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# Illegal logging detection technology based on sound pressure level in mangrove forests in Meranti Islands Regency

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## ABSTRACT

Mangrove forests are the best carbon emission absorbers. According to the Ministry of Environment and Forestry, mangrove forests can absorb 4 – 5 times more $CO_2$ than land forests. 1 hectare of mangrove alone can absorb 39.75 tons of $CO_2$/ha/year or the equivalent of emissions from 59 motorcycles per year. This means that mangrove forests have great potential to contribute to accelerating emission reductions by 2030. Only 15 countries have mangrove forests, including Indonesia. In the 1980s, the area of Indonesian mangrove forests reached 4,250,000 hectares. However, it was recorded that between 2013 and 2019, the remaining area of mangrove forests was only 3,311,245 hectares. Several causes of ecosystem damage in mangrove forests. First, illegal mining conversion (even though the productive limit of former mangrove forest ponds is 5 years). Second, the conversion of forests into plantations. Third, the conversion of forests into residential areas. Fourth, illegal logging, namely the illegal cutting of mangroves for firewood and charcoal raw materials. In Riau Province, the area of mangrove forests ranges from 75,000 – 343,750 Ha, with 25,619 Ha owned by the Meranti Islands Regency. The main problem in this area is in point 4 of the causes of damage to the mangrove ecosystem above, namely due to illegal logging. The idea proposed is to create a technology in the form of a tool that utilizes the sound pressure level (SPL) method and is equipped with a camera to detect illegal logging activities in real-time. This tool consists of input and output components. The input components used are sound sensors (detect and record sound), sensor nodes (capture and send sound data), ESP32 (microcontroller and send sound to the database), ESP32-CAM (photograph the surrounding environment), and solar panels (provide power during the day). While the output components used are the blunk IoT application, telegram, and gadgets to store sound and send notifications and photos.

**Keywords:** Illegal logging; internet of things; mangrove forest; Meranti Islands; sound pressure level

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## INTRODUCTION

Mangrove forests are excellent carbon emission absorbers. According to the Ministry of Environment and Forestry, mangrove forests can absorb 4 – 5 times more $CO_2$ than terrestrial forests. One hectare of mangroves alone can absorb 39.75 tons of $CO_2$/ha/year, equivalent to the emissions from 59 motorcycles per year. This means that mangrove forests have significant potential to contribute to accelerated emission reductions by 2030.

Only 15 countries have mangrove forests, including Indonesia. In the 1980s, Indonesia's mangrove forest area reached 4,250,000 hectares. However, between 2013 and 2019, only 3,311,245 hectares remained.

Several causes of ecosystem damage to mangrove forests are identified. First, illegal mining conversion (even though the productive life span of former mangrove ponds is 5 years). Second, forest conversion to plantations. Third, forest conversion to residential areas. Fourth, illegal logging, the illegal cutting of mangroves for firewood and charcoal [1]. Illegal logging, such as the cases that occurred in the Meranti Islands Regency in June 2021 [2], September 2021 [3], and most recently in January 2024 [4], resulted in the felling of more than 3,200 logs, threatening the sustainability of the mangrove areas in the area.

The focus of implementation is rehabilitation in nine provinces, updating expansion maps, launching a national mangrove map, and establishing a Mangrove Restoration Agency. The effectiveness of this program has been demonstrated by the increase in mangrove forest area. According to Ministry of Environment and Forestry data, in 2021 there were 3,364,080 hectares, with plans to increase this figure in the future.

In Riau Province, mangrove forests cover an area of 75,000 – 343,750 hectares, with 25,619 hectares in the Meranti Islands Regency. The main problem in this area is the fourth cause of mangrove ecosystem damage mentioned above, namely illegal logging.

