# WEB-MOBILE BASED APPLICATION TO DETECT THE ELEPHANTS' INTRUSION IN SRI LANKA: A GEOFENCING BASED APPROACH

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**Abstract**

Protecting the endangered Sri Lankan elephants and mitigating the Human-Elephant Conflict (HEC) require proper understanding of the subject. Yet, so far, the available information is fragmented or not easily accessible and often it is outdated or erroneous. While efforts are ongoing to rectify this, it is imperative that, in order to make the most effective use of information, there should be a state-of-the-art system to centralize available information, make it easily accessible and easily updated via various methods. This study attempted to evaluate the potential for using web-mobile applications and geofencing technique to detect the elephants' intrusion in Udawalawe National Park in Sri Lanka. To fulfill the aforesaid requirement, as an innovative idea, a sophisticated tracking system which comprises a web-mobile based application server and a mobile application leveraging embedded GPS data in images is developed as a prototype and tested in Udawalawe National Park having selected an elephant to fix the GPS collar. The mobile application helps to obtain the relevant elephant data by accessing the geospatial database which would be implemented in the cloud-based environment in a geofence. This system thus addresses the main problems of identification, tracking and database maintenance of identification and tracking elephants and maintains the record of them. Further, this will address the monitoring and implementation of a geospatial database of elephants. Using these feasibility study results, an infrared (IR) camera and face recognition system developed to absorb the data and present the results of the individual elephant for free access in a website to be developed. This information could be used to mitigate the human elephant conflict in Sri Lanka, and help monitor elephant behavior to greatly benefit the relevant parties like farmers and wildlife conservationists.

***Keywords:*** *Geofencing, Human Elephant Conflict, Tracking, Web and Mobile application*

**I. Introduction**

Asian elephants (*Elephas maximus*) have been included in the Red List of the International Union for Conservation of Nature (IUCN) (Rathnayake et al, 2011; Nakandala et al., 2014) and are listed under Endangered (EN) category. They are considered as the highly threatened species due to the fragmentation of habitats, HEC and loss of shelters (Sugumar & Jayaparvathy, 2014). Around 10% of the Asian elephants' population is in Sri Lanka with highest genetic diversity (Nakandala et al. 2014; Fernando et al, 2011) yet, the HEC cases are on the rise due to the high density of the elephant's population (Prakash et al, 2020) particularly, in Sri Lanka 16 districts experience the HEC incidents (Rathnayake et al, 2022) which are a major challenge for socio-economic development, particularly in rural areas. Asian elephants range for a long distance and occupy poor visible areas and they are the mammalian native to the country and have particular reverence as a domesticated elephant and cultural prominence. As the conflict increases between humans and elephants, the concern for elephants to protect is on the rise because of the statistical proof of the loss of the elephants and the incidents of the HEC and its consequences. Declining forest and increasing population growth-led settlements resulting in HEC which highly pose threats to the Asian elephants (Sugumar & Jayaparvathy, 2014; Premarathna et al, 2020). However, both domesticated and wild elephant's population have steadily declined due to loss of habitat, deforestation, and deaths due to the HEC (Santiapillai, 1994). More than 70% of elephants' ranging areas are outside of the protected areas in Sri Lanka (Fernando et al, 2020; Kopke, et al, 2021) which is also one of the major factors influencing HEC. Elephant attacks have increased in recent decades in Sri Lanka, which cause deaths and severe injuries for local communities and wildlife officers (Prakash et al., 2020; Prakash et al., 2021). The elephants' death occurrences are recorded as a retaliatory move of the people to attack the elephants, vehicle collision and significantly during the crop raiding in the agricultural lands (LaDue et al, 2021).

Elephants in Sri Lanka are mainly found in the dry zone of Sri Lanka, which covers approximately 60% of the island. Figure 1 shows the locations of elephants within the protected areas and outside of the protected areas in Sri Lanka. The abundance of elephants in the dry zone is due to the availability of water resources like tank cascades and abundant water bodies. Department of Wildlife reserves providing food and habitats, and agricultural lands. The main hotspots for the elephants are located at Udawalawe National Park (NP), Yala NP, Wasgamuwa NP, Maduru Oya NP, and Wilpattu NP. The Sri Lankan elephant can live up to 70 years in the wild, preferring areas with a mix of grasses, low woody plants, and trees, primarily inhabiting dry thorn-scrub forests. Elephants are herbivorous and eat leaves, twigs, fruit, bark, grass and roots. They also tend to stay near water sources. Major feeding bouts take place in the morning, afternoon and night. At midday, elephants rest under trees and may doze off while standing. Elephant intelligence has been compared with that of primates and cetaceans. They appear to have self-awareness and show empathy for dying or dead individuals of their kind.

