Changes in habitat coverage from 2005 to 2019 in the Udawalawe National Park, Sri Lanka


Highlights

- Considerable habitat cover changes were noted in the protected area, over 14 years from to 2005 to 2019.
- Grassland decreased by over 50% of its original extent.
- Scrub habitats increased from approximately 47% to 51%.
- Habitat management is needed for sustaining the conservation value of the Udawalawe National Park.

Conclusion:

- Substantial change in the extent of habitat types have occurred over a relatively short period of time in the Udawalawe National Park.
- Considerable reduction in the extent of grasslands.
- Delinquent consequences on the elephant is envisaged.
- Effective management strategies are needed to address the problem.
Changes in habitat coverage from 2005 to 2019 in the Udawalawe National Park, Sri Lanka

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Abstract: In protected areas (PAs) designated for the conservation of biodiversity, temporal landscape changes do occur, driven by natural and anthropogenic factors. Such changes may impact on the conservation value of the PA. In a wildlife PA, changes in habitat extents could adversely affect some of the faunal species. Our objective was to assess temporal changes in the cover of three major habitat types in the Udawalawe National Park (UWNP) that have occurred over a short term. Based on the outcome, we aimed to determine the potential impacts such changes would have on the wildlife. Considering that UWNP was established primarily for conserving the nationally threatened and flagship species *Elephas maximus*, we carried out field studies and decided on three relevant habitat types - forest, scrub, and grassland. We used multi-temporal satellite images with ground truths for assessing habitat extents in the years 2005, 2010, 2015, and 2019. Habitat cover maps were prepared using supervised classification and changes in the extents of the selected habitats were assessed. Between 2005 and 2019, the areas under forest and scrub had increased. The grassland has considerably decreased, mainly owing to invasion by scrub. Grassland depletion adversely impacts the elephant whose preferred food is grass and the high population of elephants in UWNP aggravates the situation. Depletion of food resources within the park would also lead to an increase in the human-elephant conflicts in border villages. Thus, in this study we highlight the importance of monitoring temporal changes in habitat cover in order to manage the PA and the inhabiting wild elephants.

Keywords: *Elephas maximus*; habitat cover mapping; protected areas; remote sensing.

INTRODUCTION

Habitat heterogeneity, on a landscape scale, is a key determinant of biological diversity (Tews et al., 2004; Fahrig et al., 2010). Changes that occur in the extents and distribution of habitats in the landscape could be expected to lead to alterations in the diversity of its biotic communities. These habitat changes are driven mainly by human-induced disturbance factors such as logging, reforestation, agricultural expansion, establishing human settlements, and urban development. Some natural changes also occur over time as a result of ecological succession. Protected areas (PAs) are primarily set aside for conserving biological diversity (Dudley, 2008). In PAs with a variety of different habitats, proper management would require that the mosaic of habitats is maintained in a manner that will offer the protected species the best chances of survival. In PAs primarily aimed at conserving wildlife, effective management should ensure that the habitats within the PAs would be capable of meeting the food and shelter requirements of the faunal species they sustain (Schindler et al., 2013; Nori et al., 2016). This might prove to be a challenge in landscapes that are exposed to continual change brought about by natural and anthropogenic factors (Briggs et al., 2005).

The Udawalawe National Park (UWNP), a wildlife reserve, is one of an extensive network of protected areas spread across Sri Lanka for conserving the rich biodiversity heritage of the country. The decision to establish UWNP was made in 1972 with the key objective of providing a safe refuge for the herds of elephants whose habitat had been affected by the construction of the Udawalawe reservoir and associated development activities (DWC-Department of Wildlife Conservation, 2008). Importantly, the area covered by UWNP also functions as a corridor for the movement of elephants between the surrounding areas, and hence, the park could be regarded as being a vital link in extending the elephants’ habitat range (DWC, 2008).

