Modern Solution for Human Elephant Conflict

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Abstract— **Human elephant conflict (HEC) has become a serious problem in forest border areas of Sri Lanka. There is a high vulnerability for humans where they are attacked by elephants daily. Sri Lanka is one of countries that reports highest number of elephant deaths due to HEC. Many solutions have introduced throughout the decades to mitigate this rising socio-economic issue, but still, it remains as an unresolved problem. This research will look at those conflicts and issues faced by both elephants and humans, the solutions that needs to take and practically brings out necessary precautions. In this comprehensive discussion, researchers will address the problems that are associated with existing solutions and propose a reliable solution to mitigate HEC with the help of modern technologies. Researchers take advantage of elephant's unique physical characteristic, the gigantic body to detect elephants using seismic vibrations along with Infrared based system and Microwave radar system. Researchers use Wireless Sensor Network (WSN) and Low-Power Wide Area Network (LPWAN) technologies to interconnect systems. A cost effective modern electric fence with flashlight system will use to scare-off elephants while an alarm system will be used to alert villages about the attacks from elephants.**

Keywords— Human-Elephant Conflict; Wireless Sensor Network; Seismic Vibrations; Low-Power Wide Area Network; Alarm system

I. INTRODUCTION

The elephants are the largest existing terrestrial animals. African bush elephant (Scientific name: Loxodonta africana), African forest elephant (Scientific name: Loxodonta cyclotis) and the Asian elephant (Scientific name: Elephas maximus) are three main current species of elephant. Elephants can find in different habitats areas like savannahs, forests, deserts, and marshes. Unfortunately, life of these animals is threatened due to various reasons. Mainly due to killings by humans. The African elephant is in the "IUCN Red List of Threatened Species" list as 'Vulnerable' [1] while Asian elephant as listed as 'Endangered' [2]

Elephants are mainly scattered throughout Asian and African continents. Around 50 countries in the world are natural habitat for wild elephants. The majority them are from the African continent, only 13 of these countries in Asian continent. In Asian region total of 51,000 to 66,000 elephants are living and but only 35000 to 50000 are live in their natural habitats [3]. And the Sri Lanka is natural habitat for 10% of Asian elephants [4].

Sri Lanka has land size of 65,610 km2 and have current population of 325 humans per km2. Every day, around 750 people added to the population [5]. With the growth of human population deforestation happening rapidly to fulfil land requirements. It will result shortage of foods and shelter for wild elephants. Therefore, wild elephants invade human habitat areas which results human elephant conflict. The human elephant conflict cost lives of 318 elephants and 112 people in 2020 along in Sri Lanka [6].
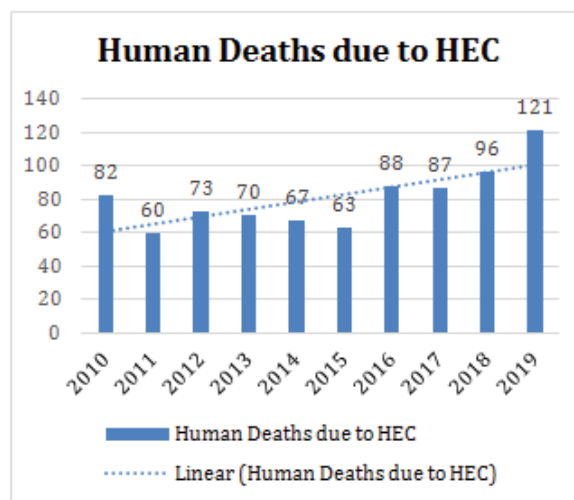

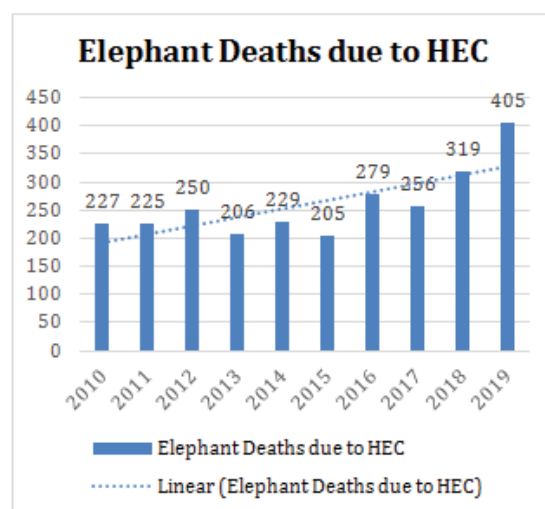Fig. 1. Human Deaths due to HEC (Department of Wildlife 2010-2019)