Protecting wild elephants is a growing matter of concern amid the expanding agricultural activities and the increasing settlements in Sri Lanka. Numerous methods have so far been implemented to manage the HEC with the view to protect elephants and people. Yet, the HEC cases are rising in the locations where the


*ISBN: 978-624-5736-37-9* *15th December 2022, Faculty of Arts &*

elephant's intrusion prevails. Also, the electric fences are a widely applicable method to control the elephant's intrusion, however, over the last couple of years, the efficiency of the electric fences are seemingly inefficient (Gunaratne & Premarathne, 2006) where the wild elephants easily cross the specified boundaries. Since the elephants are smart and powerful in nature, controlling them within physically constructed boundaries is challenging yet, there is a need for an alternative mechanism in which the geofencing is getting significant in the present global context. Geofencing is considered as a novel technique which is commonly used in farm management for grazing animals. For elephant intrusion detection the same method as a virtual fencing can be applicable with the field verification (National Institute of Fundamental Studies, Sri Lanka, 2020).

GPS technology is a widely used tool to track the movement of wild animals. Since they are available in handy size, they can be mounted with the animals to trace their movement. It can be used to track the movement of elephants using GPS-fixed collars to detect their home ranges. The geofencing is a virtual boundary delineated around an area of interest monitoring wild animal movement that features on the collars alerts when animals are close to specific locations such as human settlements, villages, or cultivated land. Geofences is an effective platform to solve HEC reducing cost for creating physical barriers such as traditional fences. Furthermore, geofencing can easily be spatially and temporally altered, and allow movement of non-target species (Jachowski et al., 2014; Sheppard et al., 2015).

Several studies have so far been done to detect the elephant intrusion and early warning system to alert the people to lessen the HEC impacts. Mary and Karthikeyan (2016) have developed an efficient early warning system for HEC. They have designed a wireless sensor network-based system for their study through which it was used to protect villages from elephants' attack. They have used wireless sensors to detect the elephant's movement however, this study has suggested the elephant's collars to track the movement and the application of IR cameras to detect the elephants with their ears within a virtual boundary or geofence. Further, Pastorini et al. (2015) has studied the elephant's movement with the GPS fixed collar which can transmit data in a scheduled time. Each collar was designed with the GPS, Very high frequency (VHF) transmitter, batteries, and GSM transmitter. The present study assesses the potential for using geo fencing to detect elephant intrusion and pre-testing for finding out the feasibility of the prototype.

The collected data concerning the elephants can thus, be readily viewed from any location, and stored securely. This study surveyed the elephants' movement patterns using the GPS fixed collars in Udawalawe National Park. Furthermore, we tested a web-mobile based application and unique server to collect the elephant's data with the GPS and IR cameras with the view to curb the HEC cases.

Modern technology has paved the way for easy access to detect the elephants or to upload the image captured by a smartphone. Then, the embedded geotagged data can be extracted automatically from a centralized server. The data can readily be viewed from any location and stored in a server.

