Supporting Elephant Conservation in Sri Lanka through MODIS imagery

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Abstract: The latest government sponsored national elephant survey was conducted in Sri Lanka in 2011, revealing the number as 5,879. This is about 10% of the total elephant population of the sub-continent. The forest cover, the living environment of these elephants in Sri Lanka is about 19,500 sq km (2012 estimation). With a very high human population density of the island (332 people per sq km, 2010), the pressure for land to feed people and elephants is becoming critical, putting the lives of both sides at risk in rural areas. Resent reports indicated about 250 elephants are killed annually by farmers in man-elephant conflicts. Apart from various local level remedies for this issue, this study suggests the conservation of elephant population can be supported by remote sensing imagery based studies. Freely available MODIS sensor imagery can be considered as a successful candidate for the purpose. The advantage of spatial resolution of MODIS image (250m x 250m) to automatically filter out very small forest patches in the mapping process. Also, the daily receiving of imagery helps to monitor micro-level temporal green area changes, which helps to understand possible local level movements of elephants. However, the coarse image resolution is not capable to delineate finer boundaries between forest and settlements and farmlands. This study used MODIS 250m imagery to map Sri Lanka's forest cover (2012) and examined the possibility to identify sizeable forest patches that elephants can roam. Finer resolution images available in Google Earth were used to examine the accuracy and structure of forest- rural village-farm environment. In future study steps, actual elephant movement information will be gathered from local authorities and existing and potential bio-corridors will be tried to identify. Furthermore, monthly green area change maps and field investigations can be produced to gain a better understanding of elephant movements. Such information will provide a very influential source of data for wild elephant conservation of Sri Lanka.

Keywords: MODIS, Human-Elephant conflict, Sri Lanka, Conservation

1. Introduction

Sri Lanka, an island with 65,610 sq km land area has a rich biodiversity with a wide array of flora and fauna (27% of Sri Lanka's plants are endemic) (Mongabay.com, 2006). The central hills of the island are the source for over 100 rivers flowing to all directions in radial shape. The population of the country has dramatically increased from early last century recently passed 20 million. When the British Empire took the control of Sri Lanka in 1843, about 90% of the Island was covered by forest (Alagan, 2009).

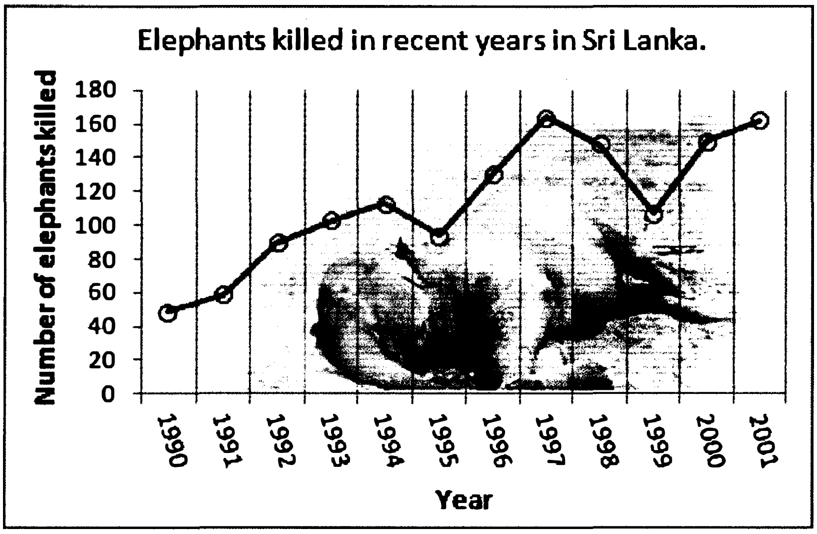

Figure 1. Elephant deaths have recorded a sharp increase in recent years. A bulk of the deaths is a result of HEC (source, IRI Technical Report 10-02, 2005).