The proposed idea is to create a technology in the form of a device that utilizes the sound pressure level (SPL) method and is equipped with a camera to detect illegal logging activities in real time. This device consists of input and output components. The input components used are a sound sensor (detects and records sound), a sensor node (captures and sends sound data), an ESP32 (microcontroller and sends sound to a database), an ESP32-CAM (photographs the surrounding environment), and a solar panel (provides power during the day). The output components used are the Blynk IoT application, Telegram, and a gadget to store sound and send notifications and photos.

## RESEARCH METHOD

### Research Instruments

The instruments used in this study are divided into those for obtaining qualitative and quantitative data. These instruments consist of the researcher and documentation tools during field surveys, such as cameras and voice recorders. The next research instrument consists of components in an illegal logging detection device. This begins with the construction of a photovoltaic (PV) device as the primary power source.

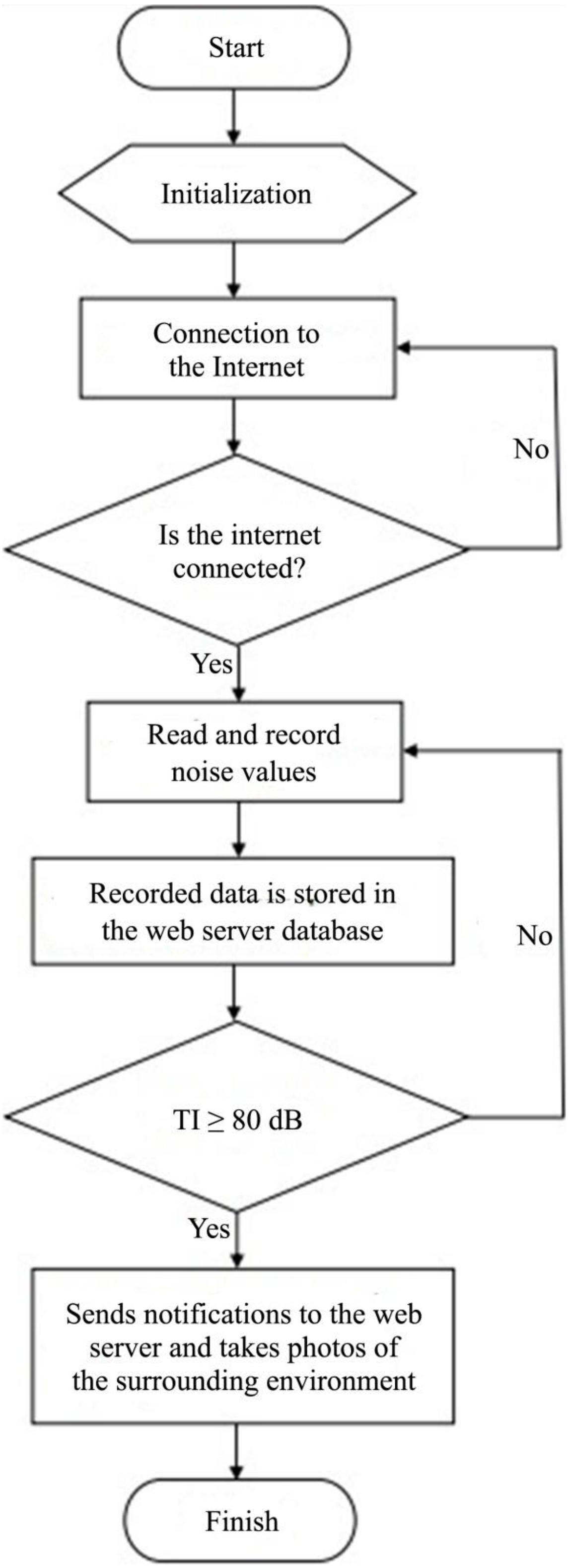


**Figure 1.** ILLOTECH system work flowchart.

The construction of this PV device requires several key components, such as a monocrystalline solar panel, a solar charge controller (SCC), a 12-volt battery, and a panel box. The SPL detector requires components such as an ESP32, an ESP-32 CAM, a MAX9814 sound sensor, and a sensor node.