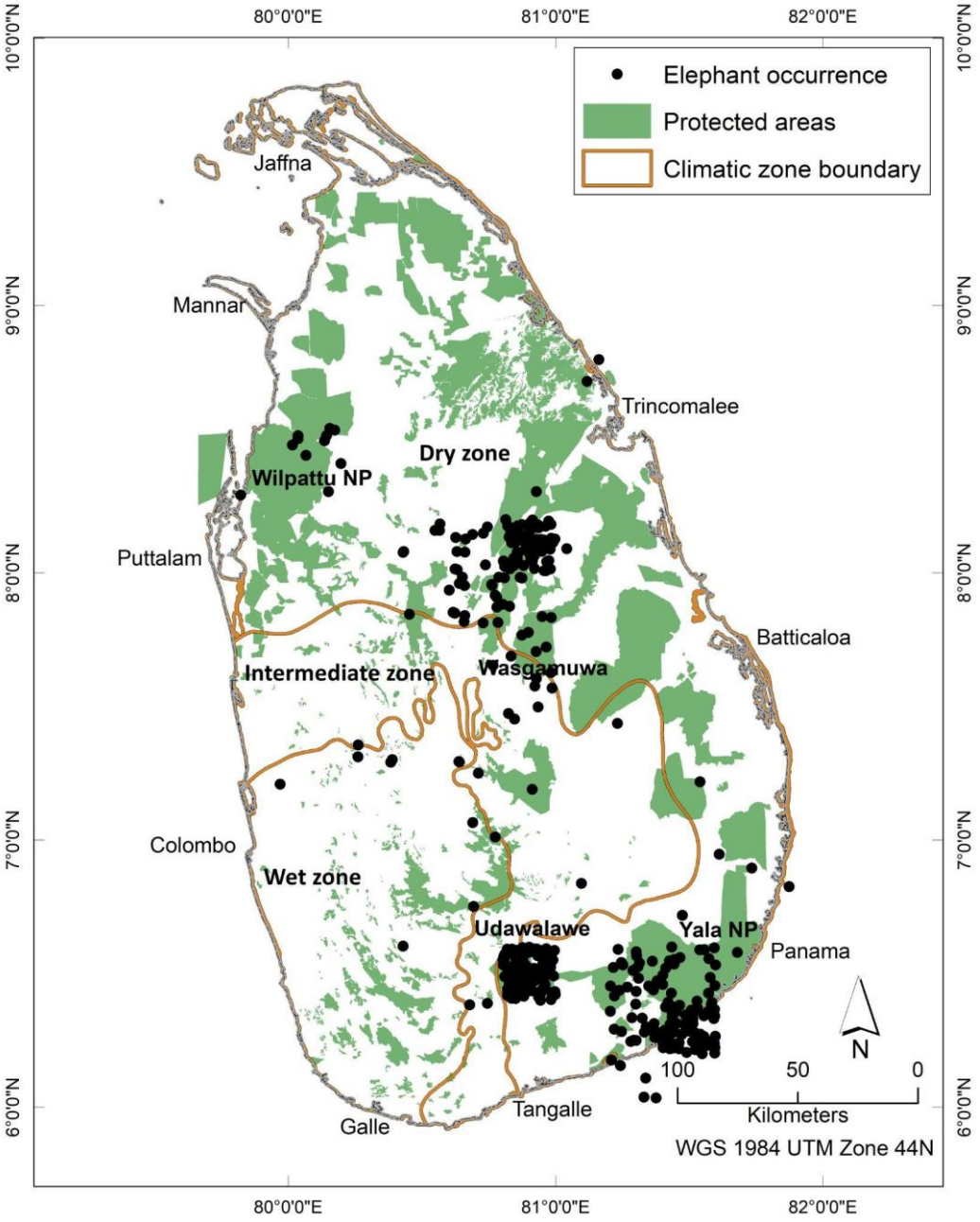



**Figure 1.** Elephant distribution within the protected area (i.e. Udawalawe NP, Yala NP, Wasgamuwa NP, and Wilpattu NP) and outside the protected area in Sri Lanka. The occurrence data were obtained from Global Biodiversity Information Facility (https://www.gbif.org).

## 2. Materials and Method

The main steps for detecting elephant intrusion and web-based mapping are as follows.

1) *What are the data types required:* It is imperative towards effective analysis that the proper data fields be determined to be represented. This may vary from location, herd size, date and time, characteristic and threat level.

2) *How to report an elephant or herd of elephants:* Elephant sightings or incidents have to be reported and entered in order to analyze movement patterns. As such, it will be necessary to determine a mechanism that is practical, accessible, quick and responsive.

3) *How to manage data:* In order to make the most of the gathered data, it is necessary to ensure that the data is properly formatted and represented in the proper manner, be it statistical, individual, geo-tagged location data, and metadata etc.

4) *Whom should be given access for reporting, analysis and decision making:* The system should be designed such that it receives up-to-date information of occurrences and sightings. However, it is also necessary to determine the primary stakeholders to facilitate effective analysis and decision making. Such authorities or entities should be consulted and coordinated within determining the incident response, geo-fence area, or identification of individual elephants or herds. Responsible authorities will have to undertake the tracking and analysis of patterns in the system to predict and determine whether a particular movement will be harmful or whether it warrants a response. The degree of automation in this regard where the system generates an automated alert should certain parameters be triggered should also be determined. These could range from an elephant sighting report in a specific geofence area, a particularly aggressive elephant being identified etc.

