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Technological Frontiers in Combatting Illicit Tree Trade: A Literature Review

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ABSTRACT—

To better understand the field of tree protection, this literature review paper looks at the state of research on the use of Internet of Things (IoT) technologies for smuggling detection and prevention. The illegal trade poses a continuing threat to trees. Therefore, creative ways to conserve it are required. This review encompasses a wide range of literature, including important topics such as sensor networks, machine learning methods, data analytics, and Internet of Things architectures designed for tree protection. The survey uses a systematic methodology and critically analyzes existing research to unveil pivotal findings and innovations in tree smuggling detection. The efficiency of IoT technology in improving accuracy, scalability, and real- time monitoring capabilities for countering illicit activities grabs particular attention. Concerning sustainable management, the information synthesis offers a more in-depth knowledge of the approaches used. The literature study emphasizes the critical importance of IoT in tree preservation and the possibilities of sensor networks, data fusion techniques, and remote sensing technologies. It investigates how these technologies help provide comprehensive and adaptable solutions capable of tackling the dynamic issues provided by tree smuggling. The literature re- view's conclusions highlight the field's potential developments and emphasize how effective IoT is at preventing tree smuggling by taking preventive steps. Improved monitoring, quick reaction systems, and sustainable management techniques are among the field's ramifications for protecting these priceless natural resources. This literature review adds to the existing body of knowledge by bringing together current research on tree smuggling detection. The synthesis of results serves as a foun- dation for future developments in technology-driven strategies for the security of sandalwood and related endangered plant species, in addition to providing information to researchers and policymakers.

Index Terms—Microcontroller and Microprocessor, GSM, Ac- celerometer, Tree Protection, Flex Sensors

I. INTRODUCTION

Illegal timber trafficking, or tree smuggling, involves the unauthorized harvest, transportation, and trade of trees and their products.

Deforestation has emerged as a pressing global issue in the face of rising environmental concerns. Among the many factors that lead to deforestation, illegal tree smuggling is a significant threat to forest ecosystems and biodiversity. Innovative solutions that combine the power of Internet of Things (IoT) technologies and machine learning algorithms are gaining traction in combating this illegal activity.

Sensor-enabled IoT devices with communication capabil- ities can be deployed in forest areas to collect real-time data. The obtained data can then be analyzed using machine learning algorithms to detect anomalies that could indicate illegal logging.

Machine learning algorithms, trained on historical data and expert knowledge, can identify patterns and relationships that are often too subtle for human observation. By analyzing sensor data and identifying deviations from expected patterns, these algorithms can flag potential smuggling activities, allow- ing for timely intervention by forest authorities.

The integration of IoT and machine learning offers a promis- ing approach to curbing tree smuggling, providing a proactive and data-driven solution to safeguard our precious forests. By utilizing this technology-driven approach, forest monitoring and protection could be revolutionized, guaranteeing the sur- vival of these essential ecosystems for future generations.

II. LITERATURE REVIEW

Following our discussion of tree smuggling detection in this section, we will provide a literature survey on the various solutions proposed by researchers and authors.

A. Illegal Logging Listeners Using IoT Networks [1]

A deep learning application requiring vast amounts of acoustic data is being developed to enhance the automated detection of illicit logging activities. To this end, an Internet of Things device network and methodology are proposed. The sensors are positioned high up in the trees and covered in a camouflage casing. The installation of these devices catches loggers in the act and deters many of them. The responsible rangers receive an email alert as soon as motion is detected. When suspiciously abnormal motion is detected, audio information can assist in validating or dismissing alerts.

Furthermore, the sound of logging activities can be recorded before loggers come into view of a camera because sound can be heard farther away than the normally usable field of view of a camera. This effectively extends the system's coverage range. We constructed an Internet of Things sound acquisition network and set it up in a real-world, albeit regulated wilderness setting. Acoustic features were extracted from recorded audio files to identify and categorize illegal chainsaw activities. Our embedded sound listener was created with excellent performance, portability, and affordability in mind. An integrated alert system that can detect sounds and visual data is their ultimate objective.

B. Design and Development of Wireless Sensor Node for Anti- Poaching [2]

This article addresses the design and development of a wireless sensor node for anti-poaching, and it was presented at the International Conference on Communication and Signal Processing in India. The main goal is to deal with the problem of tree theft, which results in the loss of animal habitats and the degradation of natural resources. A wireless sensor network (WSN) protocol-based microcontroller-based anti- poaching system is the centerpiece of the suggested solution.

