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MAPPING THE VEGETATION COVER AND HABITAT CATEGORIZATION OF MADURU OYA AND HORTON PLAINS NATIONAL PARKS USING LANDSAT 8 (OLI) IMAGERY TO ASSIST THE ECOLOGICAL STUDIES

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ABSTRACT : Availability of accurate and detailed vegetation and habitat maps is an essential requirement in the modern ecological studies. Geo-referenced vegetation maps of Sri Lanka's protected areas are scarce and only a handful of maps are available with detailed vegetation patterns. Since majority of the current ecological research work takes place within the protected area network of the island, we identified that preparing updated maps to assist the ecologists as well as the park management is highly important. In this study we developed vegetation and land cover maps for Maduru Oya and Horton Plains national parks in Sri Lanka. The procedure was based on supervised classification of Landsat 8 multispectral image data. Classification was complemented by ground truth data obtained through field surveys. The present study generated accurate (overall accuracy - 92-93%; Kappa – 0.89) and detailed vegetation/land cover maps and habitat types were proposed based on vegetation patterns. The results provide accurate information for ecologists and decision-makers to assist future research work as well as conservation and management of protected areas concerned.

KEY WORDS: Remote sensing, protected areas, vegetation mapping, supervised classification, land cover

INTRODUCTION

Availability of accurate and detailed vegetation and habitat maps is an essential requirement in the modern ecological studies. A vegetation map includes critical information for a number of different applications ranging from land management, detecting land cover changes, understanding biodiversity patterns and conservation planning (Dias *et al.*, 2004). According to Tierney *et al.* (2019) vegetation maps are based on two essential elements; a classification of vegetation and a spatial attribution of that classification. Hence, the vegetation mapping group together similar plant communities into a simplified form depicting their arrangement pattern with spatial reference (Cáceres, 2019). When it comes to field based ecological studies, the availability of vegetation maps makes the task of the researchers easier.

There is only a few geo referenced vegetation maps of protected areas in Sri Lanka. Furthermore, availability of maps with detailed vegetation patterns is scarce. As many ecological researches are being conducted in the protected areas of the island presently, we saw that there is a crucial need of preparing updated maps to assist ecologists as well as park management. Early efforts of remote sensing and GIS based land cover mapping of forested areas of Sri Lanka can be identified from Jewell and Legg (1993) to the recent publications of Rathnayake *et al.* (2019) and MoMD&E (2019). However, most of the previous work has been focused on large scale patterns of general land cover rather than localized rigorous assessments. We identified that Horton Plains National Park (HPNP) as one of the few protected areas in Sri Lanka which has been focused for in depth vegetation pattern assessments. Work by DWC (2006; 2007), Abayasinghe *et al.* (2014) and Ranawana (2014) has generated vegetation maps along with change detection for the years 1998 and 2008. Gunawardena *et al.* (2015) have estimated the above ground biomass at HPNP and during the procedure several vegetation maps have been prepared using imagery from 2008-2013. There are publication related vegetation maps for some of the Department of Wildlife Conservation (DWC) managed parks; Wilpattu (Sandamali and Welikanna, 2018), Udawalawa (Angammana *et al.*, 2015), Maduru Oya (Gabadage *et al.*, 2015) and Muthurajawela Sanctuary (Khanh and Subasinghe, 2018). There are some previous attempts to map the vegetation of Sinharaja (Madurapperuma and Kuruppuarachchi, 2014; Lockwood, 2021). We observed two main drawbacks in most of these past maps which limit their applicability in current and future work; 1) Unavailability of high resolution digitally accessible maps, 2) Lack of ground based validation and surveys to complement the remote sensing techniques. Therefore, as an initiation to supplement the needs of ecological research, management and conservation of protected areas, we developed vegetation classifications and maps for Horton Plains and Maduru Oya National Parks in Sri Lanka. Based on the vegetation classes identified, land cover composition and available literature, we propose habitat categorization for the two protected areas considered.