Fig. 2. Elephant Deaths due to HEC (Department of Wildlife 2010-2019)

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Among Asian elephant species, Sri Lankan elephant subspecies is the largest and the darkest subspecies. The Sri Lankan elephant herd typically consists of 12-20 singles or more. It may include nursing elephants, lactating female elephants, young juvenile elephants, and adult elephants [7]. In Sri Lanka, elephants have symbolic, cultural, and economic value. Tourists visiting national parks are attracted to those wild elephants. Really no species in Sri Lanka has been identified with people as an elephant for so long in its cultural and religious practices. The relationship dates back over 5,000 years to the pre-Christian period. Therefore, the solution that researchers provide to mitigate human elephant conflict should be a friendly solution not only for humans and for the elephants.

The main reason for human elephant conflict is habitat loss of elephants due to deforestation and its unarguable. In the borderline villages, humans tend to cultivate crops like sugar cane, bananas, and other fruits due to the climate. The issue with that is elephant's preference towards that kind of crops which an added bias for elephants to invade human habitats. With the movement restricted of the habitants which has been a huge issue, elephants move from place to place even in paddy fields to find food and to protect themselves. As constructions around the country is occurring and the jungles are been destroyed, elephants find it hard and move to small jungles. Therefore, people also find it on a risk basis that they are not been protected. They are required to have geographical boundaries like electrical fences but then again it will not address the main reason and only provide a temporary solution.

In the borderland villages people tend to live with fear of the wild elephants invading their habitats and destroying their crops. Villages are use many methods like firing firecrackers and thunder flashes, creating loud noises, chili rope fences, chili smoke to prevent elephants from invading their habitats. Since there is no viable solution for human elephant conflict some illegal methods like poisoning and shooting to elephants also tend to use by villages. Some modern solutions also taken to address the human elephant conflict issue. Tracking elephants using collars, identifying elephants using cameras are few of them. Government has deployed electric fences to distinguish human habitats areas from elephants. Which is the only viable solution tried so far. But due to its high cost most of villagers cannot afford that. Recently humans tended to kill many elephants for their survival and reduce their monetary losses. Even there has been no survival for baby elephants and to their families as they tend to travel from place to place and where even road accidents has made them no survival. Likewise, humans have found it vulnerable and no reliable action has been taken by any responsible party This issue has also brought the suffering for farmers to do their cultivations on a day-to-day basis as elephants has been traveling to places to find for food, survival. The reduction of the elephant population has been on a rise unfortunately on these circumstances as many killings has been occurred in the recent past. This has been a very disturbed topic and where there has been no permanent solution yet. The problematic issues have not taken into consideration as these wild elephants now include into the endangered species' list.

Analyzing on the solution, primarily to investigate the long-term solution of human-elephant conflict and specifically promoting on the resourceful implications of peaceful coexistence requires a simultaneously concentration of management efforts on site-specific considerations. Further, highlighting on areas of application of strategic plans at the landscape & natural level that directly address especially on endangering the species and on a lookout for ways to have their space for survival

II. LITERATURE REVIEW

The main reason for human elephant conflict is habitat loss of elephants' due to expansions of human habitats and agricultural areas [8]. This Human elephant conflict leads economical losses and costs both human and elephant lives. Lot of elephant invasions to villages happened in nighttime and elephant is a very intelligent animal & it changes its behavioral patterns. Therefore, its difficult track and monitor elephants continuously. Researchers can use cameras and other kind of sensors to detect elephants. But with the detection methods that use should be give better accuracy alongside with low cost and it should be withstand with the harsh environment. Electric fence is the most prominent solution which is currently used in Sri Lanka. Electric fence will create an ecological boundary between humans and elephants. Since elephants are not in in-situ, they transit from on location to another. Therefore, it is difficult to cover the whole area by elephant fences and difficult of maintain electric fences. In 2016 along Sri Lankan government construct near 4211 Km long new electric fences and to maintain electric fences Sri Lankan government spend 86 million Sri Lankan rupees annually [9].