## Block Diagram

The device's operating system begins with initialization. The photovoltaic device sends electrical power to the SPL detector to power all components. The device then connects to the internet. The device then reads and records ambient noise using a sound sensor.

The Arduino program will be programmed to read the TI value of the chainsaw (> 80 dB) from the target sensor type used. The recorded sound will be saved to the Blynk IoT application. If the sound sensor detects a sound with a TI of 80 dB, the sensor node will send a notification in the form of an alert display to the web database and the forest ranger's gadget. The ESP32 CAM will then photograph the surrounding environment and send it as a photo to the forest ranger's Telegram.

## Tool Assembly

In tool construction, there are two stages of assembly: input and output assembly. The following are the stages in assembling the tool in question.

### *Input Assembly Stage*

The input assembly in this tool consists of a photovoltaic device and a sound pressure level detector. The input assembly begins with the photovoltaic assembly, which is a device that connects a solar panel to the SCC. The SCC output is then connected directly to the sound pressure level detector.

Next, to assemble the sound pressure level detector, continue by connecting the ESP32 CAM by connecting the VCC pin to a power source (3.3V or 5V) and the GND pin to ground. For serial communication, connect the U0R (RX) pin to the TX pin on the serial adapter, and the U0T (TX) pin to the RX pin. To upload a program, connect the GPIO0 pin to GND to put the ESP32 CAM into programming mode, then connect it to the computer via a USB to Serial Adapter. Once the program is uploaded, GPIO0 is removed from GND to return to normal operational mode.

After the input circuit is complete, proceed with the output device by creating a Blynk IoT account to monitor the noise level data from the SPL detector. To display the data in the Blynk IoT application, use a value display to display noise level data and SuperChart to view noise level graphs.

### *Output Device*

After the input circuit is complete, continue with the output device by creating a Blynk IoT account to monitor the noise level data from the SPL detector. To display data in the Blynk IoT application, use the value display to display noise level data. SuperCharts is used to view noise level graphs.

## Data Collection and Analysis Techniques

This study generated qualitative and quantitative data. Qualitative data were obtained through a direct survey of the mangrove forest in the Meranti Islands Regency. Quantitative data were obtained by conducting laboratory-scale tool effectiveness tests.

To obtain qualitative data, researchers conducted a direct survey of the mangrove forest in the Meranti Islands Regency. Documentation of the survey activities can be seen in the image below.

**Figure 2.** Documentation of survey activities in the mangrove forest.

Quantitative data were obtained using the R&D method, which involves testing the effectiveness of the tool. The data collected was the intensity level (TI) (dB) under several noise conditions, marked with symbols A, B, C, D, and E. The testing was conducted on a laboratory scale, with a distance of 3 m from the sound source to the tool. The following table shows the TI and notification tests under various noise conditions. There are 5 different noise conditions marked with symbols A, B, C, D, and E. The noise conditions given respectively are 45, 60, 0, 80, and 90 in dB.

## RESULTS AND DISCUSSION

### Mangrove Forest Survey Results

Based on a survey conducted by researchers in the mangrove forest in Banglas Darat Village, Meranti Islands Regency, different types of noise were identified. These included the chirping of birds, monkeys, tree scraping, waves, and ship sounds. The TI for these noise types were derived from existing theories. The noise TIs can be seen in the table below.

**Table 1.** TI of noise types in mangrove forests.

| Noise type | TI (dB) |
|---|---|
| Tree scraping | 20 – 40 |
| Bird sounds | 80 |
| Monkey sounds | 90 |
| Ship sounds | 80 – 100 |
| Wave sounds | 40 – 70 |

Table 1 above shows that the sounds of birds, monkeys, and ships were all ≥ 80 dB. The sensors were located at an average distance of 30 meters from the source of these types of noise. In theory, the TI should decrease by 6 dB for every 10 meters. This is in accordance with the inverse square law, which states that "The surface area around a point sound source increases with the square of the distance from the source":

$$TI_2 = TI_1 - 10\log\left(\frac{R_2}{R_1}\right) \qquad (1)$$

where, $TI_1$ is TI of source (dB), $TI_2$ is TI heard at a certain distance, $R_1$ is distance 1 (m), $R_2$ is distance 2 (m).