The availability of high resolution multispectral satellite data has enabled the analysts to obtain spectral signature of different objects such as vegetation, water bodies, soil types, rocky areas, roads/other manmade structures, and many more (Mtibaa and Irie, 2016; Taufik *et al.*, 2016). However, when forested landscapes are concerned, normalized difference vegetation index (NDVI) calculation is the most widely used method for vegetation classification (Mtibaa and Irie, 2016). NDVI takes into account the visible red and near-infrared (NIR) wavelengths, from satellite imagery and provides an index of the reflectance of wave lengths by the vegetation. NDVI index value range from -1 to +1 where healthy and highly photosynthetic vegetation is represented by positive values greater than +0.5. The equation for the index can be presented as: NDVI = (NIR – RED) / (NIR + RED).

We incorporated remote sensing data with field based ground truth data to determine the vegetation classes. Habitat and vegetation characteristics were obtained at ground level to complement the remote sensing data. However, we adhered to some of the basic protocols described by Bölöni *et al*. (2007) for habitat classification. Therefore, in order to make the results understandable by a wider audience of diverse fields, we tried to simplify the classifications by reducing the number of vegetation categories, including multiple attributes of vegetation (rather than in depth phytosociological descriptions) and building upon the already available knowledge from previous work. Our analysis is based on more of a physiognomic nature which is based on the basic physical structure of the vegetation (forest, shrubland, grassland, etc.) and the main growth forms (trees, shrubs, grasses, etc.) of the dominant or co-dominant species in the vegetation formation (Ichter *et al.*, 2014).

However, additional parameters to which an ecologist would focus on were also analyzed during classifications. According to Ichter *et al.*, (2014) vegetation composition may be considered as a proxy for habitats of terrestrial systems. Hence, in a generalized form the vegetation categories can be used to segregate the habitat types. We believe that the output generated through our study would be meaningful in a remote sensing as well as in an ecological point of view.

METHODOLOGY

Study site

Horton Plains National Park

Horton Plains National Park (Figure 1) is located on the southern plateau of the central highlands of Sri Lanka (6°47'-6°50'N, 80°46'-80°50'E) and comprises a gently undulating highland plateau, the altitude ranging from 1800-2389 m (Green, 1990). It is dominated by Kirigalpoththa (2,389 m) to the west and Totupolakanda (2,357 m) to the north, which are respectively the second and third highest mountain peaks in the country (Green, 1990; DWC, 2007). This land area of 3160 ha was upgraded to national park status on 11th March, 1988, having previously been declared a nature reserve in 1969 (Green, 1990). The vegetation in natural habitats comprises upper montane rain forests ('cloud forests') and wet 'patana' grasslands, with a narrow ecotone of shrubs and herbs between them. Extensive areas of Cloud Forest have suffered from canopy die-back, the cause of which is uncertain but may be related to water stress, soil conditions, air pollution (DWC, 2007; Ranasinghe *et al.*, 2009) or natural phenomena.

FIGURE 01: View of Horton Plains National Park from Thotupola mountain peak. Grassland and Cloud forest areas are visible with the backdrop of Kirigalpoththa and Agra mountain ranges (Photo by Dulan Jayasekara, originally published in Jayasekara *et al.,* 2020)

Maduru Oya National Park

Maduru Oya National Park (MONP) (588 km^2) lies in the districts of Ampara and Polonnaruwa representing areas of the dry zone. The prominent feature of the park is the Maduru Oya Reservoir situated in the centre of the park. The climax plant community of the area is tropical dry mixed evergreen forests. However, large tracts of forests within the park had been severely exploited for shifting cultivation resulting in secondary forests and vast stretches of open plains dominated by shrubs and grasses. The park area experiences a mean annual temperature of 27°C and the total annual precipitation in the area is approximately 1650mm (Green, 1990).

