FORESTREE

Forestry For A Sustainable Future (Fall 2022)

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THE TEAM

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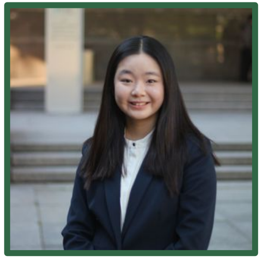

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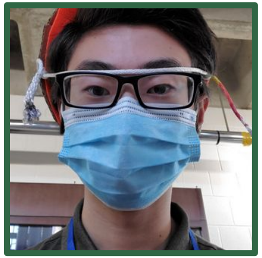

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Research on Canal Infrastructure Finance and Economics

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Data Analysis & Classification
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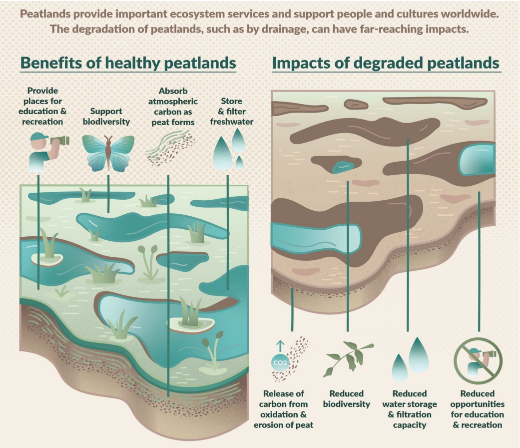
BACKGROUND

Peatlands are tropical moist forests. Globally, they cover only 3% of the land surface, but store nearly 550 billion tons of carbon. This number matches the amount of carbon stored in terrestrial biomass and about twice as much as in all the world's boreal forests. Peatlands are found in various parts of the Earth, but many are under increased threat from drainage for agriculture to infrastructure to wildfires. Indonesia is home to 23% of the world's total tropical peatlands and according to the Centre for International Forestry Research, stores an estimated 57 gigatons of carbon dioxide.



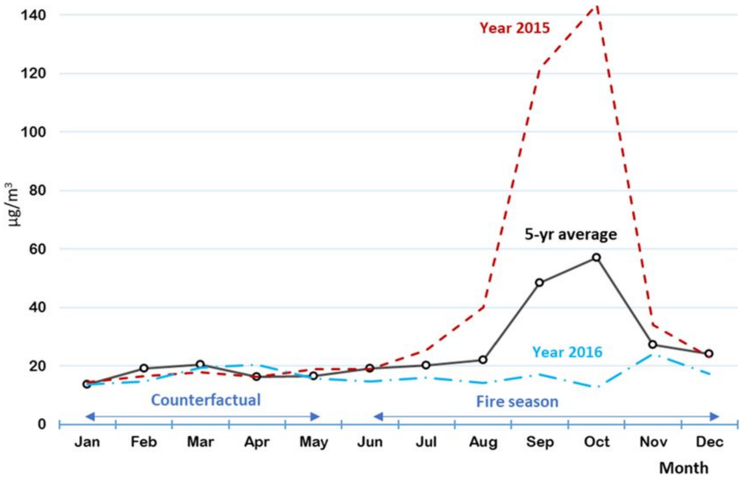
PROTECTING PEATLANDS

Wildfires in ecosystems like peatlands, which store large amounts of irrecoverable terrestrial carbon, result in the release of vast quantities of CO2 into the atmosphere, exacerbating global warming rather than mitigating it. In recent years, Indonesia has seen widespread peatland fires. These fires are now a regular occurrence, particularly during periods of drought and are closely linked changes in land-use. The implications of these fires have significant negative impact to the environment and the global carbon cycle.

THE PROBLEM

GREENHOUSE GAS EMISSIONS

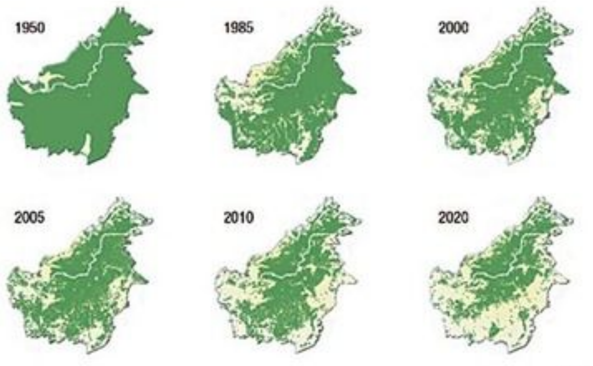
Peatlands are one of the world's largest carbon sinks and must be kept underwater and moist or else they become piles of organic materials, like leaves and branches–also known as peat–that are extremely flammable. Worldwide, due to the rising occurrence of forest fires, almost **6%** of global anthropogenic **CO_2 emissions annually** solely come from peatlands. They also release methane, nitrogen dioxide, and other particulate matter (PM).



The figure above depicts the monthly averaged population-weighted PM2.5 concentrations (μg/m³) in Sumatra and Kalimantan, Indonesia. It evidently shows the dramatic increase in PM particles during fire seasons.

HABITAT LOSS

The destruction of peatlands due to fires **reduces available natural habitats** and results in significant declines in the populations of forest-dependent species, both animals and plants. A recent OuTrop study shows that orangutans in the Sabangau Forest in Indonesia are facing significant threats and have experienced dramatic **population declines** within just two decades. Peatland fires are a massive **threat to biodiversity** and species population.

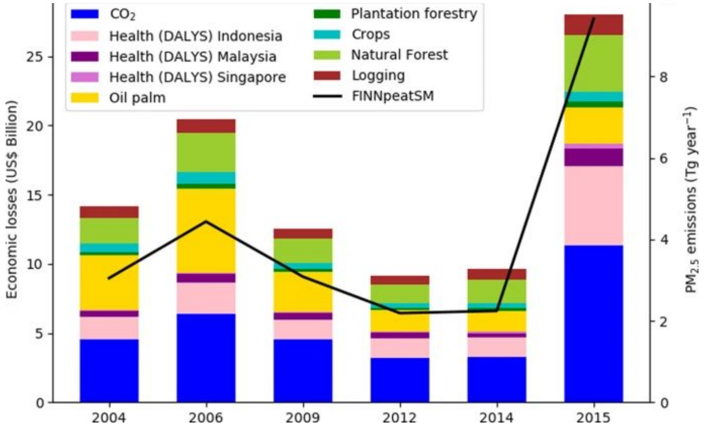


The spatial maps above is a visual comparison of forest and peatland covering in Borneo, Indonesia between 1950 and 2020.

THE PROBLEM

ECONOMIC IMPACTS

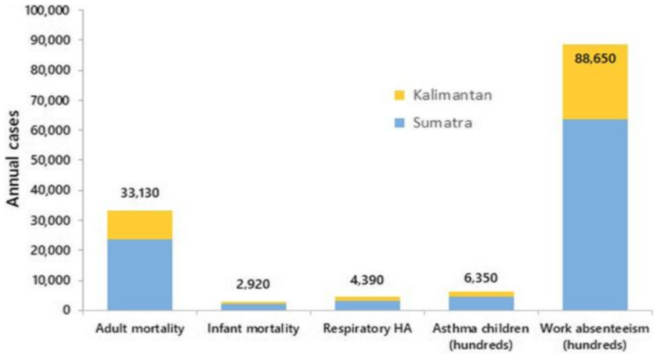
According to an article from the Nature titled "Assessing costs of Indonesian fires and the benefits of restoring peatland," the fires in Indonesia in 2015 alone resulted in economic losses totalling **$28 billion USD**. Between 2004 and 2015, peatland fires costed a total of $93.9 billion in **economic losses,** specifically from the **tourism and recreation industries.** This is often due to hundreds of thousands of cases of respiratory illnesses, job cancellations, labor shortages, school closings, and more.