This rich forest cover of the country was the breeding ground for Asian Elephants (*Elephas maximus*), that suffered by a rapid decrease in last 100 years. At the early stage, forest has been lost due to the spread of plantation agriculture introduced by the British administration. In the twentieth century deforestation was caused by expansion of informal settlements due to population increase, national development projects, government planned settlement programs, and land encroachments (Rathnayake et. al, 2002; Alagan, 2009; FRA, 2001). The rural area population has also increased sharply parallel to urban population, due to the natural increase and improvements in free healthcare system of the country (Dept of Statistics, Sri Lanka, 2001). This population pressure and rapid changes in land cover caused a massive pressure for space, igniting human-elephant conflicts and rapid increase of elephant deaths (Figure 1). Figure 2 shows the population increase with regard to selected rural districts where the bulk of forest cover is available. The increase of population has caused a tremendous pressure on land use rendering an adverse impact on wildlife.

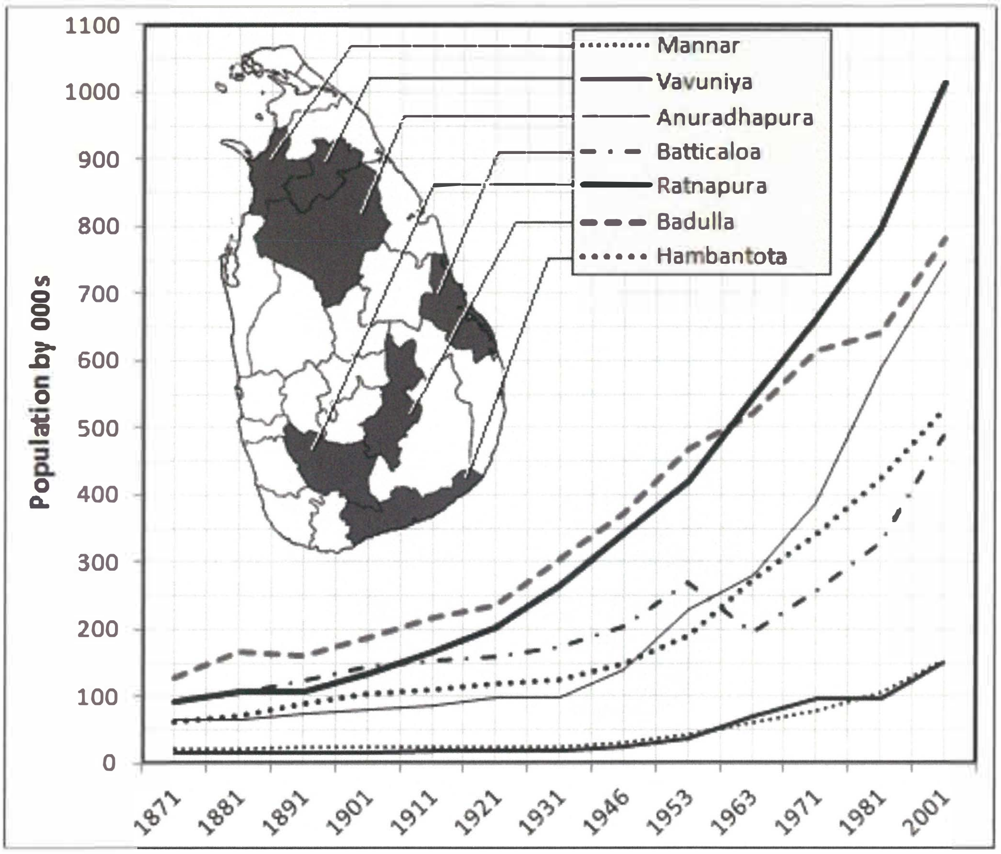

Figure 2. Increase of population in selected rural districts where a bigger potion of forest cover is available.

2. Forest Cover of Sri Lanka

Sri Lanka is characterized with a considerable topographic diversity from high mountain peaks to flat low lands (FRA, 2001). The central region of Sri Lanka rises over 2,500m (Mt Pidurutalagala 2,524 m) and a sizable area in the country exceeds 1500m above sea level, where a thick forest cover was available before large scale plantations begun in 18th century. A vast flatland along the coastal belt lies below 500 m from sea level, where most of the present day forests are located. River network flow in a radial pattern from central hills of Sri Lanka divides the island into 103 river basins (Wijesuriya 1989; Perera & Tateishi, 1991) (figure 3). Climatology of Sri Lanka behaves favorably to support the forest cover throughout the island. Sri Lanka receives rainfall from two major monsoons (south-west and north-east) and from inter-monsoon rains. The south-west monsoon (May to September) poured over 55% of the annual rainfall (GFDRR, 2011). However the present day forest cover is mainly located in low rainfall receiving flat lands of the country (figure 3) where mean annual rainfall is less than 2500mm. The pattern of river network, mean annual rainfall, elevation, and the remaining forest in relatively dry regions of the country (figure 3) indicate clear evidences of historical flush greenery in all regions. Through the population increase and economic activities, forest cover reduced and restricted to three key regions of the country, i.e., Mahaweli River basin and northern plains, Central Hills, and Yala sanctuary in southeast. The elephant population of the country is also confined into these forest areas where boundaries are located just next to busy agricultural areas and villages.