The writers go into detail about the hardware and software elements of the wireless sensor node, utilizing a transceiver, a low-power microcontroller, and a solar-powered rechargeable battery. They also go over how to measure vibration and identify motion using particular sensors, like the ADXL362 3-axis MEMS accelerometer. The Wireless Sensor Node for Anti-Poaching is primarily made up of a processing unit with a low-power MSP430F5528 microcontroller, a transceiver unit (CC2500) for wireless communication, a power unit, and a sensing unit with a 3-axis MEMS accelerometer (ADXL362). Implementing protocols for data transmission and reception as well as programming using Code Composer Studio are all part of the software design process.

While the processing unit manages data processing and base station connectivity, the sensing unit detects motion and vibrations. Wireless communication is made easier by the transceiver unit, and solar panels and rechargeable batteries provide a sustainable power source for the power unit. To- gether, these parts create a strong and efficient wireless sensor node for anti-poaching.

The testing and outcomes of the wireless sensor node, including battery life calculations, current consumption, and sensor data validation, are also covered in the study.

C. Integrated System For Real-Time Monitoring & Protection Of Sandalwood Trees Using IoT & GSM Technologies [3]

This project offers an integrated system for the real-time monitoring and protection of these trees that make use of IoT and GSM technologies. To identify unlawful cutting, the system uses wire sensors, and to detect forest fires, it uses flame sensors. A Node MCU ESP8266 functions as the primary controller, gathering and forwarding sensor data to a cloud server. The system incorporates a GSM module (800C) that allows for offline alerting. With the use of wire sensors, flame sensors, Node MCU ESP8266, the IOT Blynk app, and GSM technology, this work suggests a comprehensive system for the real-time monitoring and security of sandalwood trees

The suggested system makes use of wire sensors to find illegal tree slices and flame sensors to find wood fires early on. The Node MCU ESP8266 is the primary controller; it gathers and analyses sensor data. An integrated GSM module (800C) ensures that authorities acknowledge timely cautions in both online and offline modes, thereby mitigating the problem of network effects. The system uses a cloud server to update sensor data regularly and uses the IOT Blynk app to send alerts about robberies and fires to the specified client device. Illegal cutting and fire incidents are detected by the wire and flame sensors, respectively. Through the GSM module, the NODE MCU ESP8266 gathers and processes the sensor data, initi- ating the necessary actions and alerting authorities. The IOT BLYNK app offers a user interface for real-time monitoring, while the cloud server enables data storage and remote access. When these parts work together, they can effectively monitor and protect sandalwood trees in real time, addressing issues with illegal activity and fostering conservation efforts.

The hardware architecture and circuit design comprise the two primary components of this system's design and development. Whereas the Arduino IDE, BLYNK APP, and Embedded C are used in software architecture and software development. An essential microcontroller is the Node MCU ESP8266. It works in tandem with wire and flame detectors to identify unauthorized wood and slice fires. Providing wireless communication through GSM networks, the GSM module 800C is a crucial component of the design. Integrating it facilitates communication and provides a warning in places where internet connectivity is spotty or nonexistent.

D. Design of IoT based Anti-Smuggling System for Forest Trees [4]

Four sensors are used by the structural framework: PIR, temperature, vibration, and sound sensors. It is suggested that the system incorporate a PI camera in addition to the sensors, which are all mounted on Raspberry Pis, to monitor activity around the device's perimeter. It is suggested that the system use a PI camera, which is installed on a Raspberry Pi, to monitor activity around the device's perimeter. A relay device that keeps the Raspberry Pi from being destroyed by the heat sensor. We have added a lithium-ion battery as a backup power source in addition to the Raspberry Pi's built-in power supply. The Raspberry Pi, which is fastened to the tree, has the vibration sensors installed on it. A different pole, nominally spaced from the tree and linked to the Raspberry Pi, has smoke and heat sensors. Sensors are linked to the Raspberry Pi's GPIO pins. Python is used to program them on the Raspberry Pi running Raspbian Jessie OS. The system's ability to locate poachers in real-time will be enhanced by the application of cutting-edge computer vision technology.