Determination of vegetation and habitat categories

Initially we referred to available literature and prepared priory vegetation/habitat categories for MONP and HPNP. General boundaries of the main vegetation types were established, on a physiognomic basis (Dias *et al.*, 2004) with the help of ArcGIS (Esri, Redlands, USA) base maps available online. We established a grid of 1×1 km^2 plots covering the area of available protected area maps. However, we had to make slight adjustments to the boundaries of the both protected areas to remove some visible errors to include some significant landmarks that should be within park boundaries. Therefore, there can be <5% differences between the legislated and study generated map areas and perimeters. We randomly selected sampling plots and established sampling quadrates of 10×10 m within the larger 1×1 km^2 plots. A total of 77 and 55 quadrates were sampled respectively at MONP and HPNP. At each quadrate, environmental parameters described in Table 1 were obtained using standard methods. We performed principal component analysis (PCA) in R version 4.0.3 (R Core Team 2013) to create clusters of similar vegetation/land cover types.

TABLE 01: Summary of vegetation and environmental parameters and standard methods used (X indicates whether each parameter was obtained at the selected site)

Environmental parameter	Abbreviation	Method followed	MONP	HPNP
Stem density of plants <10cm dbh (dbh-diameter at breast height)	SD1	Average distance to the nearest woody plant with dbh <10cm calculated as 1/mean area [distance]^2	X	X
Stem density of plants >10cm dbh	SD2	Average distance to the nearest woody plant with dbh >10cm calculated as 1/mean area [distance]^2	X	X
Canopy cover	CN	Photo point analysis	X	X
Litter cover %	LC	Average by quadrates (ocular estimation)	X	X
Litter depth (cm)	LD	Measured with metal ruler	X	X
Horizontal visibility (%)	HV	Photo point analysis	X	X
Ground vegetation cover (%)	GV	Average by quadrates (ocular estimation)	X	X
Rock availability	RA	Evaluated on a scale of 1-10	X	X
Soil moisture (%)	SM	Measured using Kelway soil acidity (pH) and moisture tester (Gilson Co., Ohio, USA)		X
Normalized Difference Vegetation Index	NDVIm NDVIj (m indicate March and j indicate June)	Landsat 8 (OLI) image analysis in ArcMap 10.4.1 (Esri, Redlands, USA)	X	

Pre-analysis for supervised classification

We utilized multi-spectral images from the Landsat 8 satellite which was launched in 2013. These were ortho-rectified and terrain corrected T1 collection Landsat 8 images (OLI_TIRS sensor/path_141/row_55) available at the United States Geological Survey online database (http://glovis.usgs.gov/). Images used for HPNP were from January 13, 2017 and March 15, 2016. For MONP images were from June 29, 2019 and March 24, 2019. Image datasets with low cloud cover were considered during the selection. The Landsat 8 dataset has 11 spectral bands. However we used only the bands 2, 3, 4, 5, 6 and 7. These spectral bands were combined in ArcMap 10.4.1 to create a multiband raster dataset using the "Composite Bands" tool. Bands 3, 4 and 5 were utilized to obtain rich vegetation information. Bands 6 and 7 were to discriminate between water and dry lands (Mtibaa and Irie, 2016). The NDVI was calculated for each image according to the following equation: NDVI = (NIR - Red)/(NIR + Red) where NIR and Red are the near infrared and red bands, respectively (Mtibaa and Irie, 2016).

Based on the past literature and results of PCA analysis of ground survey data, we determined the number of vegetation classes required for image classification of the two national park areas. The number of classes selected was four and seven for MONP and HPNP respectively.

Supervised classification using Landsat 8 images

Supervised image classifications were conducted based on maximum likelihood classification (MLC), algorithm. Training samples were selected from the data obtained from field surveys performed from January 2016 to January 2021. We supplemented the training sample data set with ArcGIS base map imagery data (Esri, DigitalGlobe) ascertained for inaccessible terrain and some known locations.

Accuracy assessment of classified maps

Accuracy assessment was conducted to compare the predicted results (classification results) to ground reference data. To eliminate the possibility of bias, in addition to the actual ground survey points, we generated random assessment points using stratified random method. Accuracy was validated using field observations and base-map imagery. The error matrix was prepared and Kappa coefficient was computed in ArcMap.