UWNP is located in the dry zone of Sri Lanka which covers approximately two-thirds of the country. The typical natural climax vegetation characteristic of the dry zone is described as Dry Mixed Evergreen Forest (Holmes, 1958). Other than clearing of the forest for development activities, such as establishing village settlements, expanding irrigation agriculture, and reforestation mainly with teak, the natural forest had in many areas been cleared for shifting cultivation (chena). In this form of agriculture, practiced as a means of livelihood, the forest is cleared by the local inhabitants, the felled material burnt, and the land used for raising food crops. Hence, wildlife habitats in the dry zone would cover many areas that had been subjected to forest clearing in the past for shifting cultivation.

The Asian elephant (*Elephas maximus*) is a flagship species of the UWNP. The elephants move in and out of the park, and the total population in the park was recorded...
as being between 804 and 1160 individuals (de Silva et al., 2011). This comprises about a fifth of the total population of elephants in Sri Lanka (DWC, 2011). UWNP is one of the most visited protected areas in Sri Lanka - its primary attraction being the presence of large herds of elephants (SLTDA - Sri Lanka Tourism Development Authority, 2016). It was ranked as the second most visited wildlife park in Sri Lanka in 2018 (SLTDA, 2018). Hence, a decline in the elephant population in the park, besides posing a threat to the survival of this species in Sri Lanka, would also reduce the park’s tourism potential. Scientific insights into spatiotemporal changes in the distribution and extents of the different habitat types in UWNP would be useful for identifying actions that need to be taken in order to sustain, and further enhance, the conservation value of the park. The objectives of our study were (i) to assess short term (14 years) temporal changes in the extents of the three major habitats in UWNP and (ii) to propose actions that need to be taken, based on the results and available literature, to sustain the conservation value of the park.

MATERIALS AND METHODS

Study site – Udawalawe National Park (UWNP)

The UWNP, located at 6° 30’ 14.06 N and 80° 54’ 28.12 E (Figure 1) falls within the two administrative districts of Ratnapura and Moneragala. The Park covers an area of 308 km² and encompasses two reservoirs for storing water for irrigation; the Udawalawe reservoir (accounting for 34.05 km² at full capacity) and the much smaller Mau Ara reservoir (Ranaweerage et al., 2015). The dry season extends from June to September. The mean annual rainfall is 1500 mm, with two rainy spells - an inter-monsoonal spell between March and May and the north-east monsoon from October to January. The mean annual temperature is 32 °C and the relative humidity ranges from 61% to 94% in the daytime (DWC, 2008). The area designated as the UWNP which carries a mix of vegetation types that includes (i) dry mixed evergreen forest, (ii) scrub, (iii) grassland, (iv) riverine forest, and (v) forest plantations, the last two being very small in extent (DWC, 2008), has been influenced by both natural and anthropogenic factors. The grasslands in the park, dominated by Panicum maximum (Guinea grass) and the scrub are mainly the outcome of past anthropogenic activities including clearance of large areas of old-growth forest for shifting cultivation (DWC, 2008). Recent studies have indicated threats to the grasslands owing to both the spread of invasive exotic plant species and illegal livestock grazing (Alahakoon et al., 2017; Sampson et al., 2018). This study was conducted at the UWNP with the permission of the Department of Wildlife Conservation (Permit no: WL/3/2/31/19).

Identifying the habitats

Our first task was to identify and characterize the habitat types to be surveyed. To accomplish this, we carried out field observations throughout the park in September 2019 and studied previous published work on the subject. What was evident was that attempting to identify and name a multiplicity of vegetation types as different habitats would result in there being no clear-cut boundaries between some of the habitats so named. An example of this would be the two habitats referred to as savannah grassland and grassland by Alahakoon et al. (2017). We were also guided by the Biodiversity Baseline Survey of the Udawalawe National Park (DWC, 2008). Accordingly, we identified three major habitat types for our present study. They are (i) Forest (including old growth natural forest i.e. closed canopy dry mixed evergreen forest; disturbed and secondary dry mixed evergreen forest; riverine forest, and forest plantation), (ii) Scrub (low, bushy, thorny vegetation, also including small trees), and (iii) Grassland (areas dominated by grass, with or without scattered trees). Verification of the habitat types was done through ground truthing when some of the characteristic plant species in each habitat type as reported in DWC (2008) and Alahakoon et al. (2017), were identified (Figure 2). Ten points, well spread out within the park, were geo-referenced for each habitat type using a GPS.