E. GSM Based Illegal Tree Cutting Prevention and Monitoring [5]

The microcontroller, flex sensor, and GSM modem inter- faced with the Arduino module will be the small electronics

Unit attached to each tree. The flex sensors will detect when a tree is being cut, and the GSM modem will communicate with the server to display the cut trees on the web app. The GSM modem will also facilitate communication between the trees and the server. In the event of any variation, the app will be updated with the location and a warning message. For each distinct forest area, there will be one sub server unit. This unit is capable of collecting data from various tree units. The sub server unit will use a GSM modem to transmit data to the main server. A VB GUI for the main server will be developed to warn about gossamers with precise tree locations.

Forest authorities can use this data to make preventative decisions. Using vibration sensors, fire sensors, passive in- frared sensors (PIR), and PH sensors, respectively, the four main operations that are crucial to forest monitoring are developed in this work: tree-cutting detection, fire detection, human detection, and contaminated water detection. GSM is used in conjunction with a microcontroller to enable remote communication to a central server. Through GSM, the au- thorized person receives the sensed data from the sensors. IoT is a popular technology for applications involving forest monitoring. Additionally, this paper makes use of a Wi-Fi router module so that, if the network is disabled, employees and forest officers can communicate with one another.

F. Autonomous System for Protection of Valuable Trees from Smuggling Using Zigbee [6]

This paper aims to develop an autonomous system that can be beneficial in safeguarding forested areas. Two units—a sensing unit and a monitoring unit for the forest area—will make up the system. The electronic division of the sensing unit is made up of an RF transmitter and receiver, four sensors, a GSM module, a ZigBee module, and a microcontroller. The monitoring unit, which has a personal computer, will receive information from this sensing unit. After receiving information from the monitoring unit, the designated individual will take the necessary steps to ensure tree security. "Protection of valuable trees from smuggling using ZIGBEE and sensors" is the most promising resolution; it will use useful, practical, and reliable technology for monitoring. This project uses a variety of sensors, including vibration and continuity sensors. For communication purposes, we also use a GSM module and the Zigbee protocol. The system is divided into two stages:

A. Tree unit

B. Control unit

Sensing unit: This unit is the main unit used in the system's implementation. It consists of four sensors that provide infor- mation about things like fire damage, tree cutting, and other events.

Monitoring unit: This unit is primarily used for controlling purposes. It receives data via Zigbee technology and uses a PC to send SMS messages to a predetermined number, at which point the relevant authority takes appropriate action.

To construct the entire unit, the system is made up of three units.

Input Unit: The power supply and sensor modules make up the input unit. The sensor unit comprises a PIR sensor to detect human presence, a temperature sensor to measure atmospheric temperature, and a 3-axis accelerometer to determine whether the tree has fallen if the threshold angle is met.

Output Unit: Zigbee is used in the output unit to transfer data from the controller to the PC. The output has a continuous temperature and humidity monitor, an alert system for when a person enters, a tree that has fallen if the threshold angle is reached, and a cut in the continuity.

Control Unit: The controller and power supply make up the control unit. The entire unit must be under the control of the control unit.

The ZigBee communication protocol is used by Arduino for communication. The four main layers of ZigBee communica- tion are the physical layer, the MAC layer, the network layer, and the application layer.

The goal of this project is to create a ZigBee-based tag that will protect forest trees. It presented the improvement of an already existing system through the addition of ZigBee location technology. The ZigBee network is used to monitor forest areas' relative parameters such as MEMS, fire, intruder (PIR), and humidity concentration. Finally, the monitoring center obtains the data from the server and through the ZigBee wireless network.

G. IoT-Based Forest Fire and Smuggling Detection [7]

To protect trees from smuggling and forest fires, this project suggests a tracking and alerting system for staff members. The answer to the current issue is an IOT-enabled fire and smug- gling detector and monitoring system built on the Arduino platform. In this project, we used an Arduino Nano to build a fire detector that is interfaced with a buzzer, tilt, temperature, and vibration sensors. The primary objective of the proposal as outlined here is to detect recent fire outbreaks across various forest areas and estimate the short-term existence of fire risks.

We have been hearing for ages about illicit activities such as the smuggling of commercial and precious trees from protected forest areas, like teakwood and sandalwood. A monitoring host computer, gateways, routers, and sensor nodes make up a wireless sensor network system. In this design, a multiple-sensor network topology structure is used to reduce energy and data packet loss. With the help of several sensors, including temperature and flame sensors, the work is also able to forecast the likelihood of a fire in the area of interest. Additionally, to identify any smuggling activity in the tilt and vibration sensors of the forest.