To identify elephants which invades human habitats there should be a low cost and more accurate system. There are three main options have been described as detection methods for this research. Which are IR beam detection and geophone seismic sensor detection and Microwave Radar sensors. These three detection methods must detect elephants except from other animals and moving objects such as other animals or humans. This IR beam researchers used to detect elephants is at the first stage of their overall detection concept. The main problem is developing a long-range IR beam because elephants are large animals, they need large space to walk means, IR beam must have at least 5m – 10m length beam and that beam connectivity should be very strong. This IR beam is supposed to operate 24*7. Therefore, this connectivity should have a continuous and accurate power supply. The other most significant problem is to identify the most common path that elephants usually attack because the IR beam and the geophone should be located around that area. The other vital point is to connect this sensor beam to wireless sensor network. All these problems must be faced when developing the IR beam.

Elephant is the heaviest terrestrial animal lives in the world. African adult male elephant with average weighting between 2 -7 tons while Asian adult male elephant average weighting between 2 – 5 tons [10]. Among the elephant's Sri Lankan elephant (Elephas maximus maximus) have the second highest weight among the other elephants [11]. Researchers use this unique feature, the weight that can see in elephants to detect them. In this research, researchers use the vibration happened by its footfalls due to its large body weight to detect them. To detect footfall vibration researchers, use seismic sensor device called geophones. Geophone is the other solution which is supposed to use. Geophone needs several collections of data samples to give

a better solution, therefore; elephants' footfalls pattern gathering in testing environment is a challenge. Geophone generates very low amplitude wave. This low amplitude wave needs to be amplified. Therefore, it must develop an amplifying circuit to get geophone data to a readable format. The part is noise cancelling. It generates lots of noise when gathering data from the geophone. Therefore, it must develop a filtering circuit to remove or filter the noise.

As previously mentioned, the only clearly visible difference between elephant's footfall vibrations and other species vibrations is elephant wavelet duration is higher than others. The main purpose of developing neural network is to get a clear classification between elephants' dataset gathered from geophone and other datasets gathered from other species. So, to achieve a good accuracy, there should be a well pre-processed and well distrusted dataset. Therefore, research decide to take large dataset of elephant herds & single elephants to improve the accuracy.

As Third detection method researchers go for the Microwave Rader sensors. Those Microwave Radar sensors need to connect with other detection methods and should work simultaneously and should withstand with the harsh environment where it deployed.

The elephant detection subsystem and the elephant repelling sub system need to communicate with each other. There should be a proper technology to fulfil the communication need of the system. Human elephant conflict happens mainly near forest border areas. In these areas with the environmental conditions researchers cannot use wired mechanisms to fulfil the communication need because it is not practical due to distance between sub systems where there is more than a kilometer distance between subsystems and other practical issues like damages that can be happen from animals or by extreme weather conditions. Therefore, researchers must think about wireless communication method. When researchers use wireless communication mechanism researchers had to consider several properties. Since researchers going to implement this solution in forest border area, the wireless communication method that going to use should have higher anti-interference capability. Since there is no good Global System for Mobile Communications (GSM) coverage that researchers had to exclude idea of using GSM. To make this solution as low-cost solution it limited the options for researchers. So, to fulfil all those requirements researchers, turn towards Low-Power Wide-Area Network (LPWAN) technologies.

Researchers use flashlight system to repel elephants and build a modern electric fence to address the vulnerabilities of existing electric fence and an inbuilt advance human alerting system to alert humans about threat.

III. METHODOLOGY

Following parameters of elephants take into consideration when developing the system.

Physical parameters [10],

- Average Height: 2-3.5 meters
- Average length: 2-4 meters

Walking and running patterns [12],

- Top speed: 15 mph

- Slow walking speed: 11 mph

After some research researchers came into following assumptions,

- Frequent time elephants attack: 1600h – 0900h
- Arrives to human habitat area through specific location (Elephant pass)
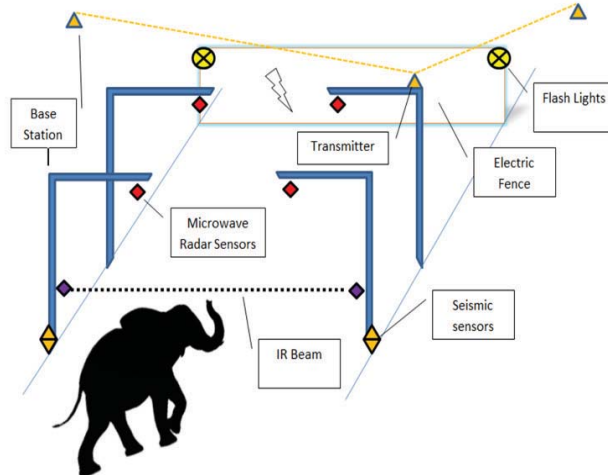- Most of time elephants tend to attack individually