Figure 1: The Udawalawe National Park (right) and the map of Sri Lanka showing its location (left).
Assessing habitat cover

Remote Sensing and Geographic Information System (GIS) techniques can be effectively used to assess changes in habitat cover. Locally, these tools have been used on a limited scale for studying the types of vegetation cover in protected areas. In the present study we used remote sensing to analyze temporal changes in the distribution and extent of the selected habitat types in the UWNP over a 14-year period, from 2005 to 2019. The boundary of UWNP was obtained from https://www.protectedplanet.net/en. Satellite images from Landsat 5 and Landsat 8 (United States Geological Survey) for the years 2005, 2010, 2015, and 2019 were used for generating habitat cover maps of the three selected habitats; forest, scrub and grassland, in order to determine temporal trends.

Satellite images with the least cloud cover over the study region had to be selected to minimize interference in classifying the different points. Also important is the selection of dates for acquiring the successive sets of satellite images, as Zhao et al. (2019) have reported that seasonal differences in the vegetation as appearing in the satellite images could mask any prevalent habitat changes. Hence, taking into consideration (a) that the four successive sets of satellite images to be taken for our study should fall, as far as possible, within a period during which there would be no seasonal fluctuations in the appearance of the vegetation and (b) the availability of suitable satellite images, we used images from the early part of the year (January to April). At this time the grass species would be in full flush. The dates of satellite acquisition are shown in Table 1.

Table 1: Dates of acquisition of satellite images from the relevant sensors.

<table>
<thead>
<tr>
<th>Year of study</th>
<th>Date of acquisition</th>
<th>Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>2005.02.13</td>
<td>Landsat 5 Thematic Mapper (TM)</td>
</tr>
<tr>
<td>2010</td>
<td>2010.02.27</td>
<td>Landsat 5 Thematic Mapper (TM)</td>
</tr>
<tr>
<td>2015</td>
<td>2015.04.14</td>
<td>Landsat 8 Operational Land Imager (OLI)</td>
</tr>
<tr>
<td>2019</td>
<td>2019.01.03</td>
<td>Landsat 8 Operational Land Imager (OLI)</td>
</tr>
</tbody>
</table>

Figure 2: The three habitat types considered in the study (photographed by K.T. Krishan in September 2020): (a) Undisturbed forest (b) Disturbed forest (c) Riverine forest (d) Scrub (e) Panicum dominated grassland (f) Grassland around reservoir.
To account for atmospheric effects, Landsat images corrected for surface reflectance were used following Masek et al. (2006). Since the Thematic Mapper (TM) in Landsat 5 and Operational Land Imager (OLI) in Landsat 8 have different band combinations, the spectral bands for the present study were selected based on corresponding wavelength ranges of both sensors. The spectral bands used for the image classification are: blue, green, red, NIR (Near Infra-Red), SWIR (Short Wave Infra-Red) 1, and SWIR 2.

Supervised classification was done with pixels with the same or similar spectral reflectance features falling into the same information category (Campbell and Wynne, 2011; Bharatkar and Patel, 2013). In the present study satellite images were classified in ArcMap version 10.5 based on the maximum likelihood classifier algorithm. Training sites for each vegetation cover type were selected based on ground truth data and high resolution images from Google Earth Pro. The historical images of Google Earth were used to identify land surface features for the years of interest.

Google Earth Pro data provides an opportunity to access classification accuracy. We used the confusion matrix method to determine the accuracy of the classified images following Bharatkar and Patel (2013). Reference points for accuracy tests were obtained from high resolution images of Google Earth. Each of the three habitats: forest, scrub, and grassland, were considered for assessing accuracy with a total of 50 reference points being used for each. The Kappa coefficients of classified images and the overall accuracies in classifying the habitat types for the years 2005, 2010, 2015, and 2019 are shown in Table 2. The values indicate a high degree of accuracy (over 80%) in the present study in comparison to other similar studies (e.g. Pathmanandakumar, 2019). Any change in habitat type in each pixel was assessed by comparing classified images created for 2005 with the later years.