The graphic above shows the economic loss caused by peatland fires in Asia. The black line is indicates FINNpeatSM fire inventory and shows the total dry season PM2.5 emissions.

HEALTH IMPACTS

Due the peatland fires, the **PM2.5** concentrations in Central Kalimantan were 26 µg/m3, which is **more than double** the recommended value set by the World Health Organization Air Quality Guidelines. According to a research article titled "The health impacts of Indonesian peatland fires", health effects of long-term exposure to PM2.5 particles from air pollution has caused, on average, **4,390 additional hospitalizations** related to respiratory diseases and **635,000 severe cases of asthma in children**.



The graph above compares peatland fires-caused air pollution and hospitality rates in Indonesia.

OUR HYPOTHESIS

Given the importance of peatlands in combating climate change and the annihilation they are facing, our solution focuses on mitigating and preventing the negative effects of the growing severity, extent, and prevalence of peatland fires in Indonesia. As one of the world's largest carbon sinks, peatlands play a critical role in the mitigation of climate change, however, as they are currently under threat, they are now actively contributing to the degradation of our environment. Through our solution's integration of emerging technologies including IoT, WSN, LoRa, CPS, and ML, and the revitalization of current peatland infrastructure like canals, we aim to effectively mitigate the threats of existing and potential peatland fires, and restore biodiversity and sustainability.

METHODOLOGY

1 RESEARCH

We conducted preliminary research on climate change, prevalent events related to forestry, and during our bi-weekly meetings, narrowed down our scope (ex: region, problem, etc.) based on our interests and findings. Further, we researched current climate projects to understand current policies, relevant programs, and emerging technology.

2 IDENTIFYING THE PROBLEM

After understanding the general context of forestry and identifying a focus point, we identified and researched upon the problem we wish to solve: peatland destruction in Indonesia. We researched the extent and intensity of forest fires in peats. We identified the where, what, who, and why and created a research plan.

3 IDEATION & ITERATION

Next it was time to identify the 'how'. As a group that is fascinated in technology, we came across projects in the US and Europe on IoT and CPS tracking and communicating greenhouse gas emissions. Our goal was to utilize, integrate, and reiterate existing technology to fit the criteria of our identified problem. We conducted further interdisciplinary research and conducted simulations using data analysis and t-graphs to better understand the classification process of ML.

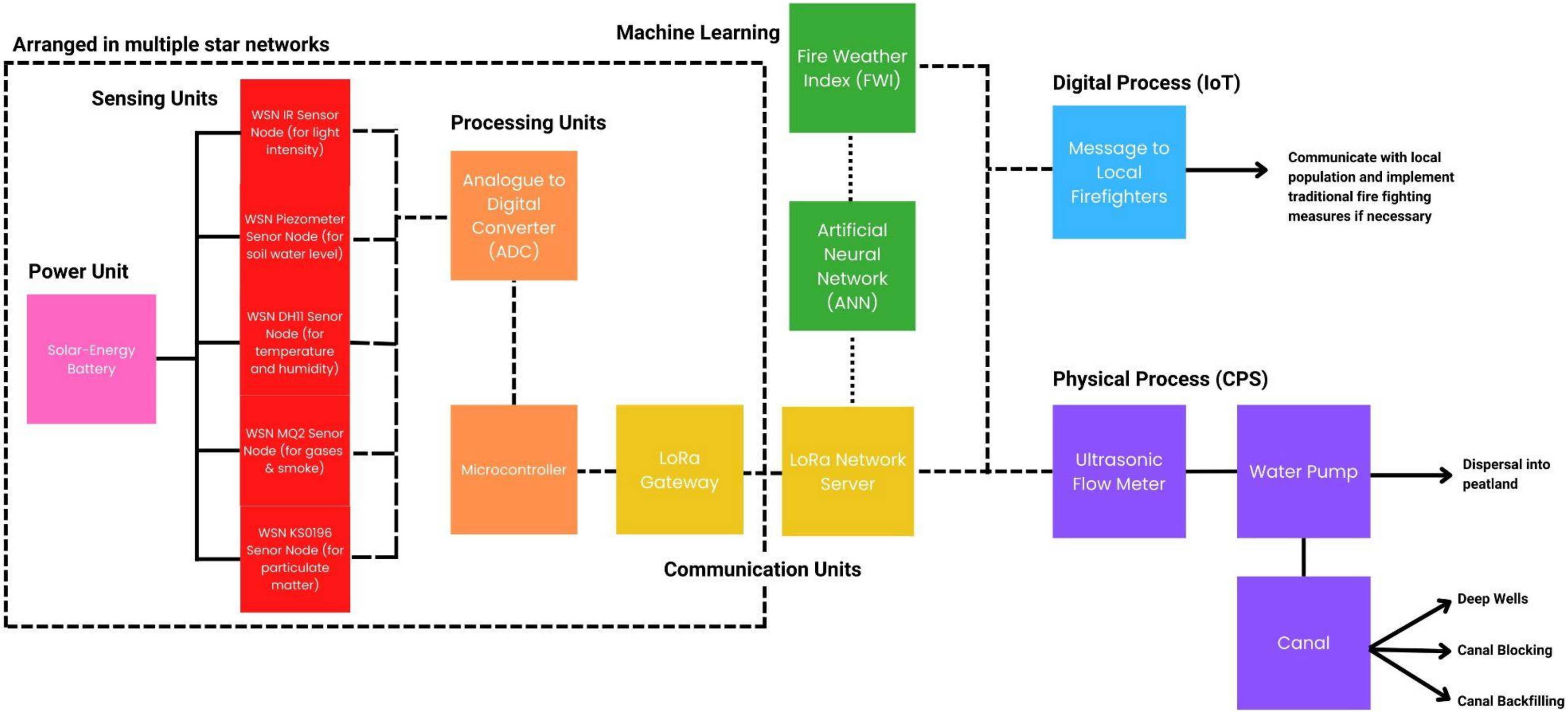
4 EXPERT OUTREACH

Based on the research articles we read and areas of our solution that we had lasting inquiries on, we contacted scholars, professors, and researchers. With 50+ messages to mentors on Launchpad and external contacts through email, we received dozens of insightful and engaging responses. Some will be highlighted in this presentation.

5 FINAL SOLUTION!

Based on further research, ideation, simulations, and adjusting based on expert responses, we connected pieces of the puzzle to create our final solution for the Forestry for a Sustainable Future challenge!

OUR SOLUTION: DIAGRAM



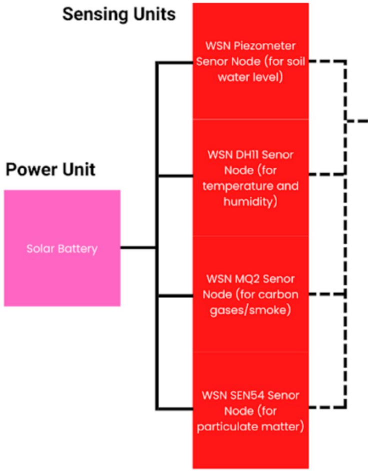
WSN: DATA

WSN nodes are infrastructure-free, wireless networks that can monitor physical and environmental conditions.

Why are WSN sensor modes ideal for Indonesian peatlands?