Fig. 3. High level diagram of the system

A. Elephant detection

In this project elephant detection is supposed to be accomplish by using three main concepts.

1) Integrated long range Infrared (IR) beam

First approach of the detection procedure according to above assumptions and details, elephants are usually arriving at specific location. It is supposed to implement this IR beam at this specific location and the length of the IR beam is approximately 6m. IR beam is suggested to implement above 3m from the ground to avoid detecting another animal or human as elephant. It was suggested to set at 3.5 seconds interval between two detections to avoid false detections.

In general market, there is no IR beam sensor that can operate for more than 6 meters. Though some laser beam can be used, due to high cost it will not be a cost-effective solution. In this project, the researchers suggested to develop an integrated IR beam that can operate for 10m. This IR beam has a range up to 10 meters (33 feet), using a single high-power LED with no lenses.
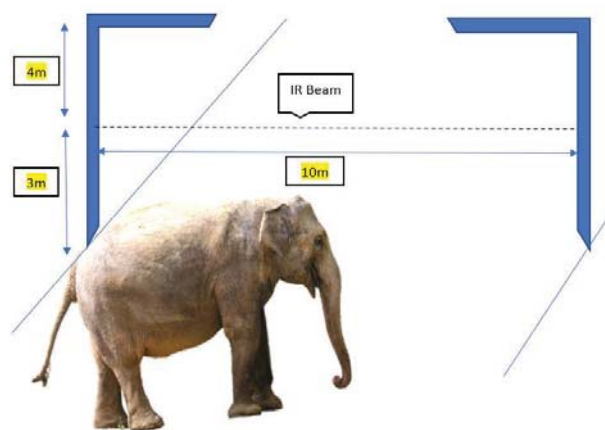
Fig. 4. Integrated Long Range IR Beam Detection

2) Microwave radar sensor detection

Second approach of the detection procedure. These Microwave radar sensors are used to detect the elephant motion. These sensors are supposed to set up at 7m above from the ground. The reason to set up at 7m is to avoid any harm to the sensors by the elephants.

Here researchers used four Microwave radar sensors to identify the elephant motion apart from any other animal or human. Two Microwave sensors are setup in straight light and all four Microwave sensors are supposed to set up as figure 5.
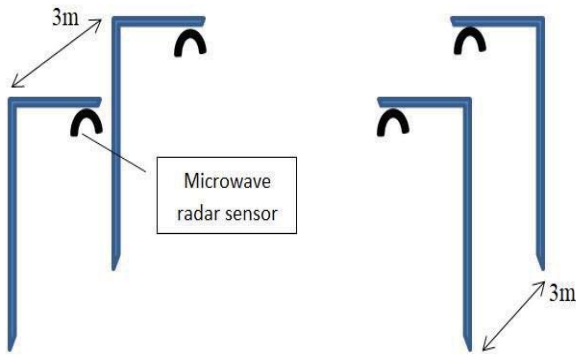
Fig. 5. Microwave Rader Sensor System

3) Geophone seismic sensor detection

Third approach of the detection procedure. Geophone Sm-24 is supposed to use, and analog footfall signals are collected. Geophone generates very low amplitude wave. This low amplitude wave needs to be amplified. Those analog signals are supposed to amplify and convert into digital signals. The converted amplified signals are going to the MATLAB tool for further analyses. Each recording is supposed to record for 45 seconds. Several recordings would be merged to gain better understand about the elephant's footfall pattern. These recordings are supposed to passed through an anti-aliasing filter with an eighth-order low-pass Butterworth filter with a cut-off frequency of 80 Hz because most of animals' footfalls frequencies are below 80 Hz [13]. it was down sampled to a sampling rate of 200 Hz. The amplified signal must be going through Butterworth noise cancellation circuit for filtering process. Then after signal must be converted to digital using another separate circuit. This output signal will direct to an Arduino Uno board. It is supposed to use i2C serial communication protocol to redirect this signal from Arduino to neural network.