RESULTS

PCA clustering of vegetation and environmental characteristics

The PCA analysis generated four vegetation/land cover clusters for MONP; dense forest, shrublands, grasslands and rocky outcrops (Figure 2b). PC 1 and PC 2 were accounting for 54.03% of total variance. However, shrubland cluster was overlapping with grasslands and forest clusters to some extent. According to the loading plot (Figure 2a) the important factors that influence the dense forest were high canopy cover, stem density 2 (index of woody plants with >10cm dbh), litter cover and litter depth. Rocky outcrops were clearly separated based on rock availability. Ground vegetation cover was higher in the grasslands. The shrubland cluster indicated mixed features of grasslands and dense forest. However, high stem density 1 (index for woody plants with <10cm dbh) was influencing the determination of shrublands.

In HPNP, seven clusters were obtained from PCA; cloud forest, cloud forest die-back/low canopy, pigmy cloud forest, carpet grass, tussock grass, marshes/dwarf bamboo, rocky outcrops (figure 3b). The first two PC axes accounted for 75.13% of total variance. The score plot indicated overlapping between the two grass types and marshes/dwarf bamboo. Cloud forest cluster was influenced by high canopy cover, litter cover, litter depth and stem density 2. Grasslands were characterized by high horizontal visibility and ground vegetation cover. Marshes and dwarf bamboo areas were easily categorized based on soil moisture content (Figure 3a).