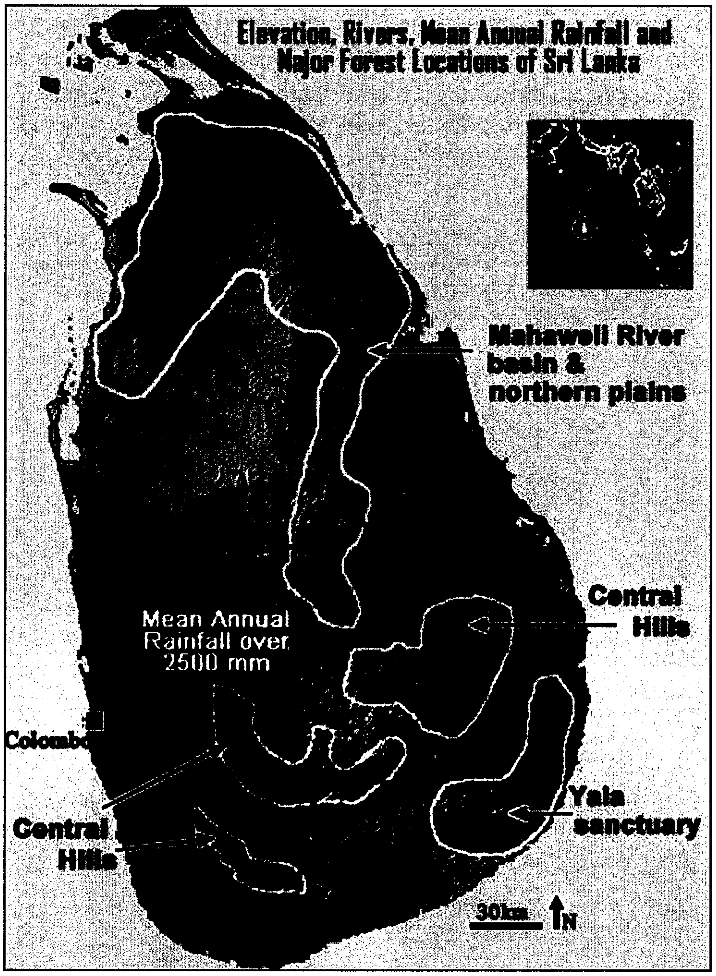

Figure 3. The central highlands, river network, mean annual rainfall and major forest locations (Mahaweli Basin, Central Hills, and Yala Sanctuary) of the island. Darker areas are high in rainfall.

The area under forest cover in recent years has given with different percentage values in different studies depending on the data source of the map, definition of the forest, and mapping methodology (Alagan, 2009; Perera & Tateishi, 1996; Rathnayake et al, 2002; Suzuki, 2007). Nearly all estimations have placed the percentage of forest cover of Sri Lanka as 25% - 30% of the total land area. However, according to the government estimations, forest cover within National parks and forest sanctuaries are gradually decreasing. Data shows this reduction from 2001 to 2009 as about 12,000 hectares (table 1). All natural and man-made changes in and around forest areas have a direct impact on elephant habitat. Therefore, assessing the limited forest cover is important for management of forests as well as to mitigate the risk of man-elephant conflict. This study investigated the applicability of MODIS 250m satellite images to establish some semi-real time information source to understand potential movements of elephants.

Table 1. Recent changes of National parks and Sanctuaries (000 of Hectares) (Source - Department of Wild Life Conservation).