- **Energy Efficient:** A WSN is able to generate energy using free-standing solar panels and consumes little power.
- **High accuracy and early detection:** Sensors are placed in multiple places within a region, and are in direct contact with the soil it's collecting data from unlike satellites.
- **Remote Access:** WSN can be mounted nearly anywhere in a forest even if there is no installed network connectivity because the transceiver module has a built-in network infrastructure and power supplied using solar energy.
- **Adaptable:** The system arrangement can be easily modified and adapted based on changing environmental or physical factors. As our technology becomes widespread, we foresee it to become more accurate and holistics.
- **Low Cost**: Our choice of sensors and overall design lend the overall WSN node.

To holistically and 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 fires, and support the sustainability of local ecosystems. Given its geography, Indonesia receives high sunlight, the WSN nodes will be powered by a small scale solar cell, which will require little maintenance - an advantage given the vast area covered by the hundreds of sensing units. he 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.



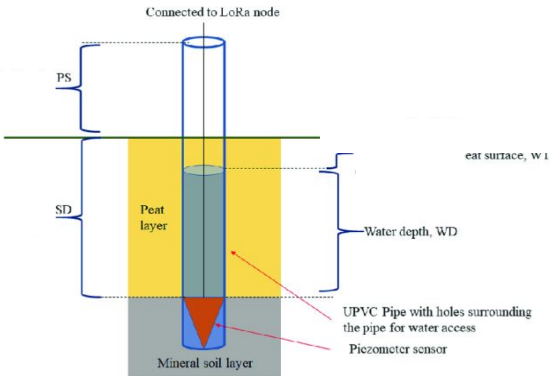
EXISTING METHOD: FLAWS

Remote sensing, such as optical and radar, is currently a prominent technique used to detect forest fires by mapping satellite images prefitted with temporal data and geographic analysis models.

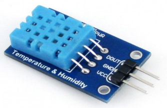
Some drawbacks include...

- Limited data from tropical regions is being communicated to satellites, which reduced the accuracy of the fire detection models.
- Usually can only detect large fires once they have already started spreading.
- Very expensive to implement and maintain due to being technically demanding.

SENSOR SPECIFICATIONS



A piezometer will be used to measure water pressure. Water pressure is an important variable to consider because water levels depend on how much pressure above water in the peat layer puts on the piezometer. The piezometer is based on the casagrande piezometer design, which includes a filter unit made of high density plastic, inside of standard polyvinyl chloride (PVC) pipes. Casagrande piezometers are able to record data in mediums with different levels of permeability, which is true about peatlands as well. A vibrating wire piezometer connected to the communication port of the LoRa gateway node. The simple design and low cost materials of the piezometric soil water sensor, lend it to be an appropriate means of collecting data at many points throughout the designated forest area. Most data parameters reflecting forest fire risk in the Southeast Asia region is predicted using a mix of data taken by national weather stations, which isn't necessarily smaller patches of forest area. This traditional data does not include soil water levels, which is perhaps the largest determinant of forest fire risk and variables our WSN considers.

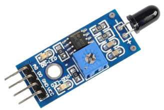


DH11: temperature and humidity

MQ2: carbon gases and smoke

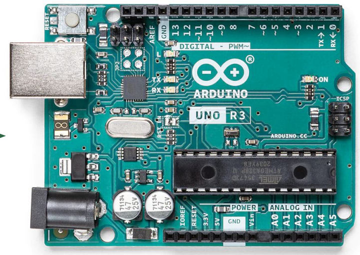
KS0196: particulate matter

Barometric sensor: air pressure



IR: light/flame detection

NEO-6M: location

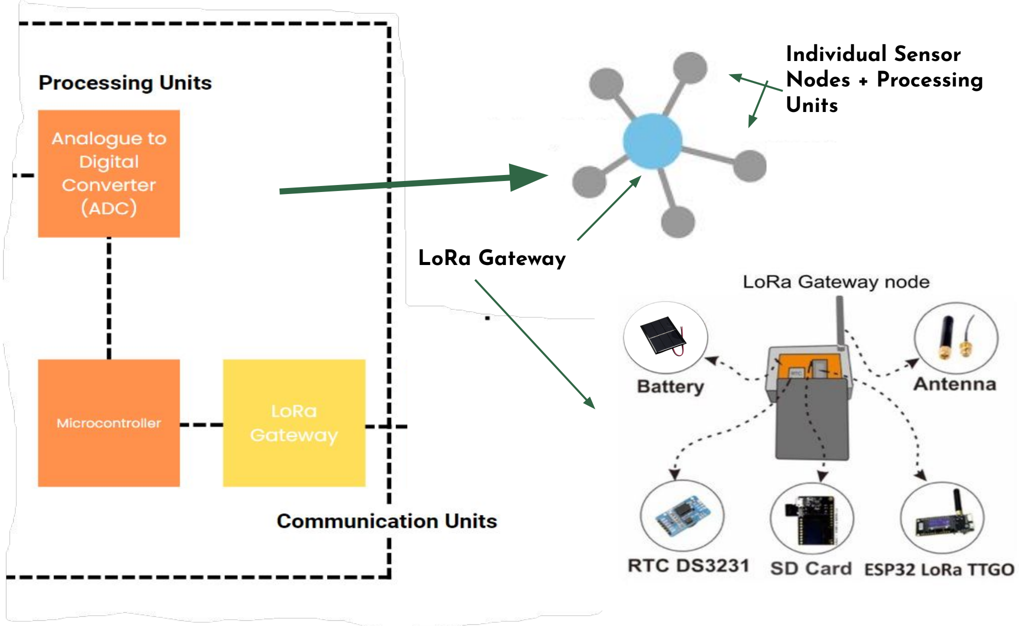


These existing sensors are affordable, which means that deploying them across hundreds of sensor node units, will not be very costly. They will be configured around an Arduino-Uno microcontroller, which will synchronize their data for easy communication through LoRa.

DATA TRANSMISSION

Raw, "real-world" data taken from each of the sensors is passed through an analog to digital converter (ADC), which converts this data into binary code for simpler data transmission across systems, and machine learning analysis.

The Arduino-Uno microcontroller uses this binary code to manage data collection from the sensors, perform power management functions, connect the sensor data to the physical LoRa layer, and managing the LoRa network protocol.



Long Range Wide Area Network (LoRaWAN) is a robust wireless modulation, ideal for managing **great volumes of messages** from thousands of sensor nodes that will be scattered across large areas. **In our solution, a LoRa gateway will aggregate the data collected by WSN sensor nodes and upload it to a cloud server. It is a reliable, quick, and cost efficient data transmission method.** The LoRaWAN system will facilitate a secure communication of data taken by the WSN nodes, to other parts of the system. Eventually, the communicated data will trigger a digital and physical process, which for our solution is the classification of a region.

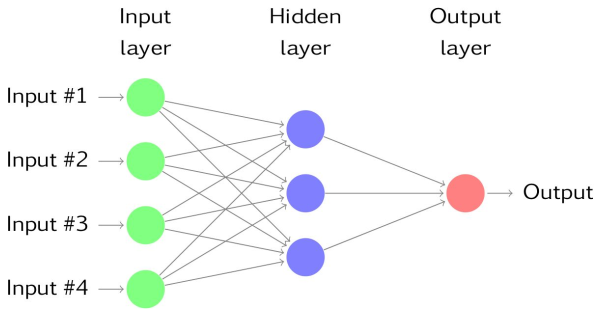
An advantage of this type of network for wireless sensor networks includes **low power consumption and minimal delay in nodes communicating** with their respective LoRa gateways. These gateways are beneficial to use in remote environments, as they can **wirelessly transmit data** via a radio frequency (RF) module, to the LoRa network server, over **distances of 20 to 30 miles**.

The 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) is centered between several nodes can send and/or receive a message to a number of different sensor nodes. This one way communication between only nodes and the gateway does not require as advanced technology as two way or multiple way channels would require.