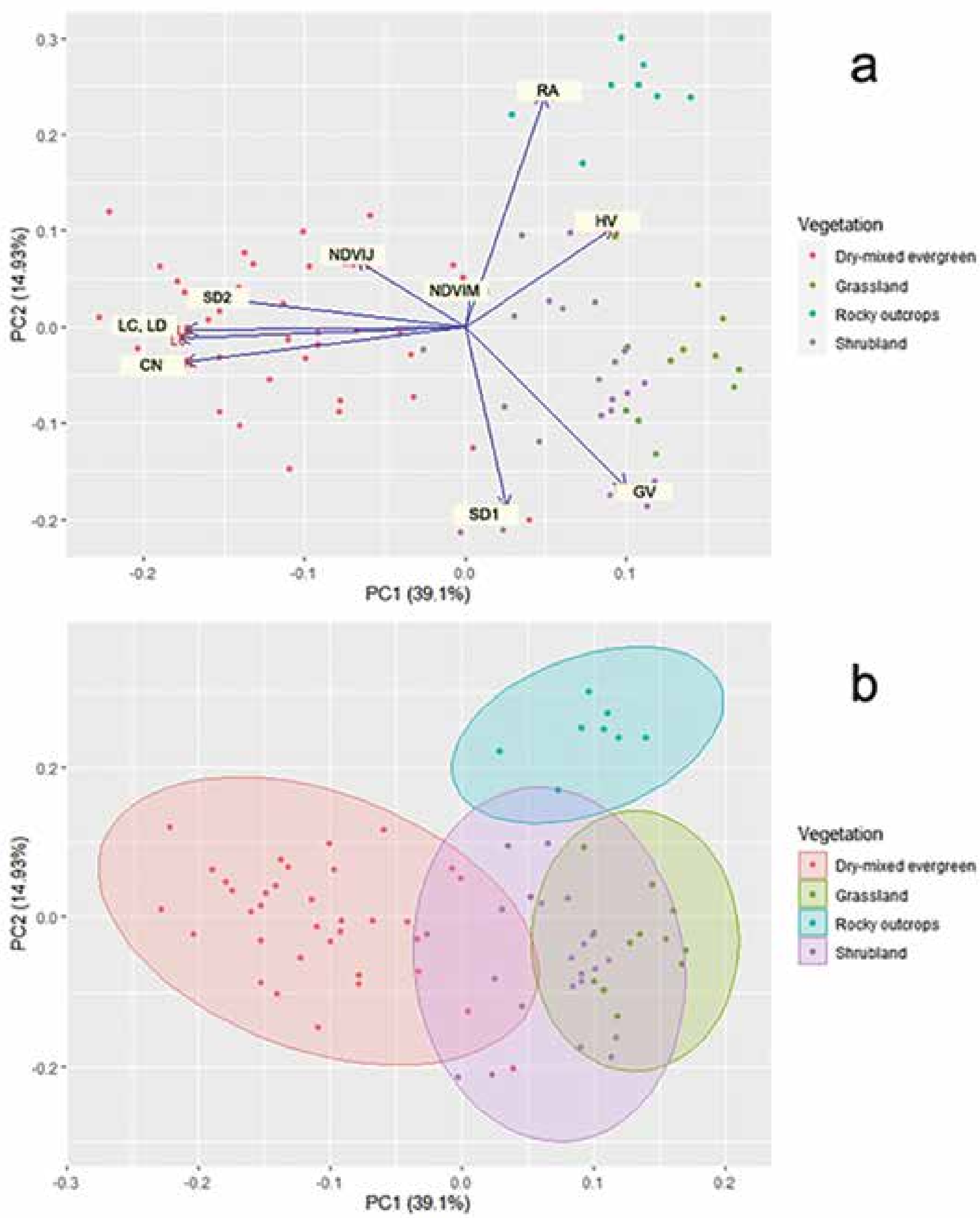

FIGURE 02: (a) Loading plot and (b) score plot of PCA conducted for MONP field survey covariates