Type	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2009-2001*
National Parks	497	506	510	506	506	513	513	522	522	+ **23**

Sanctuaries	306	308	312	307	307	313	314	314	271	**- 35**

3. The Human-Elephant Conflict (HEC)

Compare to all Asian countries, Asian Elephant *(Elephas maximus)* has a very significant presence in Sri Lanka. In early 19th century, about half of Sri Lanka's estimated 12,000 elephants were forcibly eliminated by the British Colonial Government (IRI Technical Report 10-02, 2005). According to the present estimations, Sri Lanka has about 5,787 elephants which are about 10% of the total in Asian region. If the estimated elephant population divided by the land area, elephant density of India is 0.0008 and 0.006 in Thailand, while Sri Lanka's density is 0.088 (elephantcare.org, 2008). When this large number of elephants struggle for feeding grounds and food, especially in dry seasons, human-elephant conflict became a critical issue for villagers as well as elephants (figure 4).

Figure 4. Wild elephants are roaming next to farms and life of rural villagers in south-central Sri Lanka. Here, electric fence is dividing the two fractions of the conflict.

With a sharp increase of wild elephant deaths in recent years (figure 1), conflict has turned into a widely discussed topic in Sri Lanka. Various studies have investigated the conflict including elephant population and climatic and other socio-environmental aspects (IRI Technical Report 10-02, 2005; Perera, 2009; Fernando, et.al 2011; Fernando, 2001; Tilakaratne, & Santiapillai, 2002). According to these studies, number of reasons can be identified as causes to ignite of HEC.

- **Proximity of village-forest-elephant habitat**
- **Changes in long-term rainfall pattern**
- **Dryness in regions of elephant habitat**
- Increased human and other development activities closer to forests
- Behavioral changes of wild elephants

In this study, we have focused on first three facts due to the main objective of the study, "the application of satellite images".

3.1 The Closer proximity of village-forest-elephant habitat

The Close proximity of village-forest-elephant habitat can be counted as one of the prime reasons for the human-elephant conflict. Figure 5 presents a typical environment from south-central Sri Lanka to explain the close-proximity factor. The satellite image of Udawalawa, a notorious region of human-elephant conflicts shows, village, permanent, and semi-permanent farmlands are located next to secondary forest and also within 1.5km from the thick forest. Udawalawa is belongs to Southern region of elephant habitat, which has about 25% of the total elephant population (IRI Technical Report 10-02, 2005). The green area character of this image is a typical example for most of the forest regions of Sri Lanka, which has the HEC. The proximity of forest-village character has directly affected by the fluctuations in climate conditions. Rainfall plays the direct role and increase of HEC has recorded in dry seasons (IRI Technical Report 10-02, 2005). With contrast to dryness, flood is also causing elephant deaths, especially in the eastern part of the country.

3.2 Changes in long-term rainfall pattern

The negative trend in long-term rainfall changes have discussed by Manawadu in his study, and found moderate to remarkable negative change in long-term rainfall pattern in number of districts in Sri Lanka (Manawadu & Nelun, 2008). Five dry-zone districts have identified under this negative trend, including Anuradhapura and Hambantoda where HEC is serious. This negative trend has identified by Basnayake and others too in their 2003 study on anticipated climatic change of Sri Lanka (Basnayeka at el, 2003).

3.3 Dryness in regions of elephant habitat

The relationship between dry weather and increase of elephant deaths has lengthily discussed in IRI Technical Report, which links dry season as a very important reason for increase of HEC and consequence potential high death rate of elephants. Figure adopted here from the IRI study shows this relationship (figure 6).

Figure 5. The closer proximity of village-forest-elephant habitat (image source: Google Images).

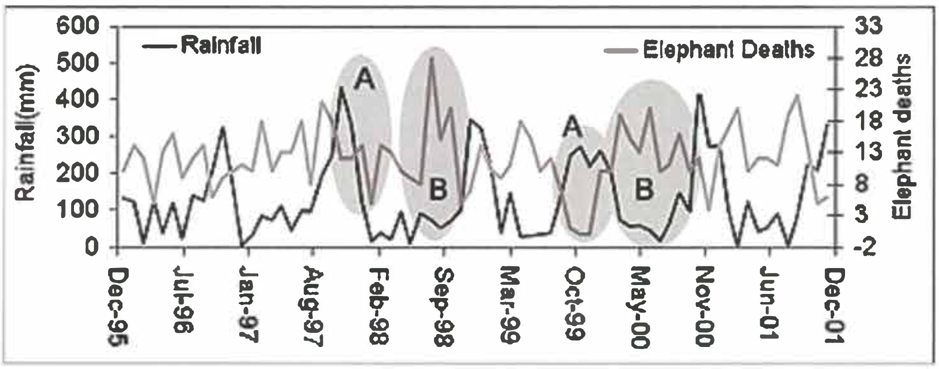

Figure 6. Death recordings of elephants have negative correlation with rainfall fluctuations. Letter A and B show two cases of high rain and low deaths and low rain and high death, respectively. (adopted from IRI Technical Report 10-02, 2005).