5) *How to alert the relevant entities, individuals and the responsible authorities in the event of a threat:* If there is a determination to be a threat from an elephant or herd of elephants, the system should be equipped to deliver alerts to the right people to respond to such alerts, using technologies to suit the urgency of the alert. These could be via email, SMS, social media, instant messaging apps or other means.

A. *Hierarchy of HEC mitigation measures*

The accepted hierarchy in addressing any conflict is to 1. Avoid, 2. Minimize, and 3. Restore.

However, in considering HEC mitigation, the more appropriate methodology hierarchy is: 1. Deterrent measures, 2. Early warning systems, 3. Repellent measures, and 4. Compensation.

The main priority should then be to prevent elephants from entering human settlements. To achieve this, deterrent measures should be adopted. Such deterrent measures, however, are dependent on the nature of the threat. As such, information is key to provide warning systems which will give sufficient forewarning

indicating elephant presence & enable the communities in taking appropriate action. The system intends to act on this factor of early warning to better avoid contact with wild elephants.

B. *Identification of elephants*

The main problem exists is that there is no proper identification and mechanism of recording the details of the elephants in Sri Lanka. Because the identification technique of the wild elephant was a burdensome experience in the past. But with modern technology, the vein patterns of the ears of elephants can be identified as a unique identification method.

C. *Keeping records*

The currently available data is fragmented and scattered between departments and often there is poor coordination /cooperation between them. The system therefore would centralize records for future use, while also preserving data better than physical files. These data must include area, section, age, and herds etc. It will thus fulfill a longstanding requirement of a centralized server of elephants in Sri Lanka for the future references.

D. *Geofencing*

Geofencing is defined as detecting wild elephants that cross a virtual fence boundary. When any wild elephant crosses the geofence boundary, a pre-planned SMS alert with GPS coordinates of the elephants' location, can be sent to the people or wildlife management center in the area in which the rangers, in a vehicle are able to intercept the wild elephant & chase them off considering the vulnerability and the value of a location (Figures 2, and 3). This technique has been successfully utilized in "East Africa" where the wild elephants soon learned that the invisible lines which make them signal not to cross.

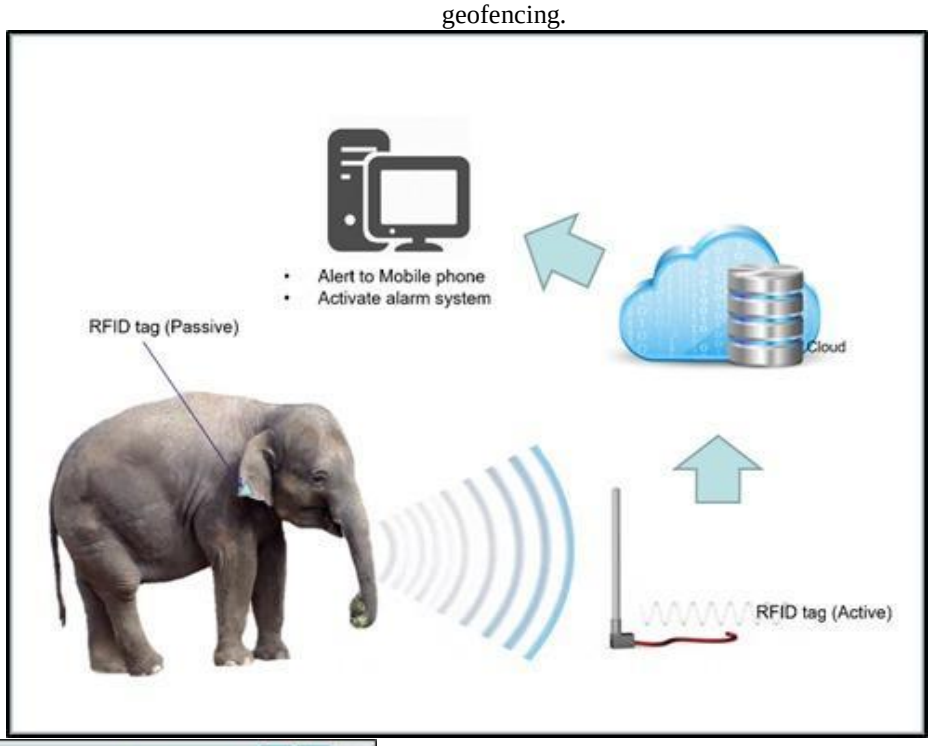
E. *Training and conditioning*

Usually, elephants are smart, and it appears that the crop raiding behavior is learned and is passed down via generations, often by older males to more younger ones. However, the reverse may also occur. Should a stimulus become a cause of discomfort, it would avoid the stimulus and eventually pass on such stimulus.