### RESULTS

**Temporal changes in the extents of the selected habitats**

Our study considered three broad habitat types for assessing temporal changes - forest, scrub, and grassland - as shown in Figure 2. Analyses of the satellite images of UWN from 2005 to 2019 show significant changes that have occurred in the distribution and extents of these three major habitat types (Table 3 and Figure 3). Being changes on a landscape scale, this is remarkable, considering the relatively short space of time (14 years) over which they have occurred.

The forest cover within UWN had increased by 29 km², from 13% to 22% of the park between 2005 and 2019. This means that forest cover had increased by as much as 68% of its original extent within the space of 14 years (Figure 4). Scrub habitat was the dominant vegetation type in 2005 and it increased further by about 12 km², from approximately 47% to 51% of the park over 14 years. Most importantly, the grass cover had decreased considerably - it had reduced by about 51 km², from 27% to 11% of the park. The satellite images show that the forest had spread into areas which were in scrub, and the scrub had spread into the areas that were in grass. The net effect was a large reduction in the extent of grassland.

### DISCUSSION

The present study provides information on temporal changes (between 2005 and 2019) in the extents and distribution of three major habitat types - forest, scrub and grassland - in the Udawalawe National Park, Sri Lanka. To our knowledge this is the first study that has used multi satellite images to assess extents of habitat changes on a temporal scale in a protected area in Sri Lanka. The high level of accuracy (over 80%) attained in the habitat assessment using satellite images combined with ground truthing in the present study, indicates that this is a reliable method for determining changes in coverage of broadly defined, major habitat types in protected areas.

<table>
<thead>
<tr>
<th>Year</th>
<th>Overall accuracy (%)</th>
<th>Kappa coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>81.2</td>
<td>0.765</td>
</tr>
<tr>
<td>2010</td>
<td>82.4</td>
<td>0.780</td>
</tr>
<tr>
<td>2015</td>
<td>86.0</td>
<td>0.825</td>
</tr>
<tr>
<td>2019</td>
<td>87.6</td>
<td>0.845</td>
</tr>
</tbody>
</table>

Table 2: Overall accuracy and Kappa coefficients of the classified images.

<table>
<thead>
<tr>
<th>Habitat</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (km²)</td>
<td>%</td>
<td>Area (km²)</td>
<td>%</td>
</tr>
<tr>
<td>Forest</td>
<td>43.09</td>
<td>13.33</td>
<td>60.02</td>
<td>18.57</td>
</tr>
<tr>
<td>Scrub</td>
<td>151.78</td>
<td>46.97</td>
<td>158.88</td>
<td>49.17</td>
</tr>
<tr>
<td>Grassland</td>
<td>86.81</td>
<td>26.86</td>
<td>50.86</td>
<td>15.74</td>
</tr>
</tbody>
</table>

Table 3: Variation in the coverage in terms of extent (km²) and percentage (%), of the selected habitat types during a 14-year period.
Our study shows that the extents of the three habitat types - forest, scrub, and grassland have changed substantially over a relatively short period of time i.e. over the 14 years, from 2005 to 2019. Whereas both forest and scrub have increased - forest by 29.3 km² (67.9% increase), scrub by 11.9 km² (7.9% increase) - grassland has shown a marked decrease of 51.2 km² (59.0% decrease). The forest area had increased replacing scrub and scrub had spread into the grasslands, both owing to the natural process of plant succession, aided in the case of scrub invading the grassland, by the aggressive spread of the exotic invasive species *Lantana camara* (Sampson et al., 2018). Interestingly, the increasing trends in extents of the forest and scrub habitats show marginal reversals between 2015 and 2019 (forest) and between 2010 and 2015 (scrub). This could be attributed to the difficulty in classifying transitional stages between the two habitats, scrub and forest. Acts of illegal clearing and burning of forest habitats for shifting cultivation or for the cultivation of *Cannabis sativa*, which were among the recorded offences in the UWNP during this period (Perera et al., 2019), may have also contributed to the decrease in forest area observed between 2015 and 2019.