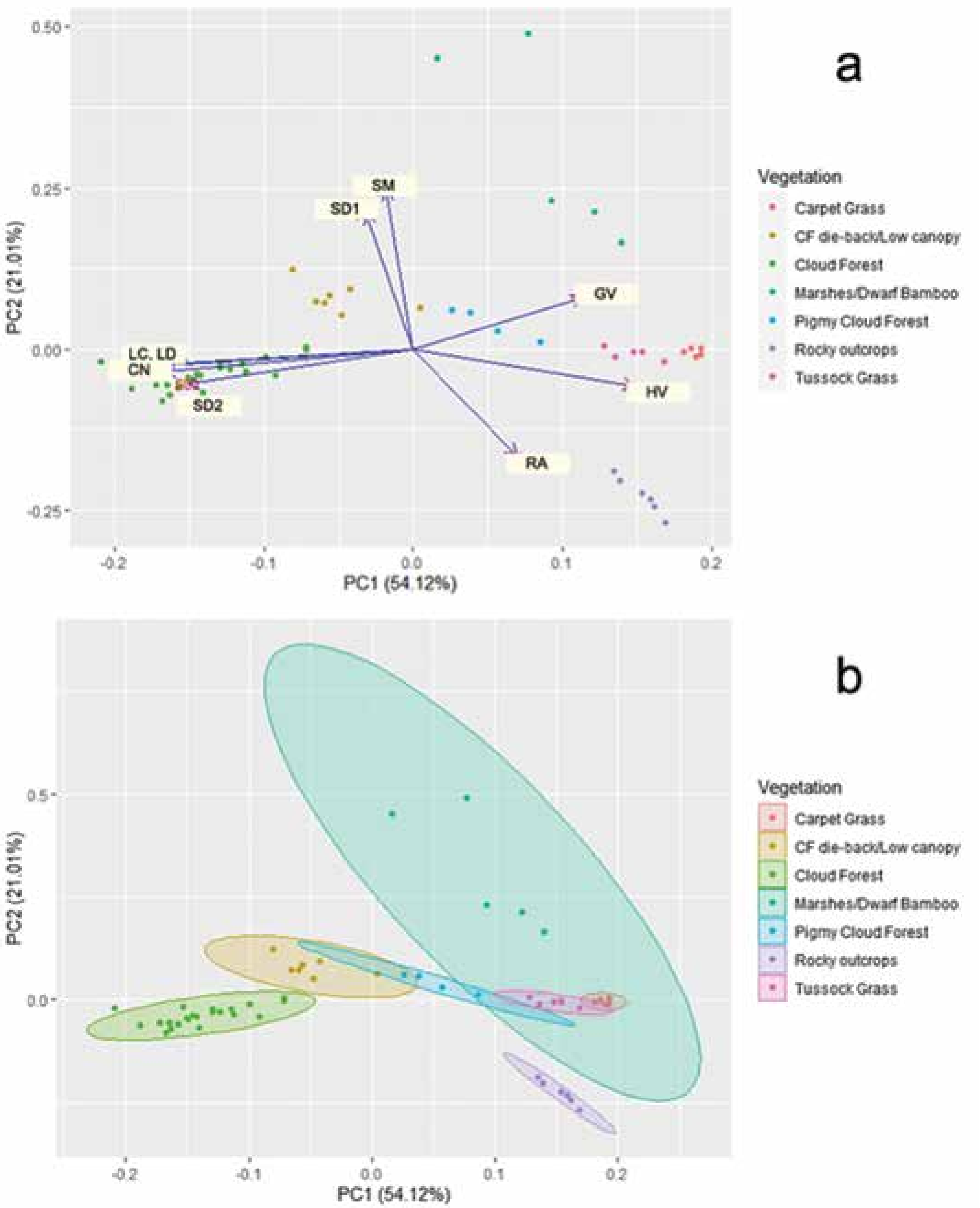

FIGURE 03: (a) Loading plot and (b) score plot of PCA conducted for HPNP field survey covariates

Spatial extents of land cover classes

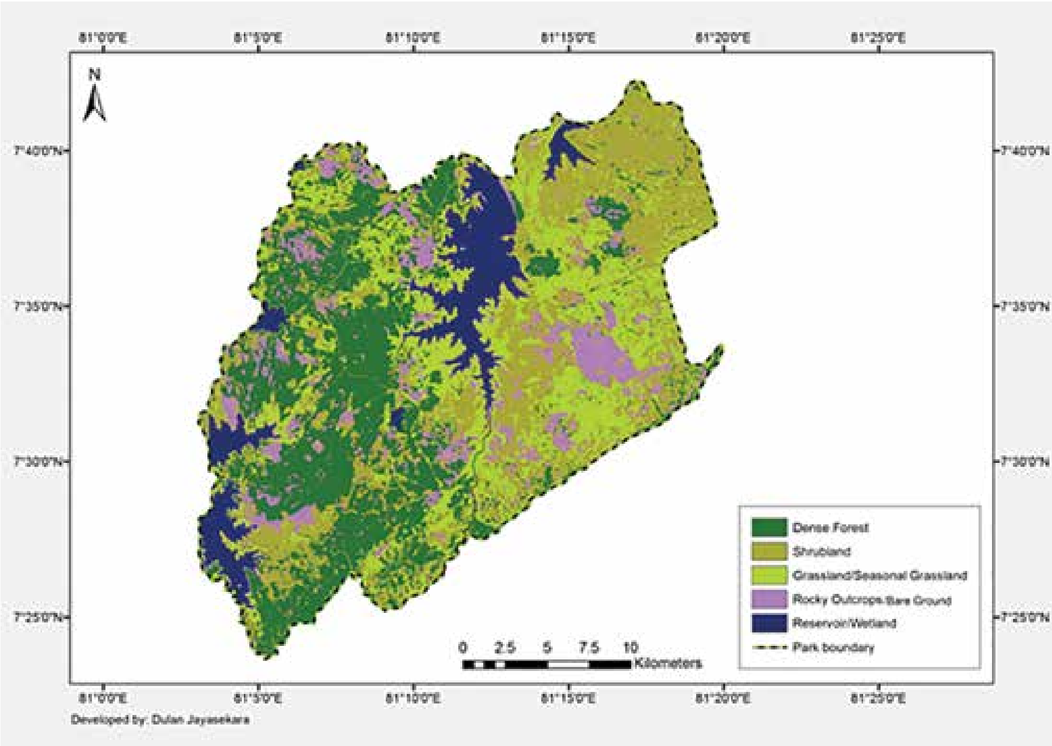

FIGURE 04: Map of vegetation and land cover classification in MONP (the map may not exclusively represent the legislated park boundary)

Based on the generated map classification highest coverage in MONP was shrublands with 37% accounting for 215,415ha of land area (Figure 4). It was followed by dense forest of climax dry-mixed evergreen habitat (29%). In HPNP, the prominent habitat type was the cloud forest (50%) covering an area of 1576ha. The cloud forest die-back/low canopy areas repesents 25% (778ha) of park area. Two grassland types accounted for 13% land coverage (Figure 5, Table 2).