MACHINE LEARNING (ML) & ARTIFICIAL NEURAL NETWORK (ANN)

In our solution, a machine learning (ML) model will continuously analyze WSN node data gathered from different LoRa gateways, in order to determine fire risk. Similar to the past forest data we have examined in our simulations, this machine learning model take in each new data point transmitted by WSN, compound the data through the model's repository, and retain the data to increase accuracy for future data According to existing research, soil water level is perhaps the most predictor of a peatland fires. Therefore, ML is critical to monitor soil water levels over time, to predict the trend of soil water levels in peatlands reduce the overall risk of these fires.

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 synchronizes this data 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). The input layer takes in the information in numerical form (the WSN raw data) and then represents an activation value where specific data thresholds for each parameter, determine each of the nodes assigned number in the hidden layer. From there, the values are parsed into a overall number rating at the output layer, and neuron concludes if there is a high (3) or extreme (4) fire risk that it needs to send the signal back through LoRa, then onto the digital communication and physical systems of our solution.

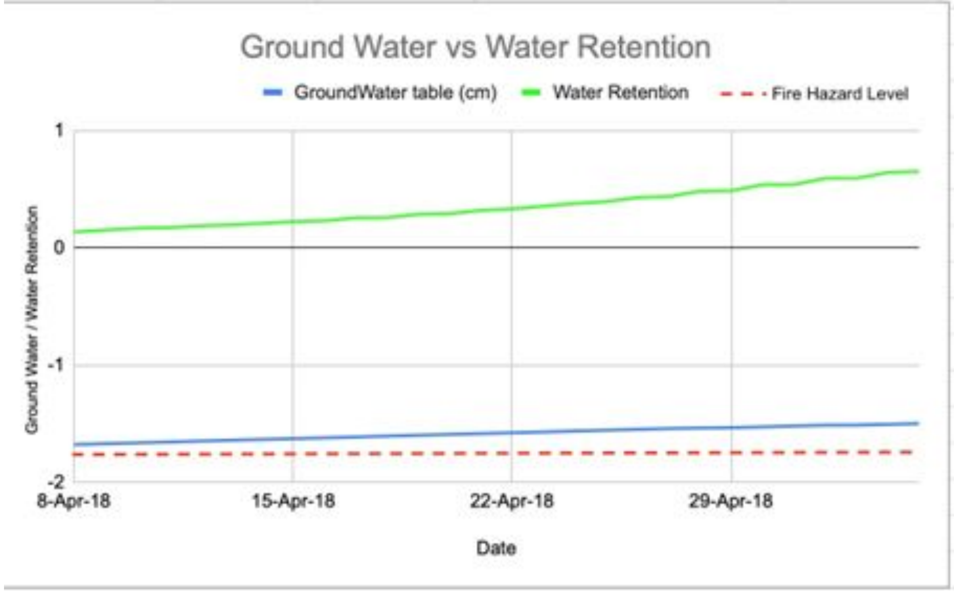


Benefits of ANN and its relevance to our solution:

- A parallel processing ability means that the many pieces of data from our sensors can be analysed simultaneously.
- The failure of one element of the network does not affect the working of the whole system, which is important, given the large number of sensors employed.
- A neural network learns from the experience, therefore does not need reprogramming, the program will be self-sufficient, which is more reliable in an area where there is not much knowledge of computer programming.

DATA ANALYSIS

GROUNDWATER TABLE VS WATER RETENTION



The graph shows the correlation between ground water level and water retention in the Batanghari region for a period of 28 days. .

MONITORING WATER RETENTION LEVELS

Monitoring the water retention of peatlands will determine groundwater contribution to rewetting the soil surface and the region's capacity to retain moisture. This will allow us to understand the conditions that could create fires. The red line in the graph shows the 26 cm threshold which indicates high fire risk and will be assigned a large value on the FWI. The month of April in Indonesia has the lowest rainfall throughout the year creating conditions that are most prone to peatland fires and shown by the low water levels and water retention on the graph on the left.

DATA ANALYSIS METHOD

To understand the correlation between groundwater level and water retention we took a sampling of data from the peatlands of the Batanghari region in Indonesia for a period of 28 days. We chose to run the data using a T-test to understand the impact of groundwater level (variable #1) on water retention (variable #2). In this analysis, a paired T-test is appropriate as it allows us to compare the two data sets and derive the probability of one impacting the other. Limitations in this data analysis include the absence of atmospheric temperature, rainfall and wind conditions, which we foresee other aspects of the WSN to collect.

DATA ANALYSIS

PAIRED T-TEST CALCULATIONS AND RESULTS

T-test analysis is used to compare means of 2 groups of data - groundwater level and water retention. As expected, we see a direct relationship between these two groups. An increase in one causes an increase in the other. As our calculation demonstrates, 95% confidence interval suggests that if we take 100 samples for our analysis, approximately 95% of the samples will contain the true mean value. Evidently, there is a strong correlation between groundwater levels and water retention in this dataset, which aligns with our prediction.

P value and statistical significance:

- The two-tailed P value is less than 0.0001
- By conventional criteria, this difference is considered to be extremely statistically significant.

Confidence interval:

- The mean of Group One minus Group Two equals -1.9401171
- 95% confidence interval of this difference: between -1.9816048 and -1.8986295

Intermediate values used in calculations:

- t = 95.9513
- df = 27
- standard error of difference = 0.020

Ground Water Table

Mean	-1.5859643
SD	0.0554460

Water Retention

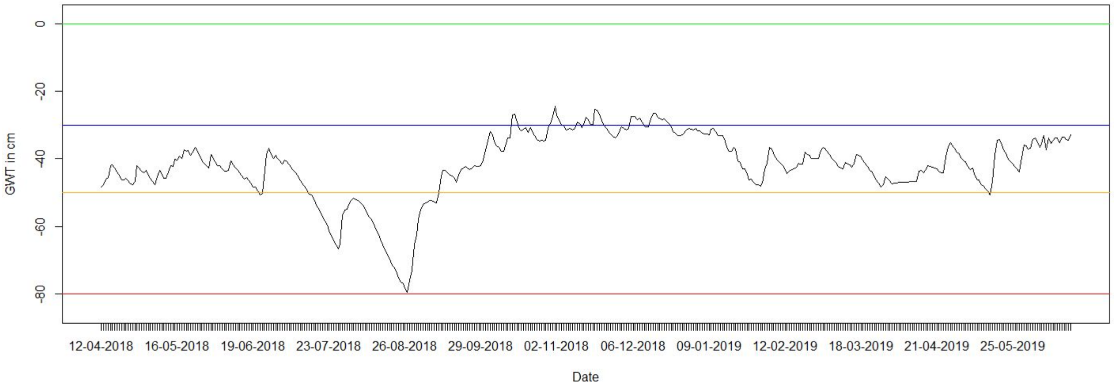
Mean	0.3541529
SD	0.1605914

SAMPLE-SIZE SIMULATION - GROUNDWATER VS. FIRE STATUS

```r
data <- read.csv('kuburayaGWT.csv')
Date <- as.Date(data$Date)
GWT <- data$GWT
# plotting the data
plot(Date,
     GWT,
     xlab="Date", ylab="GWT in cm",
     ylim=c(-85,2),
     type = "l",
     xaxt = "n")

# Add dates to x-axis
axis(1,
     Date,
     format(Date, "%d-%m-%Y"))

abline(h=-0, col="Green")
abline(h=-30, col="Blue")
abline(h=-50, col="Orange")
abline(h=-80, col="red")
```



Using R and its data analysis methods, we derived the graph above by importing the data from a research paper titled "Groundwater table and soil-hydrological properties datasets of Indonesian peatlands" and correctly formatted the structure. The graph above shows the groundwater level of a specific region in Kubu Raya, Indonesia, from April 2018 to June 2019. Groundwater is an excellent indication of the risk of fires in peatlands as drained peats have high flammability risks due to its leaves-abundant makeup. According to a study by Hiroshi Hayasaka, most peatland fires occur when the groundwater level reaches 30 cm to 50 cm deep. The blue line in this graph represents the 30 cm threshold, and the orange line represents the 50 cm threshold. Once the 30 cm threshold is reached, our groundwater level sensor will trigger our mitigation system to release water and increase the water level, thus increasing soil moisture. Further, a notification would be sent to local firefighters via their phones. In addition, we have two other thresholds, the 0 cm threshold, represented by a green line, and an 80 cm threshold, represented by a red line. The green line indicates a low fire-risk environment, and the red line indicates an extreme fire-risk environment.