The purpose of using geophones to detect elephant was finding any differences of coefficients of correlation between a representative elephant power spectrum and other species recording. However, the variances in correlation coefficients were not sufficient and the inaccuracy was quite high in this strategy Therefore, researchers build neural network. Multi perceptron feed forwarding Artificial Neural Network (ANN) is built to classify data gathered from elephants by other objects/animals.

B. Repelling Elephants

Researchers use improved version of existing electric fence to repel elephants from invading human habitat areas.
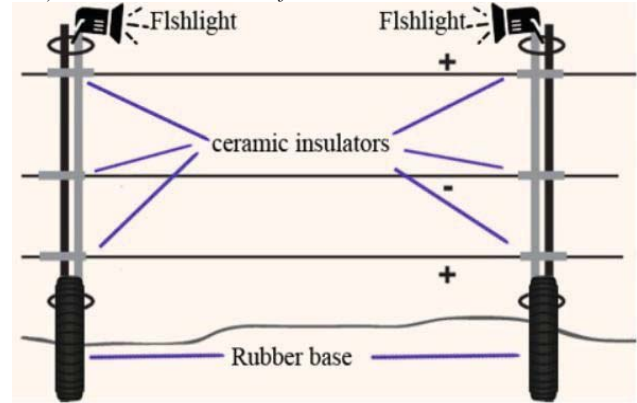
1) A modern electric fence

Fig. 6. Modern Electric Fence

To build this modern elephant fences researchers used 1.5mm diameter aluminum cables that are cable passing 9000 volts of current for 30kms. if the distance is more than 30km it must use much thicker aluminum cables, otherwise the cable resistant will reduce the current below the required 9000 volts [14]. The fence has 3 aluminum cables. upper and bottom cables carry live current and the middle one is the neutral current. cables and fens posts are connected through ceramic insulators, otherwise current can be grounded by the fence posts. the middle wire is grounded in every 10 meters. so that elephant will shock effectively when they touch the fence. the fens posts are made with solid materials like wood, but the base of the posts is flexible rubber. that allows the fence will do not break when an elephant attacks the fence.

A flashing light system embedded to electric fence also used to scare off elephants. From previous research, researchers found that elephants are scared to flashlights [15]. Therefore, researchers used a light emitting diode (LED) flashlight on electric fence which are aimed towards elephants' eyes to repel them.

A solar power is used as main power source of the electric fence but because sunlight is not constant throughout the day researchers cannot completely rely on that. Therefore, had to control the generated power by the solar panel and store the power in power storage. A battery will be used as backup power source of the electric fence system. An electric relay is used to separate the solar power and the battery power while a voltage regulator will be used to keeps the current value in a constant level. The high voltage current is producing using an 'Energizer'. Which do DC to AC current conversion and goes through a ignition coil & MOSFET amplifier to generate required current for electric fence.

Laser Protection system used in the electric fence to detect if an elephant breaks the fence or not. the alarm system received a signal when the fence is broken.

The elephant fence will not operate at every time. it will dynamically turn on when the automatic signal is coming from the elephant detection system by using inter-system communication system to inform that the elephants are heading to the fence or if elephants are trying to break the electric fence which is identified by laser protection system.

Fig. 7. Prototype of Elephant Repelling System

C. Inter-system communication

Inter-system communication system is built using NRF24L01 and LoRa LPWAN technologies.

1) Wireless Sensor Establishment (WSN)

The wireless sensor network system embedded with elephant detection system. If wireless sensor network detects an elephant using one of three parameters proven, IR beam crossing, Microwave Radar sensor detection and Geophone detection. It sends signal to receiver of WSN which connects to LoRa transmitter while it sends a signal to elephant repelling system to activate. This network arranged in a tree topology It was planned to use NRF24L01 wireless adapter to establish this wireless network. One NRF24L01 receiver can listen up to six NRF24L01 transmitter modules at same time.
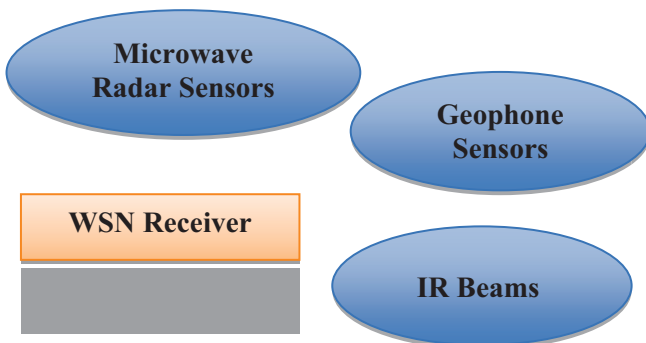