TABLE 02: Percentage coverage and actual area of different vegetation/land cover types

Vegetation/Land cover type	Percentage land cover (%)	Area (ha)
MONP		
Dense forest (DF)	29	170,171
Shrubland (SL)	37	215,415
Grassland/Seasonal grassland (GL)	14	83,520
Rocky outcrops/bare land (RO/BL)	11	65,277
Reservoir/wetland (R/WL)	9	53,466
Total area		587,850

HPNP		
Cloud Forest (CF)	50	1,576
Cloud Forest die-back/ Low canopy (CFD/LC)	25	778
Pigmy cloud forest (PCF)	4	119
Tussock grass (TG)	7	234
Carpet grass (CG)	6	194
Marshes/Dwarf bamboo (M/DB)	7	219
Other vegetation (OV)	1	30
Rocky outcrops/bare land (RO/BL)	0.1	11
Total area		3,160

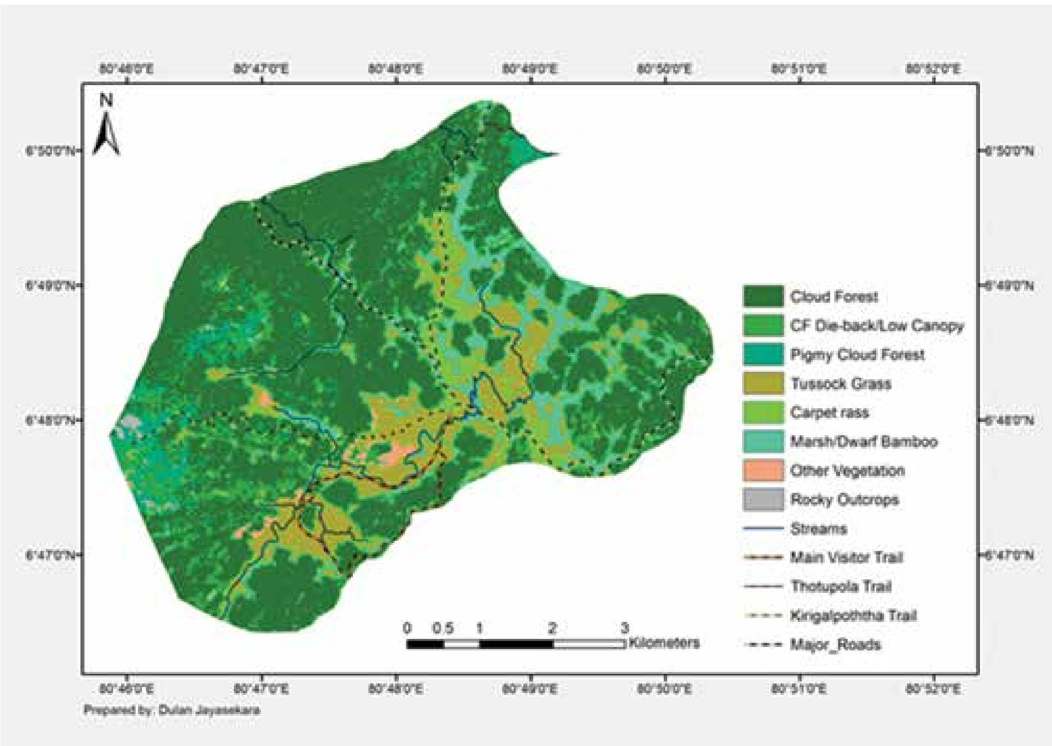

FIGURE 05: Map of vegetation and land cover classification in HPNP (the map may not exclusively represent the legislated park boundary)

Accuracy assessment of results

Kappa coefficient values of 0.89 were obtained for both analyses. Values >0.80 are considered to be good. The overall accuracy was 0.92 and 0.93 respectively for MONP and HPNP (Table 3, Table 5).