SAMPLE-SIZE SIMULATION - TEMPERATURE VS. FIRE STATUS

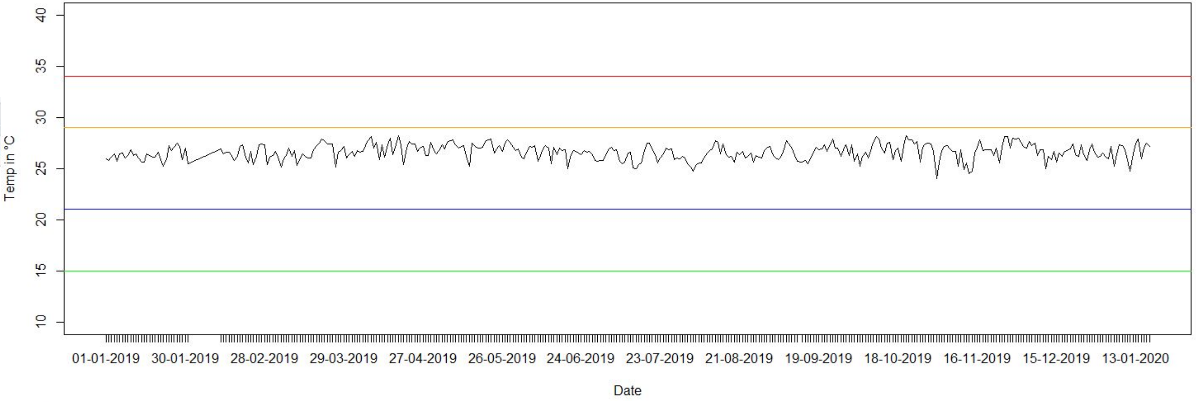
onScript.R × TemparatureSimulationScript.R × data ×

Source on Save

```r
data <- read.csv('forestedtemp.csv')
Date <- as.Date(data$Date)
Temp <- data$Temp
# plotting the data
plot(Date,
     Temp,
     xlab="Date", ylab="Temp in °C",
     ylim=c(10,40),
     type = "l",
     xaxt = "n")

# Add dates to x-axis
axis(1,
     Date,
     format(Date, "%d-%m-%Y"))

abline(h=15, col="Green")
abline(h=21, col="Blue")
abline(h=29, col="Orange")
abline(h=34, col="Red")
```



Using R and its data analysis methods, we derived the graph above. The graph shows the temperature of the Sebangu Tropical Peatland, Kalimantan, Indonesia, from January 2019 - January 2020. To create this graph, we collected our data from a database on figshare. As in the GWL vs. Fire Status graph, the green, blue, orange, and red lines all represent thresholds. The green line indicates a low fire risk. The blue line indicates temperatures with a medium fire risk. The orange line shows temperatures with a high fire risk. Lastly, the red line indicates temperatures with an extreme fire risk. If the temperature passes the blue threshold of 21℉, our system will inform local authorities of the potential risk of fire in the specific area.

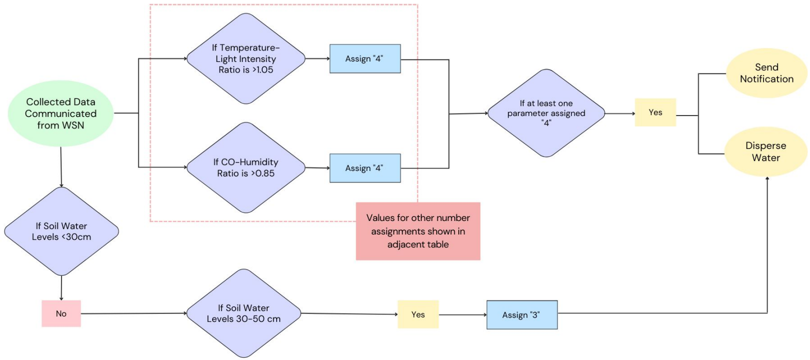
In short, temperature is a good indicator of fire presence as it is a form of heat. Specifically, as underground fires are becoming more prevalent, temperature provides a good baseline alongside the other variables our WSNs would collect and machine would consider.

FIRE WEATHER INDEX (FWI)

We analyzed **data from past fires** and looked through **research articles** to create the graphs in the previous slides to determine the fire risk that certain levels of each parameter yield in. For temperature, light intensity, CO/CO2, and humidity, we used an established **threshold ratios** of 1.05-1.15 and 0.85-0.95, respectively; this meant that we could only obtain a value for extreme fire risk. An important limitation to note these thresholds were set based on the open-data that we have access to, however we cannot guarantee are the most accurate. As our machine continues to gain data and we consult more sources, we are certain that our thresholds and classification process would become more and more robust.

Water Depth (cm)	Temperature (°C)	Temperature and Light Intensity Ratio	CO and CO2 Concentration (PPM)	Humidity and CO ratio	Fire Risk Activation
<30	<21		<350		1 = Low
30-50	21-29		351-380		2 = Medium
50-80	29-34		381-400		3 = High
>80	>34	>1.05	401-430	>0.85	4 = Extreme

FWI & ML DIAGRAM



Click to expand

The indexing function detects fire and fire risk. Future applications involve utilizing this indexing function to detect instances of deforestation by the detection of sound and maintaining favorable crop growing conditions in agroforestry.

WATER DISTRIBUTION

The other end of our system's **physical component** (besides the forest WSN) is the **dispersion of water**. Traditionally, water monitoring and water dispersion is performed manually. However this in-person interaction with the system may not be feasible for individuals in remote locations, like forests.

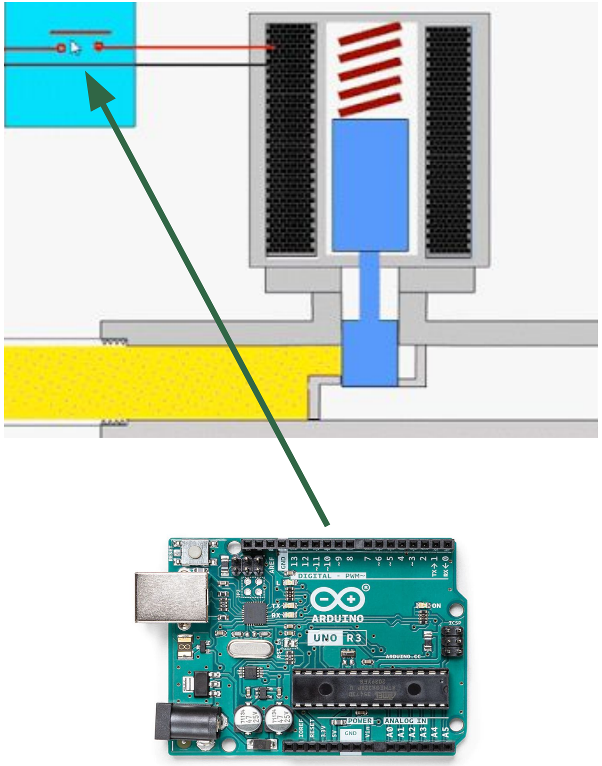
This system includes **four** main components:

- **Sensors**: Detect variable modifications and transfer the live data through an ADC for proper signal reading to a microprocessor.
- **Actuator**: Uses an electromechanical relay – an electrically operated switch – to instigate physical motion for machines or devices to run.
- **Processor:** A microprocessor that can easily read sensors data, process, store, and update output devices required, and transfer data between devices and machines when needed
- **Power Unit:** Like for the WSNs, a solar power unit will be used. This is optimal given the warm and bright weathers in Indonesia, as well as the fact that the relay will only be activated during instances of fire risk as dictated by the FWI. This will be a reliable and efficient energy source.

