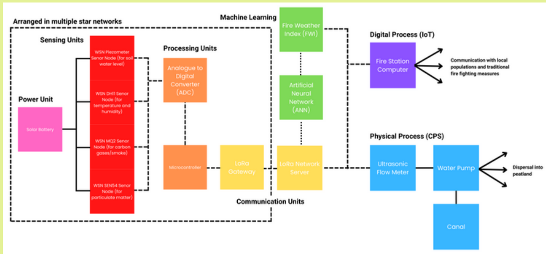

Figure 2: Schematic diagram of technologies

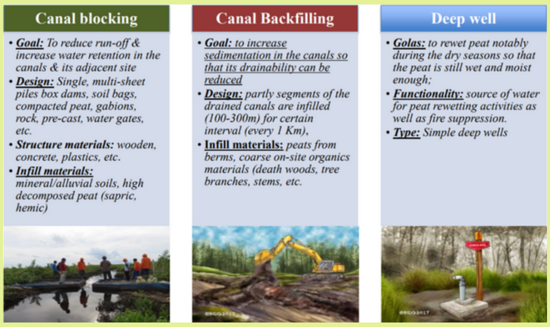

Figure 3: Peatland wetting techniques

Figure 4: Construction of canal blocking and canal revitalization

Canals

Many canals had been used to drain Indonesia's natural peatlands for the conversion of land into oil palm plantations or acacia trees. There are three ways to use and revitalize existing canals and dams in our solution: **canal blocking**—building weirs to reduce and retain run-off; **canal backfilling**—redistributing on-site organic peat and/or coarse organic materials so the water drain rate of the canal/ditch is reduced (levelled compacted embankment); and the **building of deep wells** to maintain water table levels during drier months. In short, the goal is to **allow water levels to reach the peat surface based on a region's conditions**. Necessary construction materials include wood (single sheet/plank dam, multi-sheet piles), soil bags, rocks, compacted peat, concrete, and precast. Due to construction with organic materials, canal-blocking structures could be **held naturally** if built with a middle segment of compacted soil, in which trees and other plants can be planted for a complete natural restoration method. The majority of canals (thousands) have been blocked off by peat through the use of excavators. Canal backfilling involves flattening the canals' banks and the land, making it easier for water to spread out over a larger area. The last method, the construction of deep wells, will access aquifers far below the surface and be used to obtain water.

Data Analysis and Simulation

For our preliminary research, we retrieved data specifically from Kubu Raya, one of Indonesia's largest peatlands. From previous studies conducted, we used **simulation and data analysis platforms** to create the following technological system wireframe and graph to represent the relationship between groundwater and fire prevalence.

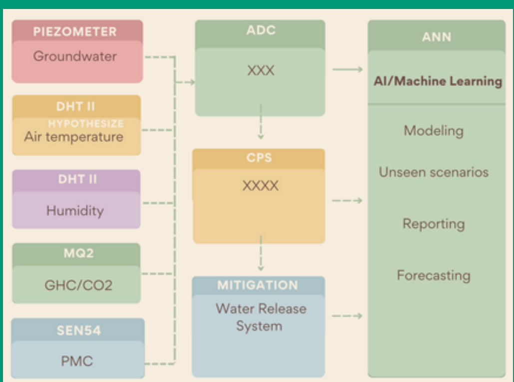

Figure 5: Wireframe of the systems within our solution

The graph on the right shows the groundwater level of a specific peatland region in Kubu Raya, Indonesia from April 2018 to June 2019. According to a study by Hiroshi Hayasaka, most fires in peatlands occurred between 30 cm and 50 cm deep. Once the 30 cm threshold is reached, it would trigger our mitigation system to release water and increase the water level, thus increasing soil moisture. The green line in this graph represents the 30 cm threshold, and the red line represents the 50 cm threshold. In short, data points between the red and green line represent fire-risk zones and those below the red line represent fire-active zones.