Optical sensors and motion sensors are used in detection techniques to combine features such as color, motion, spectral, spatial, temporal, and texture characteristics that are linked to the physical characteristics of smoke and flame. After the ac- tivity is identified, a transmitter that is attached to the Arduino sensor circuit transmits the data to the control system. Using a GSM module, the control system processes the data and sends an SMS message to the registered mobile number. This

Location is displayed in the mobile Google Maps application. If the temperature rises, the LCD will quickly notify you of the current condition. If the buzzer is raised and the range is exceeded, it will automatically alert the local authorities and send a message to the registered mobile number. Additionally, the same number will receive an alert message for tree cutting whenever additional movements or trees are cut in the forest area. The project opens the door for quicker advancements in the field of "EMBEDDED SYSTEM" and makes a significant contribution to it.

H. Implementation of a Forest Monitoring and Alerting Sys- tem [8]

This system builds a network of sensors, with a controller acting as a node and transmitting data to the Raspberry Pi, a more potent central station. When an alert needs to be sent, the conditions will be included in the code at the central station. A Wireless Sensor Network (WSN) model is used in the suggested paper. WSN is an Internet of Things (IoT) application wherein various sensors are employed to measure their environment. A sensor node that can be fastened to a tree is created in the suggested model. This sensor node is made up of four sensors: a sound sensor (LM393), an accelerometer (ADXL345), a humidity and temperature sensor (DHT11), a tilt sensor (SW520D), and a controller (NodeMCU) that has an embedded Wi-Fi chip (ESP8266).

The MQTT (Message Queue Telemetry Transport) Proto- col is used to transfer data between the Raspberry Pi and NodeMCU. The suggested model in this paper sends emails with alerts to the relevant email addresses. If the node or a specific sensor fails, an alarm is also set off. Furthermore, a webpage for viewing and analyzing the values at the nodes has been made. The ESP8266 Wi-Fi chip on the NodeMCU is used to transmit the processed data using the MQTT protocol to the central station, which is the Raspberry Pi. Specifically, the Raspberry Pi. To record different sensor values specific to a tree, the node module needs to be positioned atop the tree.

I. Real Time Forest Anti-Smuggling Monitoring System Based on IoT [9]

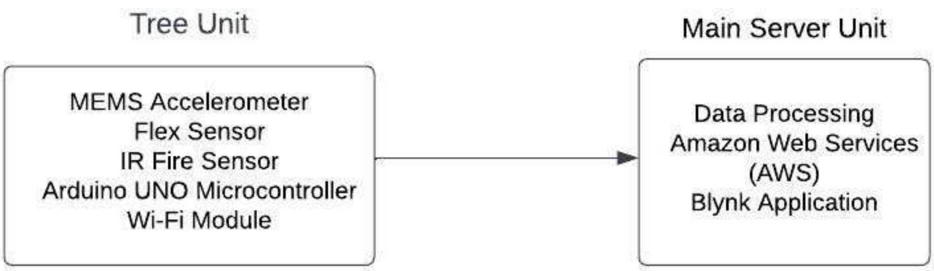

Fig. 1: Existing system of Real Time Forest Anti-Smuggling Monitoring System Based on IoT

A real-time IoT-based forest anti-smuggling monitoring sys- tem is described in the document, to prevent the illegal logging and smuggling of valuable trees in protected forests. The Ar- duino Mega 2560 microcontroller, flex sensor, accelerometer sensor, GPS module, WiFi module, infrared fire sensor, PIR sensor, and liquid crystal display (LCD) are some of the parts that make up the system.

The identification of illicit activities like fire, deforestation, and unauthorized movement within forest areas is one of the document's main conclusions. Real-time alerts and informa- tion can be sent by the system to the relevant authorities and a central server. The module works by employing sensors to keep an eye on the trees and identify any unauthorized activity. Data is then sent over the internet to a server. The Blynk app is also used by the system for control and visualization.

Through the use of numerous sensors and communication modules, the system can identify instances of illicit logging and tree-cutting. Every tree has an embedded system unit that includes a WiFi module, sensors, and an Arduino UNO microcontroller. The accelerometer, flex, and infrared fire sensors are among the sensors. These sensors keep an eye on the trees and use the internet module to communicate the trees' current condition to the Base Station. After being transmitted via WiFi, the data is stored and examined on the server. To visualize and control the events that the sensors detect in real- time, the system also makes use of the Blynk app.