WSN data is communicated to the water to **Arduino Uno**, which then again transmits them to the physical motor pump.

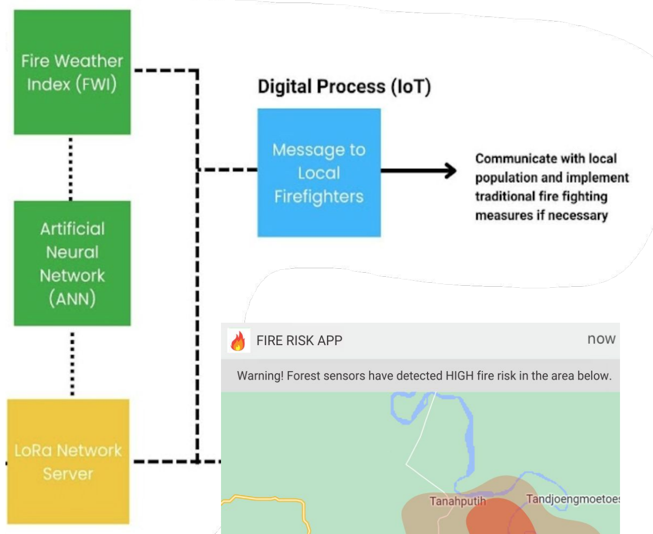
According to the FWI if...

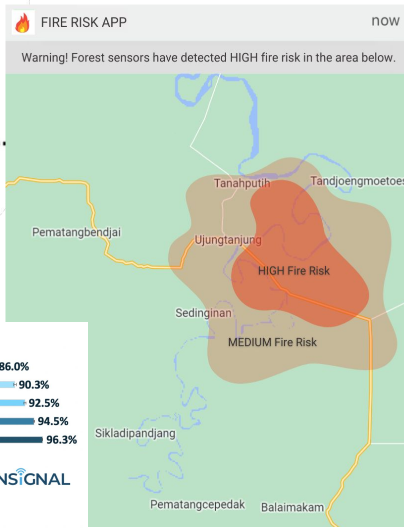
1. The FWI is **within the fire risk** threshold ⇒ the motor pump is turned on via Arduino Uno to **reinforce water levels** and a notification is sent to local firefighters.
2. The FWI is **below the fire risk** threshold ⇒ **no physical action** is taken.
3. If the motor is already on, the **WSN data is continuously compared with the FWI**.



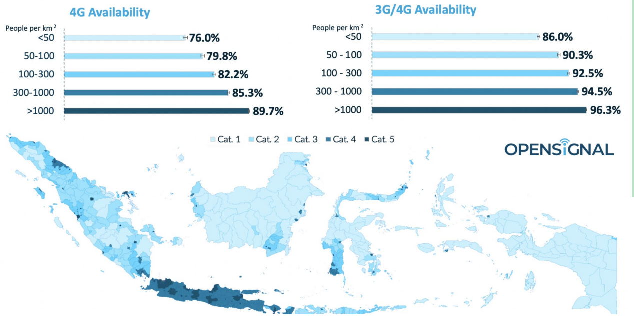
DIGITAL COMMUNICATION

In many cases, the physical water distribution system would not be able to eliminate fire risk as it only increases water levels using canals. However, our technology will greatly **reinforce traditional knowledge** and methods firefighters in Indonesia already use to suppress fires. Our solution employs the digital output of **alerting local fire stations and a phone notification to local firefighters via a simple app** that is currently being used called the SMART Patrol Information System. This app is employed by multiple Indonesian communities to record and report real-time action of fire prevention patrols based on 79 parameters to better enable wildfire prevention, detection, and early suppression. The mobile app aspect of this program is available to fire management officials, enables fire brigades to report on wildfires. If there is a high fire risk, as determined by comparing live data with the FWI, a notification sent through the app to necessary personnel. The app will visually **show the location of the fire risk** according to node(s) whose data readings indicated high fire risk, and through the GPS node on sensor units. Based on the risk, they may further choose warn the local population or farmers using existing communication methods. This will also allow the firefighters to work alongside the automation of canals to effectively extinguish the fires early. Regular in-person checkups by experts and remote tracking will allow careful measuring and monitoring of the progress and effectiveness of the technology. Given that 3G and/or 4G **Wi-Fi connection is available to most parts of Indonesia**, we deem our solution as feasible and effective. **A recent study found that using an app to communicate to firefighting volunteers could save 56.48% in preparing a response to the fire.**





Indonesia's network of district-level volunteer firefighting groups, known as "Masyarakat Peduli Api (MPA)", are formed by local village heads. Even though Indonesia's Ministry of Forestry established a Forest Fire Brigade at the national level called the "Manggala Agni (MA)", its capacity is sometimes overextended, which makes the volunteer groups invaluable. Many of these groups lacked proper training and equipment since the units are more informal, however, since 2015, the UN has been conducting comprehensive training sessions for these volunteers, especially in peatland areas, making them experienced in firefighting specifically in their local environment.

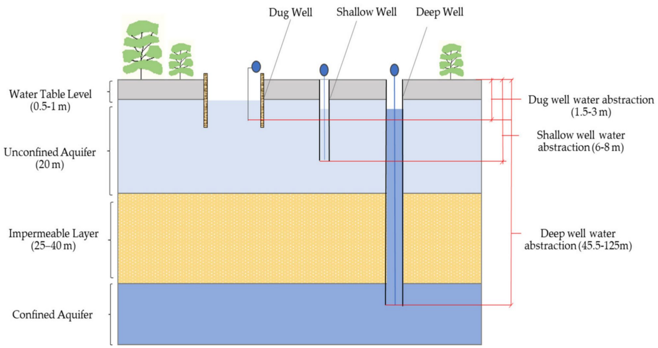


REVITALIZING CANALS

To source water for the water distribution system, we will tap into existing canals. Indonesia has many draining canals in place in peatland regions due to the commercial necessity for water removal. Our solution involves reusing canals instead of constructing new irrigation systems for sake of finance and redesigning draining canals.

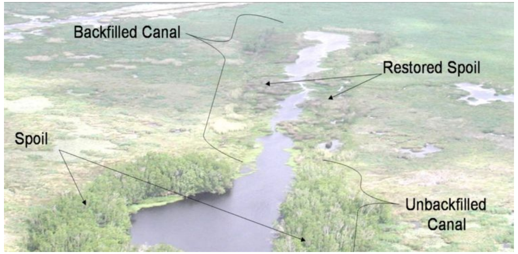
DEEP WELLS

Deep wells will be used to pump water to the surface in case of water level falling. These can also be used during fire responses. These can be planted relatively near canals to further expand area that pumped water reaches. This can also be connected with CPS for water usage during a fire.