The first photo shows officials and villagers are struggling to transport a single-violent elephant from a conflict area to safer forest for the elephant. The second photo is showing a wild elephant is raoming next to the electric fence set by the government authorities to protect villagers and farms. With the pressure for foods in dry season, elephants started to approach villages and for finding crops. Once they used to attack villages for food, the behavior may continue even without much drought due to the attractiveness of the crops (mainly rice, then other upland crops) (Fernando, et.al 2011). Apart from the crops, the farm wells and other water tanks in villages are converting to gathering spots for elephants when drought hits. The first photograph in figure 7 shows four elephants trapped in one of farm well. The other photos shows wildlife officials and villagers are trapping one violent elephant that killed number of villagers to transport to inner jungle.

Figure 7. Dealing with wild elephants; relocating and electric fencing.

4. Applicability of MODIS Satellite Imagery

In order to examine the applicability of satellite data in conservation of elephants, image characteristics of widely available satellite data types were checked. In recent years there are many well developed operational satellite systems are on the market to support decision-making and forest management at global and local scale (Perera et al., 1992; Eurisy report, 2011; Lehmann et al. 2012). Through the advancements of the technology, high resolution imaging sensors have been launched and the data acquired by these satellites are becoming useful for producing detailed land cover maps.

While these advantages are promising, it is extremely difficult to get cloud-free satellite imagery for Sri Lanka due to the near-perennial tropical cloud coverage over the mountains and long recurrent periods of the satellites. The high cost of finer resolution satellite images is another very significant hurdle. With regard to Sri Lanka, the country suffered 30 years long civil war which was just ended in 2009. Under this pretext data acquired by MODIS system can be suggested as a reasonable solution for regular monitoring. Table 2 presents some of the technical information of four major earth observation systems.

Table 2. Comparison of basic components of four prominent earth observation satellites.

Satellite	Recurrent	Swath	Spatial Resolution depending on the band
Landsat TM	16 days	185 km	15 to 60m
SPOT 4-5	2-3 days	60km	2.5 to 20m
ALOS	46 days	35km	2.5m
Terra/Aqua - MODIS	Daily	2330km	250 to 1000m

Source: NASA and SPOT web sites

After MODIS (MODerate- resolution Imaging Spectrometer)(MODIS, About MODIS, 2012) images became available, many scientists have successfully produced land cover maps with MODIS data or combined with other GIS (Geographic Information Sysyems) data to make use the advantages of MODIS system (Friedl et al., 2002; Hall et al., 2002: Price, 2003; Zhan et al., 2002). Geometrically corrected MODIS data products such as MODIS NDVI (MODIS, About MODIS, 2012) and true colour image data (NASA, MODIS Rapid Response Systems, 2011; Gumley et al., 2003) are available through NASA for the global community at no cost. Taking advantage of these pre-processed NASA's MODIS products and its inherited technical advantages (daily recurrent and broader swath), this study used MODIS NDVI products to conduct the forest cover assessment. The present study was partly based on a recent study published by the author on experimenting on application of MODIS and Landsat MSS data to observe land cover changes in a selected sub-region of Sri Lanka (Perera & Tsuchiya, 2009).

5. Vegetation Monitoring and Elephant Conservation

5.1 NDVI analysis

The successful applicability of MODIS NDVI products for forest cover change detection in Sri Lanka was presented in two previous studies by the author (Perera & Tsuchiya, 2009, Perera at el, 2012). Based on those research findings, seasonal NDVI values of a selected location in south Sri Lanka (area including Udawalawe national park) was analyzed as a case study.