The components utilized in the forest anti-smuggling system are covered in detail in the document, along with their uses and functionality. For remote tree detection and monitoring, the approach also incorporates the system with Amazon Web Services (AWS). The system's objectives are to stop unlawful activity and safeguard priceless trees by providing round-the- clock monitoring of trees in protected forest areas.

J. Anti-Poaching of Trees in Forest-Based on IoT [10]

To protect trees from smuggling and forest fires, this project suggests a tracking and alerting system for staff members. The answer to the current issue is an IOT-enabled fire and smug- gling detector and monitoring system built on the Arduino platform. In this project, we used an Arduino NANO to build a fire detector that is interfaced with a buzzer, tilt, temperature, and vibration sensors. The primary objective of the proposal as outlined here is to detect recent fire outbreaks across various forest areas and estimate the short-term existence of fire risks.

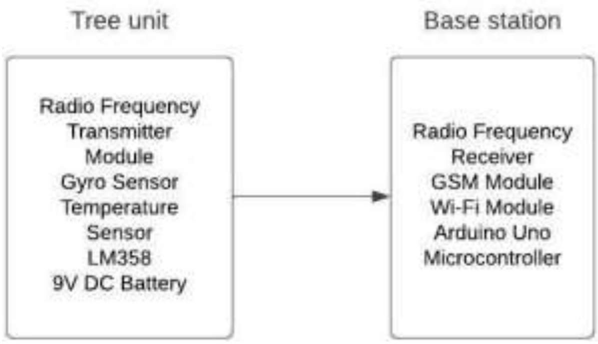

Fig. 2: Existing system of Anti-Poaching of Trees in Forest-Based on IoT

K. Sandalwood Tree Protection Using IoT [11]

This post offers a defensive tactic using IOT (NodeMCU nodes). If thieves try to damage sandalwood trees or take down the security system, the recommended system is designed to send a text message to the owner or the appropriate authorities, enabling them to take the necessary action. The LCD, buzzer, Nodemcu 8266, and power supply make up the user node. The Nodemcu 8266, GPS, circuit breaker, and vibration sensor make up the tree node. The user can view the longitude, latitude, and current location of the trees from the user node, which is situated in the forest officer's office.

Paper	**Methodology**	**Operating System**	Operating Voltage	**GPS**	**Limitations**
[1]	Mel-frequency cepstral coefficients	Rasp- berry Pi	5v	Yes	The effectiveness of MFCC in all types of forested environments and under various conditions is not fully explored, which could be a limitation. Each listener unit will incur 4G data plan charges. This shows that data transfer may incur recurring expenses.
[2]	Hybrid routine protocol(zrp)	msp 430f 5528	3.6	No	Complexity in design. A complicated protocol is used for communication between nodes and the base station.
[3]	-	Ar-duino mega 2560	2-5v	Yes	The device is larger in size. It is easily destructible.
[4]	Zigbee wireless communication protocol	Ar- duino Uno	5v	No	Complex design. Limited communication range. The device has no security.
[5]	Data processing and analysis (GSM	NODE MCU ESP8266	3.3v	No	Tree bending is not detectable. No device security. Complex design
[6]	-	Ar-duino Uno	5v	Yes	The number of SMS messages that can be processed by a GSM modem per minute is very low -only about six to ten SMS messages per minute
[7]	Computer vision technology	Rasp- berry Pi	5v	No	Difficult to store and manage data. The cost is higher. No device security.
[8]	-	Ar-duino Nano	5v	Yes	Complex design. The cost is higher. The device has no security.
[9]	-	Ar-duino Uno	5v	No	Design complexity is more. No positioning capacity. The detection methodology is limited to tree bending.

[10]	MQTT protocol	Rasp-berry pi	5v	No	It has low real-time control and low-level hardware access. Higher complexity in the data transmission.
[11]	-	Node mcu 8266	3.3v	Yes	Hardware components are used on both sides, which increases the cost of the project. Vulnerability to cyberattacks due to the increasing complexity of on-chip components
[12]	-	Ar-duino Uno	5v	No	High cost. The effectiveness of the system heavily relies only on the accuracy of the tilt, which may result in a false output.
[13]	Image processing tool (Deep learning, simu- lation)	80 Mega- 32	1.8- 5.5v	No	It is based on simulation rather than practical implementation, the accuracy cannot be calculated.
[14]	ANN (image processing)	Rasp- berry Pi	5v	No	The output is only based on the camera and does not take into account any other factors.
[15]	LPWAN proto- col	ARM Cortex M4F	2.5-5.5v	No	The LoRa technology used for pervasive monitoring in forest and rural scenarios may experience signal degradation due to vegetation and obstacles, reducing communication range in dense woods or non-line-of-sight scenarios. The system is only functional with axe stroke noises, which may result in a false output.