This research thus has two main focal points. Firstly, to fulfill a longstanding need for a centralized server to gather, analyse and disseminate data on elephant populations, habitats, corridors, incidents of HEC or the like easily to a wide audience. The server, in conjunction with ArcGIS, serves to provide a cartographical representation of the data received.

Furthermore, using the Infrared (IR) camera, the unique earring patterns of the ears of wild elephants can be identified. Image processing technology has been immensely used for this purpose. Thereafter, a cloud-based database has been used to store the unique details of the wild elephant.

**Figure 2.** System components of web mobile application for detecting elephant passing through geofencing.



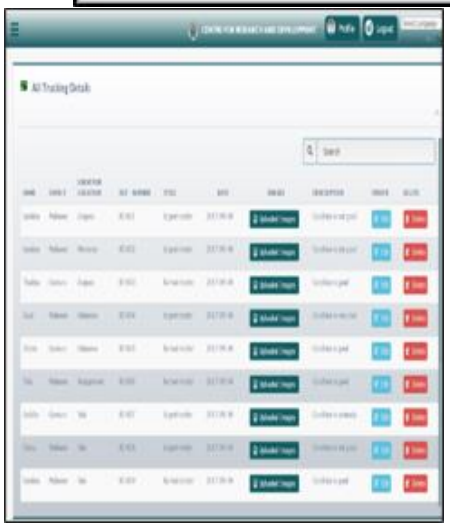




**Figure 3.** Deployment of Mobile Device and Web Application to track wild elephants

**Tools and software used for the prototype**

We used a charge-coupled device (CCD) camera, Raspberry passive infrared (PI) board, USB adapter cable, Micro SD 16 GB Memory card, Power Bank 10000 mAh, Android Mobile application, Google Application Programming Interface (API), Personal Home Page (PHP) language and MySQL database as tools and software for developing the prototype.

The prototype model was tested in Udawalawe NP based on which the concept is proposed to the national level elephant detection process with the view to efficiently manage the HEC. Elephants can be counted based on the ear patterns and the movement can also be found with the aid of GPS which would be mounted with collars. Whenever any elephant with RFID tag (passive) intrudes, RFID tag (active) would detect the elephants and send the alert to the mobile phone. Consequently, the particular elephant can be detected and identified via the mobile application so that the villagers or rangers can be alert or understand the elephant and its location. Also, the cameras would detect the elephants based on the ear pattern and send the details of the elephants to the centralized server in which the features would be detected. If the features are matched with the centralized server, the particular elephant can be identified and tracked easily. Here, the system helps to detect the elephant's intrusion and to detect the particular elephant as well as to store the data in a centralized server. The prototype reflected success in Udawalawe NP and it can be suggested to implement in a wide range where the elephant intrusion and the HEC cases are rife.

**3. Results and Discussion**

HEC is a serious wildlife management issue in the dry zone of Sri Lanka. For example, Prakash et al. (2021) reported 20 deaths (24.7 percent of fatalities) of wildlife officers by elephant attacks. Most casualties from elephants occurred outside the protected areas than within the protected areas. The livelihood of rural communities in the dry zone are depending on shifting cultivation and human lives are in risk due to elephant raids at the cultivated lands.

Geofence biotelemetry system is a cutting-edge and novel technique to solve HEC. We tested this prototype method in Udawalawe NP, it can be applicable to control the HEC and to protect the elephants (Figure 4). Elephant movement and their home range can be detected using the biotelemetry system and unmanned aerial vehicle survey, which is useful to delineate virtual boundaries in vulnerable areas.