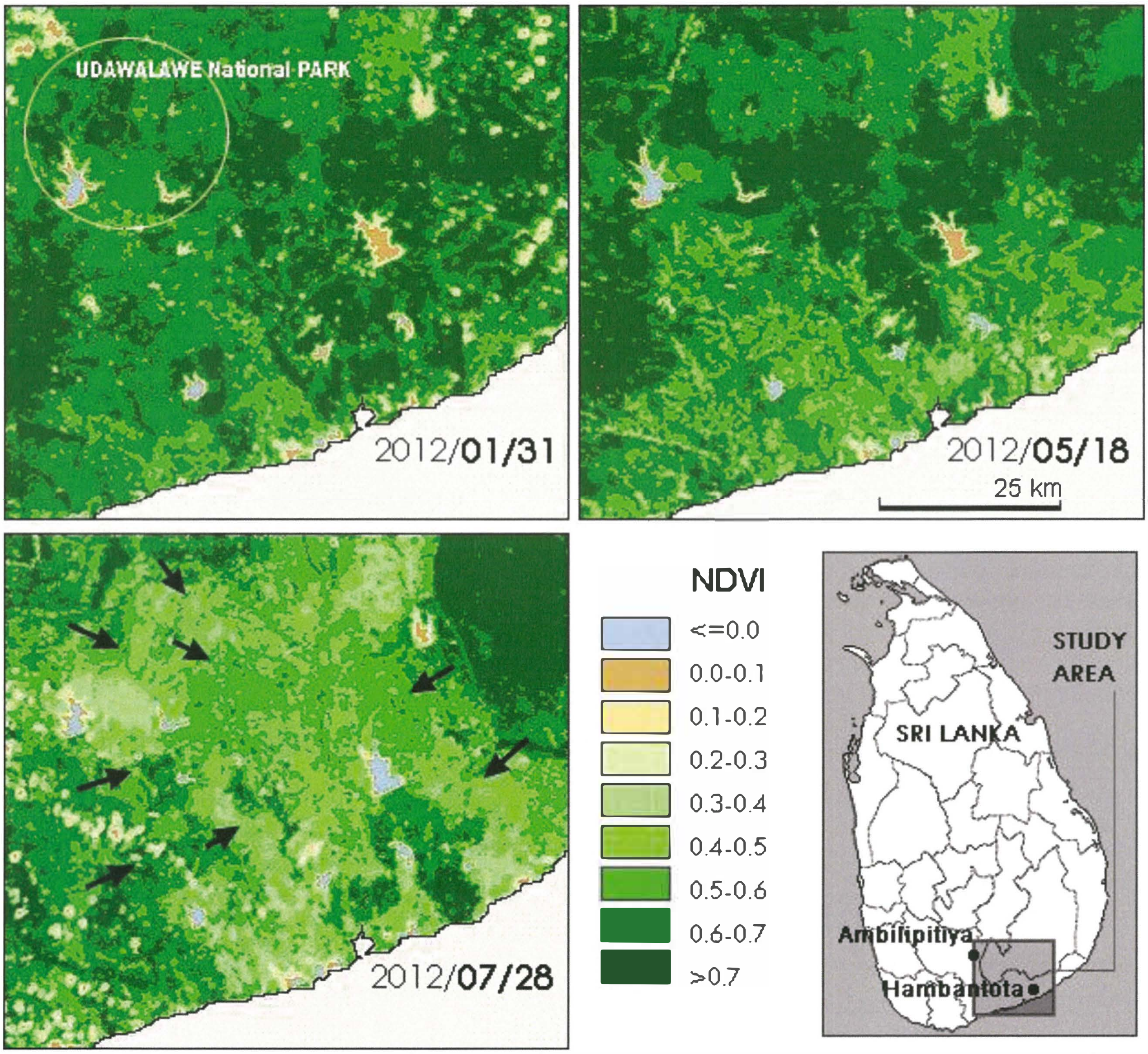

Figure 8. NDVI analysis of a selected area around Udawalawe National Park. Arrows suggest possible aggressive movement direction of elephants in dry season, when vegetation green drops.

The Udawalawa National Park is a popular spot for elephant viewing and located within the study area. Also, HECs are also severe, and only second to north-central Sri Lanka's incidents. NDVI image production process is bypassed in this study to avoid lengthily writing. Three NDVI data sets were produced and values were categorized into 9 classes (figure 8). Areas over 0.4 can be counted as high in green and are dominating in both January 31st and March 28th images. January rainfall seems low in the graph (figure 9), but January is a wet month, due to heavy rainfall of November and December. The July 28th image is falling into dry season and central part of the region has turned into NDVI value less than 0.4. Image dates are also marked on the figure 9 graph which presents mean annual rainfall of 2 spots around the study area. The fluctuation of NDVI parallel to rainfall can be seen with regard to these three images.