Two previous studies DWC (2008) based on field work conducted from March to July 2008 and Alahakoon et al. (2017) based on field work conducted between December 2005 and January 2007, have reported extents of the vegetation types in the UWNP. An attempt to make a direct comparison of habitat extents as reported in these two studies with the data obtained in the present study would not be meaningful owing to differences in the composition of the habitats as described in each case. The extent of forest as seen in the present study (13.3% and 18.6% of the park in the two years 2005 and 2010, respectively) are much greater than those recorded in DWC (2008) and

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**Figure 3:** Habitat maps of the Udawalawe National Park generated for the years 2005, 2010, 2015, and 2019.

**Figure 4:** Percentage change (from the base year 2005) in the three major habitat types (forest, scrub, and grassland) in the Udawalawe National Park over 14 years.
Alahakoon et al. (2017). This disparity could very likely be attributed to the differences in classification of the ‘forest’ habitat. The present study included a broad range of sub-habitats under ‘forest’ - climax dry mixed evergreen forest, successional and disturbed dry evergreen forest, riverine forest, and forest plantation - whereas Alahakoon et al. (2017), giving a coverage of around 7.5% has taken into consideration only ‘tall forest’ and riverine forest. DWC (2008) reports a coverage of 4.5% for undisturbed closed canopy forest and riverine forest and on disturbed forests states ‘extent unknown’. Regarding grass cover, disparities in extents reported can also occur depending on the time when the satellite images are taken, since grasses come into full flush mainly during the rainy season. This factor was recognized in the present study and the four sets of satellite images used were those taken towards the end of the period during which the dry zone experiences wet weather caused by monsoonal and inter-monsoonal rains.

The present study recorded an increase in the extent of scrub which is one of the typical vegetation types in the dry zone. Scrub habitats often occur in juxtaposition with grasslands as seen in the satellite images (Figure 3) and as previously reported by Alahakoon et al. (2017). In UWNP the scrub habitats consist of native species and exotic invasive species. The aggressive spread of alien invasive species would have contributed to the increase in extent of scrub habitat in UWNP. Two species Lantana camara and Chromolaena odorata have been identified as problematic species which are spreading rapidly in the scrub and encroaching on to the grasslands (DWC, 2008). It is documented that L. camara has invaded an area of around 2,650 ha in this national park (Fernando et al., 2016). Elsewhere, habitat loss from such invasive species has become an important conservation focus for habitat management for the Asian elephant (Wilson et al., 2013).

Grasslands have been recognized as one of the most important wildlife habitats in the UWNP. It has arisen owing to the practice of shifting cultivation in this area until around 1972. In Udawalawe it is reported that following the designation of the National Park in 1972, people living inside its boundaries were relocated and the land, abandoned after raising food crops for a few seasons, reverted to grassland (DWC, 2008). Knicker (2007) states that recovery of soil nutrients, especially nitrogen and phosphorus, is really slow in a burnt land and may take as much as 35 years for full recovery. During this time ecological succession is known to take place replacing grass species with other herbaceous vegetation, followed by scrub species. The spread of invasive species from adjoining scrub habitats would accelerate this process.

Under-brushing of scrub vegetation and the removal of L. camara and other invasive species carried out on an ad hoc basis in UWNP (Fernando et al., 2016) might have helped to control the spread of scrub vegetation, although only marginally, considering the scale and frequency of the operation. In successional habitats, such as the scrub and grasslands, temporal changes occur naturally, but might be affected by anthropogenic factors leading to the spread of invasive species. For instance, a study conducted on the sides of jeep tracks within the UWNP reports that the density of C. odorata is significantly greater on the sides of intensively used trails in comparison with less used trails, suggesting that human disturbance might have facilitated the spread of this species (Hettiarchchi et al., 2021). Domestic cattle being released into the park also lead to the spread of invasive plants by dispersing seeds (Odadi, 2011; Chuong, et al., 2016; Sampson et al., 2018). They can also alter the vegetation structure and diversity within an ecosystem, possibly posing an additional threat to the elephants (Schulz and Leiminger, 1990; Porensky et al., 2020).

What implications would habitat changes have on the elephants and the wider faunal community?