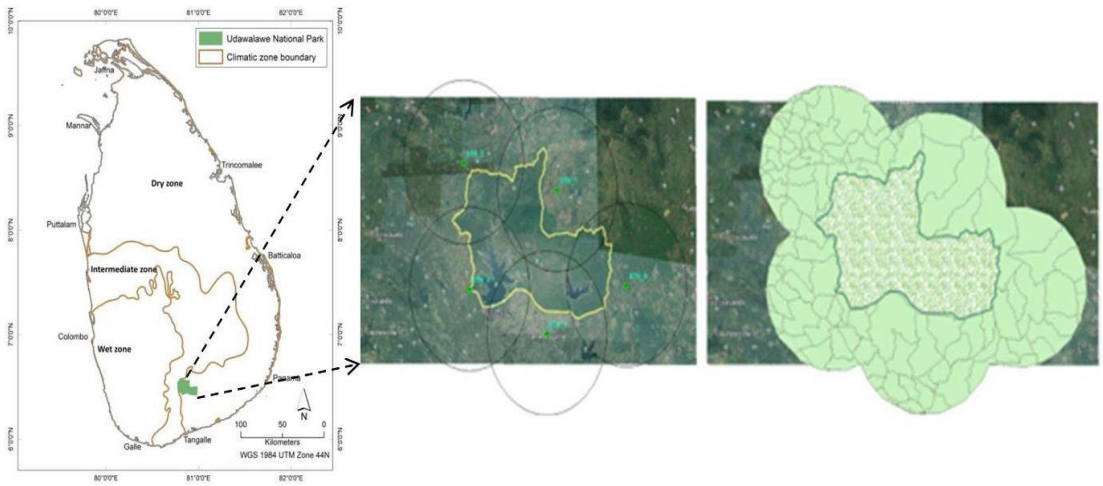



**Figure 4.** A geofence area in Udawalawe National Park in Sri Lanka. Udawalawe NP boundary and geofencing boundary are shown in the middle and the rightmost side image respectively.

Many HEC cases have so far been recorded without any warning or alert to the locals regarding the elephant intrusion. Particularly, in herd to reach areas, the elephant intrusion detection is vital since the smart phones are commonly accessible in every corner of the island. The positive results were apparent upon implementation amongst the rural community. Even with the mobile application, locals could avoid the wild elephants' corridors, or the intruded locations and it would help to decrease the chances for the HEC cases and resultant loss of the people or the elephants. The system was used over several months in Udwalawe NP and was found to be highly effective for the speedy detection of elephant intrusion.

It was highly successful in determining approach vectors and points of wild elephants entering and was instrumental in the effectiveness of deterrence measures deployed afterwards. Geofence areas were used to great success in this instance as well to monitor incidents and sightings to determine the appropriate response. Unmanned aerial vehicle technology with the aid of infrasound can be used to chase elephants away from the virtual boundary. Identification of elephant migration routes within the virtual boundary in Udawalawe NP is important to create corridors with tree bridges to link with the existing protected reserves.

Consequently, the elephant loving community can access the details through a web site which would be accessed easily, and they can arrange the supportive functions to protect and secure the future of the elephants in Sri Lanka. This also may help to protect the wild elephants from train accidents and other sort of fatalities with the mobile and web application where the relevant details could be obtained via a map for their further action, either by a central control center or by individual locomotive drivers.

**4. Conclusion**

Currently, the process of obtaining the elephant identification is in progress to update the cloud-based database. Further, after the completion, this may provide the opportunity to track the movements of wild elephants, data repository of elephants, possible to perform various queries such as find the particular elephant, possible to predict the movement patterns of wild elephants.

Moreover, after the completion, this may provide the ability to track the movements of wild elephants, maintain a data repository of elephants to perform various queries such as find the particular elephant, possible to predict the movement patterns of wild elephants and ultimately it will help to reduce the HEC. In future iterations, it is envisioned to incorporate RFID tracking elements with the monitoring system either via mobile stations or fixed emplacements to feed into the centralized server.

Since the application of electric fences and the other methods to curb the elephants', intrusion require higher cost and result in inefficient outcome, the geo fencing as a virtual method is a timely needed system which can be applicable island wide. Limiting the elephants within physical boundaries has proved to be a challenging task and it is evident that most of the elephants in Sri Lanka are outside of the protected areas. Therefore, it is needed for heading towards an alternative method which should compromise the existing challenges.

To conclude, a positive outcome can be achieved in deploying this system, the interactive nature and scope of using mobile phones and the internet can increase our awareness and understanding of wild elephants in Sri Lanka and directly speak to the people and change their attitudes and motivations towards their conservation.

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