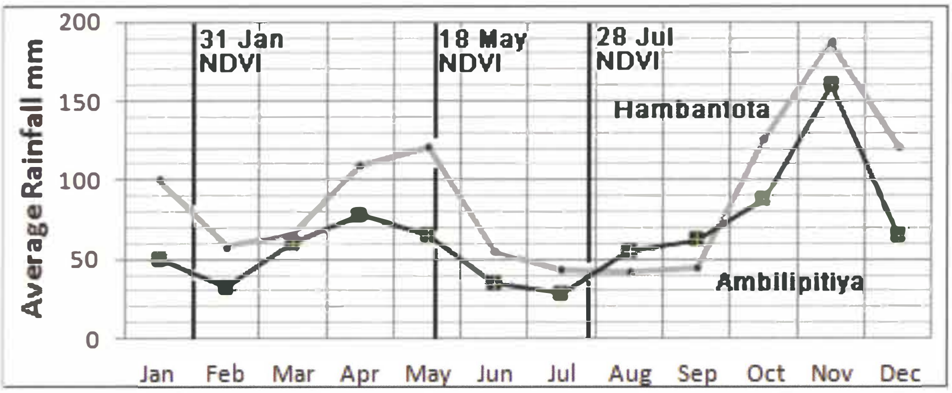

Figure 9. Mean annual rainfall of selected two weather stations (see locations in figure 8). Dates of three NDVI images presented in figure 8 are also displayed here to emphasize the relation between NDVI values and rainfall conditions.

5.2 Linking MODIS image interpretation with elephant conservation efforts

As presents in figure 8, three NDVI images have successfully showed the fluctuations in vegetation green parallel to rainfall amount. The use of NDVI for identifying potential hotspots in HEC has three assumptions;

a) Seasonal changes in greenery in Sri Lankan forests are negligible.
b) The impact of drought is successfully represented by dynamics in NDVI values.
c) Elephant attacks on villages and farmlands are increasing when the drought prolongs.

As mentioned in previous section, lower values of July NDVI image can be linked to less green vegetation in-between thick forest regions of east and west. This may caused elephants to search for alternative fresh leaves or other food, igniting conflicts with villagers. The case study result indicates the possibility of producing country-wide NDVI change detection and combined with GIS data base to establish elephant movement direction when the vegetation green fluctuates. Accordingly, NDVI provides a valuable tool through the utilization of freely available daily MODIS data to form an early warning system based on spatial information for HEC. When above mentioned three assumptions are met, the trends in NDVI values provides a clue to identify the locations of high risk or hotspots of HECs. This approach will help authorities to identify areas to be focused in elephant conservation as well as to protect villages from potential risk of elephant attack. Under future study prospect, the information and initial results found in this study can be used to buildup a logical data processing algorithm using semi-real-time NDVI products from MODIS 250m data to support HEC mitigation and elephant conservation efforts.

6. Conclusions

The applicability of MODIS satellite data to support elephant conservations plans was investigated in this study. Even though the spatial resolution of MODIS is low, its freely accessible daily data availability provided number of advantages in regular earth surface monitoring. This study mainly discussed the background information of forest cover of Sri Lanka, Human Elephant Conflict (HEC), and technical capability of identifying green area changes using MODIS data. Number of reasons for acceleration of HEC was identified and a link was established between those reasons and applicability of MODIS satellite images to extract some valuable information to support elephant conservation plans. MODIS images of a selected area in southern Sri Lanka were analyzed to produce NDVI images. Image processing aspects and justifications of suitability of NDVI for the study were discussed in details in some previous studies by the author and not lengthily repeated in this study. The NDVI images calculated from MODIS data acquired in wet and dry weather conditions showed the clear changes of green area which can be used to identify corridors of elephant movements. This approach will help authorities to identify areas to be focused in elephant conservation plans as well as to protect villages from potential risk of elephant attack. Under future study prospects, island wide NDVI observation under wet, semi-wet and dry conditions and integration with a GIS database to buildup hotspots of HEC and establishment of potential elephant corridors can be listed.

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