TABLE I: Summary of the literature's contributions to tree-smuggling detection and the corresponding restrictions

When at least one of the two components—vibration sensors and circuit breakers—is activated, the user node will be notified of the current longitude and latitude. The term "tree node" refers to this attachment to the tree.

The vibration sensor or circuit breaker will break when the tree is replaced or if any illegal tree cutting occurs. After that, the user node will receive the data from the Firebase server, and they will be able to easily track the location of the tree using GPS. Live longitude and latitude will be displayed on the user node, and when the buzzer activates, the Firebase software tool will continuously display the locations of the trees.

This model is not limited to tree protection; it can also be used to detect vehicles and safeguard valuable items.

L. IoT-Based Anti-Smuggling System for Trees in Forest [12]

By using GPS technology, the system allows us to locate the tree where the poaching is taking place. The system also makes use of a chip, or board, that has several embedded sensors (like the Flex Sensor and Fire Sensor) that are managed by the Internet of Things. These sensors are accessible via the Android app that is installed on the Android smartphone, and they monitor and regulate characteristics like tilting, burning, and cutting of the trees. The Android app will communicate with a sensor unit installed on the tree's stem as part of the system. The Wi-Fi module facilitates communication between the Android app and the tree unit. The Flex sensor picked up the bending motion.

A fire sensor will be monitored for any fire hazards. When metal comes into contact with a tree's surface, a metal detector is used to find it and notify the administrator or forester. The suggested system consists of GPS and GSM technology, as well as sensor and actuator circuitry. The location of the tree is determined by the system's GPS. The relevant authority receives an email or SMS with the tree's location. The ATMega328P is a low-cost, high-performance 8-bit microcontroller that can be used for processing. You can use a Li-ion rechargeable battery as a power source. Battery recharging is possible with solar energy.

M. IoT based Anti-Poaching Alarm System for Valuable Trees [13]

This project aims to preserve valuable trees, such as teak and sandalwood, which are in high demand. Three sensors are used in the design system: a sound sensor, a temperature sensor, and a tilt sensor. Designing a transportable wireless sensor node that will be a component of a wireless sensor network is the main goal. Two modules will make up this system: an android phone module and a sensor and controller module that will be located at a tree spot. This is an Internet of Things project. When a tree bends, the tilt sensor and buzzer activate, and when a forest fire occurs, the temperature sensor activates the water pump via a relay switch.

If an incident occurs, this generated data is then sent to the forest officer so that the proper action can be taken.

N. Monitoring Illegal Tree Cutting through Ultra-Low-Power Smart IoT Devices [14]

The paper outlines a methodology for employing ultra-low- power smart Internet of Things devices to identify illicit tree- cutting activities in forests. The system is based on long-range wireless communication and convolutional neural networks (CNN) for audio event classification. The objective is to offer 85% accuracy smart IoT-based forest monitoring that is both economical and efficient. A CNN-based classifier, a pre-processing module for data representation and feature extraction, an acquisition module for sampling and quantiz- ing incoming sound, and a long-range low-power wireless communication module make up the system architecture. The LoRa protocol is used by the system to provide low battery consumption and wide coverage.

A variety of forest-related sound classes, including chain- saw, chirping birds, crackling fire, crickets, handsaw, rain, and wind, are included in the training and testing dataset. The prototype device is powered by a Li-Po battery pack and has a 32-bit ARM Cortex MF4 chipset with 256 kB of SRAM and 1 MB of Flash memory. In a rural area with woods and multiple buildings, experimental tests were carried out to assess the LoRa wireless network coverage and the energy consumption of the IoT device. The overall goal of the system is to use Internet of Things devices to detect illegal tree-cutting activity in forests in a lightweight and effective manner.