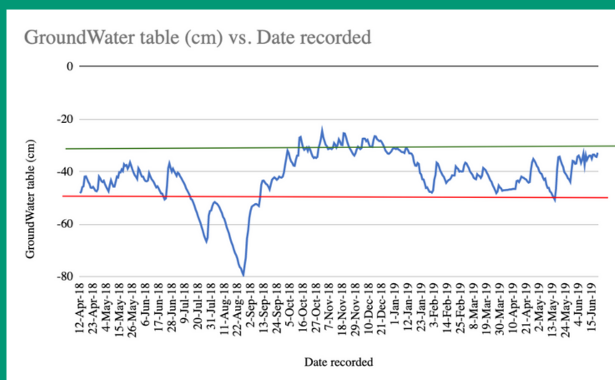

Figure 6: Organized data of Groundwater in Indonesia in 2018

Health and Wellbeing

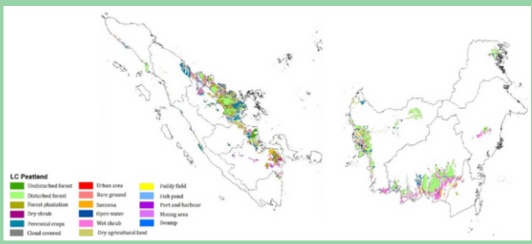

Figure 7: Distribution of Different Types of Peatlands in Indonesia

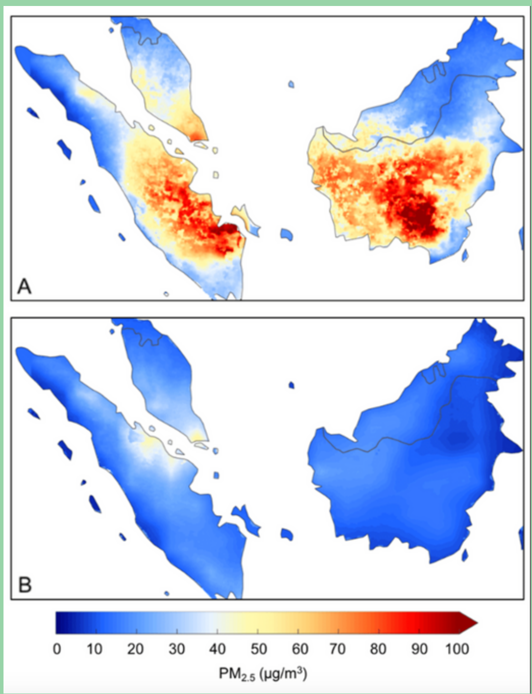

Figure 8: Air quality during fire seasons (A) vs. non-fire seasons (B)

Due to overpopulation and high population density, coupled by **lack** of climate innovation and infrastructure that effectively address climate and ecosystem changes, Indonesia has become incredibly **vulnerable** to air pollution, which have been largely **exacerbated by the prevalence and intensive of peatland fires.** Consequently, there has also been an exponential surge in health effects and complications that are correlated to the rise in forest fires.

Many scholarly studies have examined the **long-term health effects** caused by the exposure to **fine particles pollution** (PM2.5) produced by peatland fires. On average, around 33,100 adults and 2,900 infants die prematurely each year from air pollution. According to a research paper from Environment Health titled "The health impacts of Indonesian peatland fires", peatland fires cause, on average, 4,390 respiratory-related hospitalizations, 635,000 severe cases of asthma in children, and 8.9 million lost workdays **annually**.

Lack of **local governmental and community action** has been made and the awareness of the impacts of climate change and health are still limited. According to a research article titled "Assessing the health impacts of peatland fires: a case study for Central Kalimantan, Indonesia", the average increase in the annual mean PM2.5 concentration due to peatland fires in Central Kalimantan was 26 µg/m3 which is **more than twice the recommended** value of the World Health Organization Air Quality Guidelines.

Finance

Economic losses are **directly tied** to peatland fires. These uncontrolled fires have resulted in massive air quality drops and have destroyed local farms, severely limiting human respiration, and resulting in labor losses, hospitalizations, and many respiratory-related deaths. Not only have the wildfires negatively impacted Indonesia, but smoke has been **spreading to neighboring countries** such as Malaysia and Singapore, both of whom also saw dips in the economy, with a total of $1.3 billion for Malaysia and a total of $0.3 billion for Singapore. Data shows the **economic losses** due to just the six largest fire events between 2004 and 2015 cost the government a total of **$93.9 billion**. The wildfires during **2015 alone totalled $28 billion**, equivalent to **~3.3% of Indonesia's GDP**. 33% of the $28 billion was due to land-cover damage, 40% from the imputed damage value associated with CO2 emissions, and 26% from the economic losses associated with long-term health costs. The study estimates that **if restoration had been in place**, the area burned in 2015 would have been reduced by 6%, reducing CO2 emissions by 18%, and PM2.5 emissions by 24%, preventing 12,000 premature mortalities. Peatland restoration could have resulted in economic salvaging of US$8.4 billion for 2004–2015.