Among the fauna that would be affected considerably by the habitat changes observed in the UWNP is the elephant. The elephant populations in Sri Lanka are on the decline and hence the protection of this species is a high conservation priority. It is well documented that the most preferred habitat of the elephant in Sri Lanka is grassland (Fernando and Leimgruber, 2011; Alahakoon et al., 2017). The elephant feeds on grasses which show dense growth, are easy to gather, and have few secondary compounds (Fernando, 2015). Some of the species of grasses consumed by the elephants are Panicum maximum, Cyrtococcum trigonum, Heteropogan contortus, and Cynodon dactylon (Angammana et al., 2015; Alahakoon et al., 2017). In reservoirs, as the water level drops in the dry season, parts of the reservoir bed get exposed, allowing seasonal grasses to sprout. The elephants are known to gather on the exposed reservoir bed to feed on this grass (Ranjeeka et al., 2017). In UWNP the grass cover in the exposed tank beds would provide a seasonal addition to the elephants’ food resource, compensating for the loss of habitat owing to the construction of the reservoirs. Moreover, this resource becomes available at a time when the resources in the high grassland areas get reduced owing to the drought conditions.

In UWNP, where elephants are the prime attraction, the considerable reduction and continuing decline in grassland as observed in the present study would be a matter of grave concern. Adding to the decline in grass cover, the grasslands are prone to invasion by exotic species that are not consumed by the elephants (Alahakoon et al., 2017). Apart from grass, elephants are also known to feed on some woody species - e.g. bark of Bauhinia racemosa, a common native species in scrub habitats (Alahakoon et al., 2017), but high forest and riverine forest are seldom used for feeding (Alahakoon et al., 2017; Sampson et al., 2018). Elephants have also to compete with other herbivores that feed on grass, and the limited extent of grassland as of now and its continuing decline, will seriously impact on all these faunal species. Given this condition, the overgrazing by domestic cattle within the national park, which is illegal, aggravates the situation. One of the indirect but important consequences of the dwindling fodder resources within a protected area is the movement of elephants to border
villages and to cultivations around human habitations in search of food, which aggravates the human-elephant conflict (Fernando, 2015).

The mosaic landscape of UWNP, while being an important habitat of elephants, also provides refuge to many other vertebrates, some endemic to Sri Lanka and/or nationally threatened. Of the habitats in UWNP, grassland recorded the highest species richness for birds and mammals and relatively high species richness for reptiles (DWC, 2008), indicating that the observed decline in grassland cover would be detrimental to many other species besides the elephant. This adds to the importance of recognizing habitat management as an important issue for maintaining the integrity of this protected area.

Some of the locally applicable management practices that would be useful for maintaining good quality grassland and increasing its spread are: periodic controlled burning of selected areas of scrub, and under-brushing and removing invasive plants in other areas. Fire has been shown to be important in the UWNP for reducing the spread of invasive plants and promoting lush growth of grass (Sampson, 2013). What is important is that these actions, at a suitable scale, should be incorporated into management plans and carried out systematically.

On a wider perspective, the many development activities carried out in Sri Lanka over the past few decades (restoration of irrigation reservoirs, expansion of agriculture, establishing human settlements) have greatly reduced the extents of habitats for the elephant and other species of wildlife. This has been compensated for, to some extent, by the establishment of a network of protected areas in the country. The present study shows the need to continually monitor the food resources available to the wildlife in the PAs, in the present case to the elephant *Elephas maximus*, and carry out management practices to conserve and further increase the required resources.

CONCLUSION

This study has shown that multi-temporal satellite images could be effectively used to assess changes in the habitat cover in Protected Areas. One of the noteworthy findings was that grassland habitat of the Udawalawe National Park has significantly decreased over the period 2005 and 2019, mainly owing to the invasion by scrub. This would ultimately affect the fodder availability for wild herbivores, especially of the elephants in the park. Thus, monitoring and managing temporal changes in habitats, particularly in elephant-dominated terrain, should be considered a top priority.

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DECLARATION OF CONFLICT OF INTEREST

The authors have no financial conflicts of interest to report.

REFERENCES