The architecture of the system is made to minimize data transmission over wireless networks and lower IoT device energy consumption. Low battery consumption and long- range communication are made possible by the use of LoRa technology. To accurately classify an incoming audio signal, pre-processing techniques such as linear spectrogram, Mel- scaled spectrogram, and Mel Frequency Cepstral Coefficients (MFCC) are utilized to highlight and represent the signal's fea- tures. For processing audio features and dimensionality reduc- tion, the neural network configuration employs a convolutional neural network (CNN) with particular layers. Furthermore, the system employs network quantization and the CMSIS- NN library to boost performance and efficiency while taking resource consumption and classification accuracy into account.

O. Advanced Forest Conservation Against Wildfire, Deforesta- tion And Endangered Species Detection System [15]

An assistant professor from Sri Ramakrishna Institute of Technology in India, along with a group of students, developed an advanced forest conservation system that is the subject of this document. Through the use of technology, the system seeks to combat problems like wildfire, deforestation, and the identification of endangered species. It covers issues with forest fires, wildlife conservation, and the trafficking of trees.

An AVR microcontroller interfaced with multiple sensors, including a GSM communication module, a fire sensor, and a 3D accelerometer, powers the system. The sensors are used to keep an eye on forest conditions, spot forest fires, stop the trafficking of trees, and recognize threatened species. Additionally, the system uses MATLAB for image processing in order to detect species. The authors stress the need for a more effective and economical solution by highlighting the inefficiencies and high costs connected with the current approaches.

The methodology entails contrasting the suggested and current systems to highlight the shortcomings of the latter and the possible benefits of the former. An ATmega32 AVR microcontroller, a 3D accelerometer, a fire sensor, and MAT- LAB for image processing are among the hardware parts of the system. The system's efficacy in tackling the identified challenges is demonstrated by the authors' validation of its performance through simulations and experimental outcomes.

P. Innovative Protection of Valuable Trees Form Smuggling Using Artificial Intelligence and Image Processing [16]

The suggested anti-tree smuggling system protects priceless trees like rosewood, teakwood, pine, and sandalwood by using artificial intelligence and image processing. To detect theft and automatically send alert signals, the system makes use of cameras installed in forested areas. Its objectives are to monitor poaching activity, lessen deforestation, preserve ecological harmony, and safeguard wildlife. The primary parts of the system are the automatic triggering of alert signals, the use of artificial intelligence for detecting theft, and image processing via cameras.

The system can monitor poaching activities, lessen de- forestation, uphold ecological equilibrium, and safeguard wildlife. Furthermore, a lot of data related to the regulation and management of forests can be processed and analyzed through the use of artificial intelligence, specifically the Artificial Neural Network (ANN). As a result, the system may be able to evaluate and distinguish tree crowns more effectively, apply crown detection models to derive tree attributes and supply valuable information to refresh current tree inventories. Additionally, the system can extract large amounts of informa- tion from natural systems' true color image data using deep learning-based techniques, improving the efficiency of forest management and reducing instances of illegal logging.

All things considered, stopping tree smuggling and preserv- ing a healthy ecosystem can be greatly aided by the integration of artificial intelligence and image processing.

III. CONCLUSION

The literature review on IoT-based tree smuggling detec- tion concludes by highlighting the exciting possibilities of combining cutting-edge technologies to stop illegal forestry operations. Together, the reviewed studies highlight the critical need for clever and practical responses to the growing problem of tree smuggling, which seriously jeopardizes the stability of the environment globally and our ecosystems.

The synthesis of the reviewed literature emphasizes the im- portance of a thorough approach by highlighting the complex nature of tree smuggling detection systems. Combining ma- chine learning algorithms with Internet of Things (IoT) devices is a powerful approach that offers adaptive learning, data- driven insights, and real-time monitoring. The combination of IoT sensors, satellite imagery, and machine learning models shows a comprehensive and scalable framework that can more precisely detect, prevent, and respond to tree smuggling activities.

Furthermore, the review of the literature illustrates how this field of study has developed and how detection mechanisms are constantly becoming more complex and refined. Together, the surveyed papers add to an expanding body of knowledge that guides the creation of more resilient and intelligent tree smuggling detection systems as technology develops.

The reviewed literature highlights advancements in the IoT and machine learning combination for tree smuggling detection, but it also points out directions for further research.

The literature review essentially highlights how the Inter- net of Things can revolutionize the field of tree smuggling detection. We can work to create comprehensive, effective, and long-lasting solutions that protect our priceless forests and guarantee their preservation for future generations by encouraging creativity and teamwork.

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