From this equation, it can be seen that when the TI at a distance of < 10 m, the sound heard is the same as the sound at the TI of the source. However, if TI > 10, the TI value will decrease by 6 decibels for each increment.

### Tool Implementation

The innovation created by the researchers is ILLOTECH, a tool that utilizes the SPL method equipped with a camera to detect illegal logging activities in real time. ILLOTECH is still being developed in prototype and laboratory scale form. ILLOTECH can assist forest rangers in monitoring and identifying illegal logging activities in mangrove forests. ILLOTECH is integrated with IoT, allowing rangers to monitor forest conditions via gadgets or PCs. ILLOTECH consists of input and output components.

The input components used in ILLOTECH products include a sound sensor, ESP32-CAM, ESP32, monocrystalline solar panel, solar charge controller (SCC), sensor node, 12-volt battery, and step-down module.

The output components in ILLOTECH products utilize the Blynk IoT application to send notifications in the form of warning displays. Furthermore, Telegram software is used to send photos if the sound sensor detects a sound level greater than 80 dB.


**Figure 3.** ILLOTECH product implementation.

The ILLOTECH system begins with the SPL reading and recording ambient sound using a sound sensor. The Arduino program will detect the chainsaw's Intensity Level (TI) at 80 dB. If the sound sensor detects a sound exceeding 80 dB, the sensor module will send a notification in the form of a warning display to the Blynk IoT app. The ESP32-CAM will then photograph the surrounding environment and send it to the Telegram device on the forest ranger's device. This allows the forest ranger to identify the location of illegal logging and take immediate action to stop it.

**Prototype Testing Effectiveness Results**

After the device assembly phase was completed, the device's effectiveness was tested. This test aimed to determine whether the device functioned according to the system's specifications and could provide notifications to the forest ranger. This test was conducted by creating noise conditions at various sound levels (dB). Five sound levels were used: 45, 60, 70, 80, and 90 dB. The test results can be seen in the following Table 2.

**Table 2.** ILLOTECH effectiveness testing.

| Intensity level (dB) | Notification available | |
|---|---|---|
| | Yes | No |
| 45 dB | | ✔ |
| 60 dB | | ✔ |
| 70 dB | | ✔ |
| 80 dB | ✔ | |
| 90 dB | ✔ | |

Table 2 above shows that the device does not provide notification when the noise level is < 80 dB and continues to read and record sounds in the surrounding environment. However, if the noise level is ≥ 80 dB, the device provides a notification via the Blynk app. The ESP32-CAM then sends a photo display to the device's Telegram.

## CONCLUSION

The conclusions of this study are:

1. Mangrove forests can absorb 4 – 5 times more carbon than terrestrial forests. The area of mangrove forests in Indonesia in the 1980s was 4,250,000 hectares. However, between 2013 and 2019, 261,141 hectares of mangrove forest were lost.
2. The cause of mangrove decline is none other than human neglect and irresponsibility towards nature, an example of which is illegal logging in the Meranti Islands Regency.
3. ILLOTECH is a tool that utilizes the SPL method to detect illegal logging activities. ILLOTECH consists of input and output components. The tool's working system begins with the SPL reading and recording environmental sounds with a sound sensor.
4. ILLOTECH is expected to facilitate forest rangers in monitoring mangrove forest conditions and minimizing illegal logging activities, especially in mangrove forests, so that the mangrove ecosystem can be maintained and become a source of oxygen for the future.

## SUGGESTIONS

In the future, ILLOTECH products will be developed into a real-world product. Direct trials of the device will be conducted in mangrove forests to determine whether it can be used to combat illegal logging.

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