Fig. 8. Overview Architecture of WSN
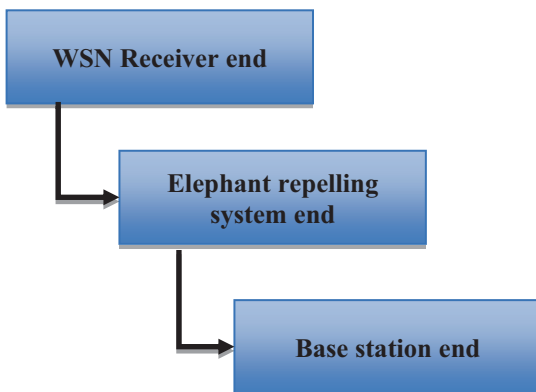
2) LoRa Transmission

Fig. 9. Overview of LoRa Communication

SX1278 model of LoRa is used to build a peer-to-peer communication between WSN receiver end & elephant repelling system and elephant repelling system & base station. Base station resides in the threatened villages and it consists of alarm system to alert people. Those 3 WSN receiver end, elephant repelling system end and Base station end are equipped with LoRa transceiver

D. Alerting humans

In the base station located in the village, it has an embedded alarm system to alert people about threats from elephants. This alarm system activates when elephant detecting system detects and the elephants repelling system activates or when elephants break the fence and invade towards village. Which is identifies through the laser protection system of elephant repelling system. These two conditions have their own alarm tone. So that the villagers will not be confused. As mentioned earlier the communication procedure for the alarm system is done by LoRa SX1278 modules. When LoRa module passes the signal that came to the Arduino Nano module in the base station system. Then the Arduino Nano module processes the signal and identifies who is the sender. is it the fence or the elephant detection system. Based on that Arduino board will send the signal to the specific pin on the sound driver. Then the Siren is turned on with that specific tone. The power mechanism of the base station system is same as the electric fence power mechanism which uses both solar panels and battery pack as alternative power source

IV. CONCLUSION AND FUTURE RESEARCH DIRECTIONS

Among 13 Asian countries where natural habitat for elephants, Sri Lanka is habitat for around 3000-4000 elephants which is 10% of Asian elephants km^2 in an area of 65,610 km^2. Human elephant conflict in Sri Lanka costs lives of 150 elephants and 50 - 70 people every year. The existing solution is electric fence only capable of mitigating human elephant conflict up to some extent due to its own limitations like neediness and the cost for regular maintenance. Therefore, more practically and cost-effective solution is needed. This research paper reports the findings of the initial stages of an ongoing research project titled "Modern Solution for Human Elephant conflict" which will overcome the limitations of current system.

This is a wireless sensor-based network which primarily uses geophones, Microwave Rader sensors and IR beams to detect elephants and integrate with alerting and elephant repelling system. In the first stage of research, researchers discover a method to detect elephants using the vibration of elephant footfalls gathered from geophones, readings from Microwave Rader system and readings from IR beam system developed by the researchers. The second phase conducted to process data gathered from geophones and build a reliable communication method using LoRa and NRF24l01 units. Third stage leads result of previous stages to develop the method to scare away elephants using sudden flashlights, smart electric fence and alerting people using siren system.

At present IR beam-based and geophone-based elephant detection methods and intersystem communication systems are developed and checked with real world scenarios. And prototype of elephant scares away system created. Researchers faced a problem to clearly identify elephants from geophone gathered data therefore neural network used to separate correlation coeffects of elephants' footfall

vibrations from other noises. The project continues and future work involves the creation of the pilot program and its actual implementation on site. In this 12-month geophone deployment, IR beam detection and wireless sensor-based solutions, researchers believe that the experience gained, and lessons learned is applicable in alleviating human elephant conflict and will be valuable for advancement of other solutions to mitigate human elephant conflict.

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