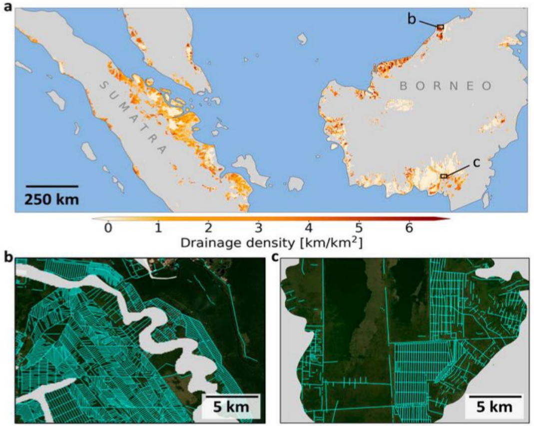
CANAL BACKFILLING

Increases sedimentation in the canals, flattens spoils on banks to level surrounding land. These involve compact peat dams. Backfilling and blocking can be used together to encourage vegetation regrowth, which can increase peatland water retention.



CANAL BLOCKING

Other than concrete, much of the weir (dam) will be used with organic material. Thus, the collected water will gradually increase to cover its surrounding areas.. For large-scale rewetting in degraded peatlands where forest is to be restored: compacted peat dams (no spillways) and partial canal infilling.



Canal classification results. (a) Map of drainage density [canal length per peat area, km/km2] across SEA peatlands at 1 km resolution, retrieved from 2017 satellite imagery. Gray is non-peatland area. Black callouts outline example areas with 5 m resolution in (b) Sarawak, Malaysia/Belait, Brunei, and (c) Central Kalimantan, Indonesia.

FINANCE - INDIVIDUAL COSTS OF OUR SOLUTION

1 CPS component:
- LoRaWAN: ~$5-$8
- Casa grande piezometer: $10
- Arduino-Uno microcontroller: $10.59
  - DH11: 5pcs for $10.29 (1 for $2.06)
  - MQ2: $2.40
  - KS0196: $11.00
  - Barometric pressure sensor: $5.49
  - IR sensor: 20 pcs for $12.99 (1 for $0.65)
  - NEO-6M: $12.59
  - **Total: ~$54.78-**

WSN Labor cost: $80h for RF surveying, $80/h for wireless sensor setup, $80/h for integration by control vendor
- **Total: $240/h**

One unit of CPS & WSN: **$284.78/h**

Total potential cost + affordability:
Dams: 157,000 km^2/(.5 km)^2=628,000 ≈$314 mil - $942 mil
CPS + WSN: 157,000 km^2≈60618 mi^2. 60618 mi^2/(20 mi)^2≈67-152 (~$19080.26-~$43286.56).

Infrastructure cost:
- Canal Backfilling: ~500-1500$
- Canal Blockage: concrete at >$50,000

Area to cover:
- ~157,000 km^2 of canals
  - Ex-Mega Rice Project of 2014 alone built total length of ~4,600 km and depth of up to 10 m of drainage canals throughout ~1 Mha peatland
- Every 500m, add dam

Future Projections:
- Long-term: research in Scotland shows restoration now would provide £191 million annually of societal benefits
- Short-term: gain an estimated average of £77.76 per household per year in Scotland.

Labor			
RF surveying (labor)	$80 /hr	0.5	$40
Wireless sensor setup and placement (labor)	$80 /hr	4.5	$360
Integration by control vendor (labor)	$80 /hr	3.5	$280
Total labor cost			**$680**
Total cost estimate			**$3,858**
Cost per sensor			**$104**

Labor costs of WSN installation.

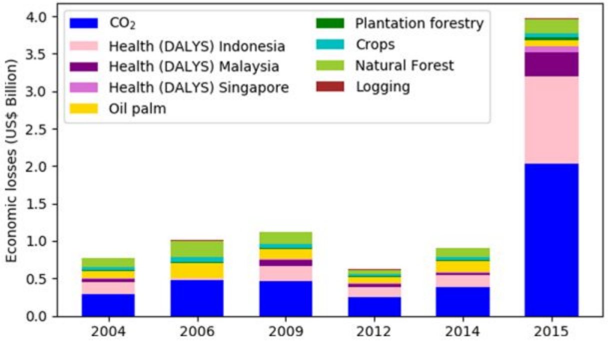


Fig. 5 The estimated reduction in economic losses and damages caused by fires after peatland restoration. Bars show the reduction in economic losses, in US$ billion, split by category. The Disability Affected Life Years (DALYs) costs are split by the country being affected.

POSSIBLE IMPLICATIONS/LIMITATIONS

DEVICE ACCESS

Internet access is a critical part of the feasibility and effectiveness of our technology. Based on a survey conducted in 2019, 94 million adults do not have access the internet. Nearly half of Indonesian adults did not own an internet-enabled phone because of socioeconomic impacts such as poverty. A part of our solution is using internet access to connect to the local fire station and to transfer data, but if the internet access is not accessible for areas around peatland or forest then it would impact our technology to send messages to the local fire station and volunteers. Gunung Leuser National Park, one of Indonesia's rich forests, has low data internet data access, as a result, it is difficult for local organizations to track the forest's biodiversity, freshwater, and other critical ecosystem services. However, recently, Global Forest Watch (GFW) partnered with the Jane Goodall Institute and RESOLVE to make cutting-edge maps and big data tools such as deforestation alerts and VIIRs daily fire alerts, also a mobile application allows users to access GFW data without an Internet connection. As we are communicating the firefighters who do have internet access we hope to overcome this barrier. Furthermore, we hope that in the future, internet access would increase. Prospects estimate that almost 85% of Indonesians would have internet access by 2026.

LOCAL SUPPORT

Currently, peatlands are being drained and burned to supply fertile agricultural land. However, as part of our solution, should a region be classified as having a fire or at risk of a fire, we would be rewetting the region, reversing all the draining and possibly destroying crops. We must explore and endorse effective and affordable alternatives to slash and burn for local community citizens such as re-fertilization.

Further, we must garner support from locals about our technology. While IoT is a relatively new technology and not utilized abundantly in Indonesia, a survey from 2018 shows a glimpse into the mindset of the people regarding usage of IoT.

Survey Results:
The majority of the market (53%) wants IoT devices to be physically compact, lightweight and small. Further, Indonesians consider that IoT technology for agriculture (30.48%) will provide the most benefit to the country.

Concerns:
54.29% of the Indonesian market is reluctant to use new technology that has not been tested and 46.19% are concerned about quality, but can be reduced through government implementation and successful testing.

CULTURAL CONSIDERATIONS AND SIGNIFICANCE

One of the largest forests, Berbak National Park is scorched by the peatlands fires. The Nerbak National Park is protected since 1935 under Dutch colonial law and recognized as wetland that supports significant wildlife reserves for Indonesian communities.

Additionally, peatland fires destroyed one of the Indonesian biggest incomes: palm oil. Palm oil serves as an important cultural food intake for major Indonesian populations; however, the peatlands fires have limited the production of palm oil. Not only will our solution aim to protect the sustainability and vitality of peatland ecosystems, but also the wellbeing and cultural preservation of local communities.

Ethical issues include the need to get voluntary participation from local communities and informed consent signed. Making sure our technologies do not impact the local culture, does not cause conflict in current occurring environmental projects in Indonesia, and do not harm participants. We must balance the desire of mitigating and preventing disastrous peatland fires with the needs and desires of local Indonesian communities who would be directly impacted by our actions.

POTENTIAL IMPACT & FUTURE STEPS

ENVIRONMENTAL

Peatlands are one of the world's largest carbon sinks, storing twice as much carbon as all the world's forests. The rise in peat fires have resulted in the active contribution to the release of carbon and loss of biodiversity. Our solution aims not only to protect Indonesia's peatlands which are currently experiencing fires, but also those who are at rise of catching on fire. Using WSN allows data to be accurate and live unlike generalized estimates produced by satellites and models. Further, the spherical shape of our sensors, use of resilient metals, solar batteries, and more makes our solution easily integratable to peatland ecosystems.