The true impact of the fires includes, but isn't limited to, **hundreds of thousands of cases of acute respiratory infections, disruption of economic activity, closure of schools, and habitat destruction with long-term impacts and burdens on ecosystems.** In 2016, the BRG planned to restore 2.49 Mha of burned peatland, with an estimated cost of $3.2-7 billion. By 2019, only about 900k ha of burned peatland have been restored, which is about 37.5% of the planned amount.

** all monetary values converted to USD

Cultural Considerations

The Indonesian government has failed to protect the rights of communities living on or near peatland regions. Minimal ongoing monitoring of local peatlands has caused irreparable damage to one of the **world's most important carbon sinks**, peatlands. For instance, PT Sintang Raya, a subsidiary of South Korean Daesang Corporation, expanded its plantations in peatland in three tidal villages in West Kalimantan **without genuine consultation with local residents and adequate compensation for the loss of their farmland or livelihoods**. The Indonesian government lacks the protection of land rights of local communities thus affecting the cultural and practical aspect of the peatland villages.

Scholarly Feedback

Upon conducting outreach to over 50 scholars, mentors, professors, and researchers on Launchpad and through email, we have garnered almost a dozen responses with insightful ideas, feedback, and inquiry questions to consider. One particular piece of feedback we received was from **Dr. Stibniati (Nia) Atmadja**, who co-authored a research paper we read while conducting research on REDD+ projects. She also has significant expertise in studying forests, climate change, and livelihood interactions in tropical countries. With experience in peatland research, she urged us to consider **geographic differences.** Despite the small size of Indonesia, the country is as it is divided into 4 main islands that experience different climates, topographies, and more. Based on this, and to maintain the validity and consistency of our research, we have decided to collect data and focus our research on **Kubu Raya, Indonesia**, which has vast peatland regions. Later down the line, we will **expand** our research to other locations within Indonesia and make comparisons and conclusions. Further, due to her expertise in evaluating forestry management projects and climate innovation, one factor important to consider is **humidity** as many types of technology are **easy to break down** specifically in Indonesia. This will be an important factor that we will consider next week as we further develop the physical product of our technology. Other pieces of feedback we gathered come from researchers from the University of Plymouth, the University of Cambridge, North Carolina State University, the United States Environmental Protection Agency, and other post-doctoral independent researchers. We've gathered other insights including understanding the accessibility of different peatland regions, the presence of other seasonal wildfires in Indonesia, the practicality of revitalizing canals, and more.

Next Steps

Research

We will continue to analyze the relationship between the technology of our solution to the **geographic, social, and political circumstances in Indonesia**, to ensure the non-technical **feasibility and productivity** of our solution. We will also further work to align the technology scheme that members of our team's "research group" prepared, with the simulations and data analyses completed by members of our "simulation group" .

Specifically for finance, we will look further into other impacts of fire and economic ties and ways to increase financial gain and minimize loss. For emerging technology, we will **contact IoT experts**, scholars with more in-the-field experience building similar technology, and financially-focused engineers to help provide expertise on a more **accurate estimation of our solution's costs.** Further, we hope to gain more insights into building prototypes, conducting research, and exploring the steps needed to be made to get our solution into use.

Simulation

We will use a **machine-learning-based simulation** that analyzes a **collection of individual variables** such as groundwater level, air temperature, humidity, wind speed, and direction. IoT sensors will feed the datasets into a central processing system to determine fire-related risks in targeted peatlands. These datasets will help estimate potential fire activity in near-real time. **We will create a programmed simulation to mock this process.** If the model foresees factors such as low groundwater levels, low soil moisture, high temperatures, and low humidity, the region's risk and presence of fire can be evaluated. These trigger points will be used to **initiate** the mitigation system of increasing the peat's access to soil water. As this data is used for immediate action, it will also be passed over to **ANN**, and using **artificial intelligence and machine learning**; we will use datasets for longer-term benefits such as reporting, modelling, and forecasting.