SOCIAL

Peatland forests are nutrient rich and serve as fertile land for farmers and reserves for local communities. Our solution is protecting the security and liveability of communities near peatland region. Furthermore, it is supporting the physical and mental wellbeing of local communities by reducing air pollution and exposure to PM2.5. By providing an effective and live set of data for local communities to track peatlands, action when concerns are realized can be fast and efficient. Furthermore, the spread of our technology will educate locals of the need to protect peatlands and urgency to uphold climate action.

ECONOMIC

The six largest fire events in 2004-2015 caused a total of $93.9 billion. If peatland restoration were in place, it is estimated to save $8.4 billion, which demonstrates the long-term potential of our solution. The majority cost from damages from peat fires were land cover occurred in 2006 (US $11 billion) and 2015 (US$9.4 billion), with costed between US$4 billion and US$7 billion. Coupled by restructuring burnt infrastructure and the cost of health impacts, there's no doubt that peatland fires created caused significant burdens onto Indonesia's government and the insufficiency of current action. We are confident that our affordable solution will save billions of dollars in loss due to fires.

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

11 SUSTAINABLE CITIES AND COMMUNITIES

13 CLIMATE ACTION

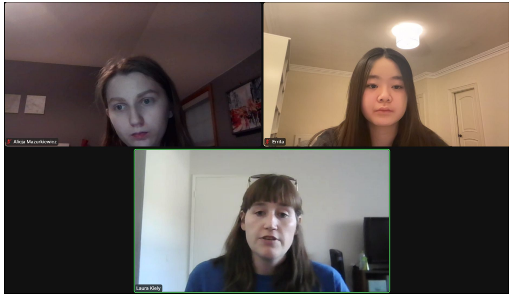
15 LIFE ON LAND

Overall, our solution uses wireless communication and data indexing to foster the collection of information and automation of action over vast and diverse peatland forest areas. Unlike models and satellites, WSN detects accurate and specific data rather than generalized and limited estimates. Our next step would be to collaborate with local officials including Indonesia environmental agencies, to truly ensure that the implementation of our solution aligns with the local population, and that any non-technological infrastructure such as canals can be revitalized.

INTERVIEW WITH DR. LAURA KIELY

WHO IS SHE?

Dr. Laura Kiely is a Chemical and Environmental Engineering postdoctoral researcher at the University California, Riverside. She manages the New England Relocation Team within the Fidelity account. She has a PhD and her research project was on Indonesia peatland fires and health implications. She has multiple research publications about Indonesian (many of which we consulted), such as "Assessing costs of Indonesian fires and the benefits of restoring peatland". She is an expert on regulating Indonesia peatland fires and it's connections with local communities' socioeconomic results.



QUESTIONS

- We know that a lot of peatland fires also occur when farmers use slash and burn to clear land. However, these fires can get out of control or spread without knowledge, especially underground. Are there any alternative methods that reduce cost for land clearing without the use of fire? What is the popularity of these methods?
- Your paper's continuously refer to "peatland restoration", but what exactly does this entail?
- Looking through your research paper "Assessing costs of Indonesian fires and the benefits of restoring peatland", what are the economic benefits of restoring peatland? Are there any possible drawbacks? What methods are currently being used?
- What other health problems does PM2.5 cause? What are current mitigation strategies? How can this and CO/CO2 be measured?

ADVICE

- Peatland restoration is anything that helps support the sustainability of living organisms in the area and protects them from fires. It's a general term used to encompass different projects and policies.
- The technology you have created is promising and seems quite feasible, but it's important to find ways to get people on board because fires are set intentionally for slash and burn. Re-wetting land used for farming means destroying all their crops. You must work with local farms and community members to meet their demands.
- Policies and projects for peatland restoration has been largely unsuccessful because often its large companies who want to take advantage of the peatland resources and illegally deforest. In the future, we foresee our technology ensuring the accountability of all stakeholders such as detecting sounds of illegal deforestation.
- Current fire radiative power such as satellites used to detect fire isn't efficient enough compare to our solution and technology because our solution can track underground data such as groundwater and fires.
- How will you communicate? Currently, rural volunteer firefighters use apps on their phones to react to immediate fire emergencies – just like we will when a region is classified as having a fire.

OUTREACH & EXPERT ADVICE

Dr. Scott Davidson

As the lead of the Group lead for the Plymouth Peatland Research Group and expert peatland research, Dr. Davidson emphasized that we must look into how we can "successfully direct/divert water sustainably in these regions" given the vast area of land and irregular location of canals.

Dr. Paul Lunt

Dr. Lunt is an Associate Professor in Environmental Science at the University of Plymouth. He stated, "I think the main misconceptions about climate change and carbon sequestration is that a warmer climate is not necessary bad for peatlands provided the warming is accompanied by increased and more regular rainfall."

Professor Sean Comber

Professor Comber is a professor of Environmental Chemistry at the University of Plymouth. He forwarded us to other contacts he had of peatland/forest researchers. Further, he provided us with a research article titled, "Assessing costs of Indonesian fires and the benefits of restoring peatland."

Christine Wiedinmyer

Wiedinmyer is a research professor and air quality expert at the University of Colorado Boulder. She forwarded us a research article titled "Particulate matter, air quality and climate: lessons learned and future needs" She also forwarded us to the contacts and works of past colleagues including Professor Dom Spracklen and Dr. Laura Kiely.

Dr. Aiora Zabala

Dr. Zabala is a senior fellow at the Department of Land Economy at the University of Cambridge where she coordinates and delivers lectures on Environmental Policy and Economics. She was also the co-founder and Senior Editor at Nature Sustainability and has published articles on peatlands. Given her profound background in research and sustainability project management, she directed us to the "Global Forest Watch" to find rich spatial data on a range of variables such as early warnings. She also recommended the "Google Earth Engine" and using GIS training (Geographic Information Systems) to collect data on relevant forest fire risk indicators.

Dr. Stibniati Atmadja

Dr. Atmadja is a peatland and climate change researcher based in Indonesia. Based on her unique expertise and experience doing hands-on research in Indonesia, we specifically asked her about the feasibility of our innovation given peatland conditions unique to Indonesia. She stated, "In my opinion the solutions to peatland fires need to be based on local conditions, opportunities, and institutions. The pitfall is when one offers solution that is not based on field realities, the solution is not even addressing the real problem." Based on this, we studied the current situation of peatland fires and garnered a social and personal perspective on the problem we hope to tackle. Further, she recommended us to narrow our research to a specific region for better comparative analysis and then expand. This is because ""mainland' in Indonesia. Peatland is scattered in 3 islands." Because of this, all our analysis and data sets are gathered from one of the largest peatland regions in Kubu Raya, Indonesia. Finally, she also introduced possible barriers that must be considered such as internet access, breakdowns due to humidity, and theft.

Acknowledgements

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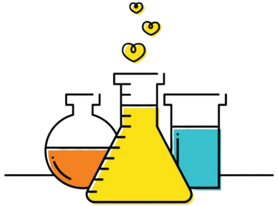
Royal Swedish Academy of Engineering Sciences

For sponsoring this challenge and fostering the urgency for sustainable development.

Dr. Bharti Singal

For being an amazing mentor, providing us invaluable resources, sharing additional insights, fostering a sense of community, and guiding us throughout the whole project.



Scientists and Researchers

For dedicating time to answering us inquiries about specific aspects of our solution and directing us to research papers and other experts.

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