DISCUSSION

This study generated detailed vegetation and landcover maps for two of the prominent national parks in Sri Lanka. Even though purely remote sensing based approches are common in classification analyses, the incorporation of ground based field surveys with remote sensing

TABLE 03: Accuracy assessment of the classification for MONP

Class	**DF**	**SL**	**GL**	**RO/BL**	**R/WL**	**Total**	**U_Acc**	**Kappa**
Dense Forest	56	2	0	0	0	58	0.97	
Shrubland	0	67	3	2	1	73	0.92	
Grassland/Seasonal grassland	0	3	25	0	0	28	0.89	
Rocky outcrops	0	3	1	17	1	22	0.77	
Reservoir/Wetland	0	0	0	0	18	18	1	
Total	56	75	29	19	20	199		
P_Accuracy	1	0.89	0.86	0.89	0.90		**0.92**	
Kappa								**0.89**

TABLE 04: Accuracy assessment of the classification for HPNP

Class	**CF**	**CFD**	**PCF**	**TG**	**CG**	**M/DB**	**OV**	**RO/BL**	**Total**	**U_Acc**	**Kappa**
CF	145	4	1	0	0	1	0	0	151	0.96	
CFD	4	34	0	1	0	0	0	0	39	0.87	
PCF	3	0	10	0	0	0	0	0	13	0.77	
TG	1	0	0	36	0	0	0	0	37	0.97	
CG	0	0	0	2	7	0	0	0	9	0.78	
M/DB	1	2	0	1	0	26	0	0	30	0.87	
OV	0	0	0	0	0	0	5	0	5	1	
RO	0	0	0	0	0	0	0	6	6	1	
Total	154	40	11	40	7	27	5	6	290	0	
P_Acc	0.94	0.85	0.91	0.9	1	0.96	1	1	0	**0.93**	
Kappa											**0.89**

provide more accurate results. It can be clearly seen in the results of the accuracy assessments. In our clustering process, we selected vegetation and environmental parameters that can be obtained from the field surveys without sophesticated phytosociological investigations. Therefore, the applicability of these classifications would support a broad ecological audience and even the general management decision making.

In MONP, we identified four vegetation classess. Three classes could be distinctly seperated based solely on ground survey parameters while the shrubland habitat was showing mixed characteristics. The reason for this result was actually related to the nature of the shrublands which can be considered a sucessional stage between the grassland and the dense climax forest. However, the Landsat 8 classification abled to separate the shrubland habitat. The new map provides more detailed and accurate vegetation and land cover patterns than previous map by Gabadage *et al*., (2015). MONP include a small area of old teak plantation which currently consist of many dead/ dying teak plants. Since we did not observe any significant differences in the data on above area and due to the limited distribution, it was not considered as a separate class. Our results show that the remnent dense forest area of dry-mixed evergreen climax forest in MONP is <30%. It is highly important to conserve this area with high priority in order to facilitate the biodiversity to thrive as the forested landscapes of Sri Lanka keep diminishing and shrinking. Therefore, the occurrence of man-made fires (which are frequent in MONP) and illegal logging should be strictly mitigated. Based on the overall results of the present study and considering the available past literature, we propose five main habitat types for MONP; 1. Dense forest (dry-mixed evergreen), 2. Shrubland, 3. Grasslands 4. Rocky outcrops, 5. Reservoir/Wetlands. These habitats can be identified based on general vegetation features and landscape features along with associated flora and fauna.

The vegetation classess in HPNP were more diverse than MONP. The altitudinal, topographical and climatic conditions of the park would have resulted in this diversification. Most of the vegetation classes generated for HPNP have been identified in the past studies. However, in this study we focused on putting together a summarized and detailed account on the possible classifications for HPNP. Ranawana (2014) has identified six of the seven classes identified in the present study. However, the seperation of two grassland types was absent in that analysis which was focused on identifying the cloud forest die-back. Work by DWC (2006, 2007) and Abayasinghe *et al.,* (2014) have identified all vegetation classess in separate studies. However, the maps generated by DWC (2006) may have overestimated the cloud forest die-back areas probably due to the low resolution and limited interpretation of satellite images as mentioned by Abayasinghe *et al.,* (2014). The lack of vegetation detail in previous maps was filled by Abayasinhe *et al.,* (2014) where they have generated more detailed and accurate vegetation maps. However, excluding the pigmy cloud forest and rocky outcrops can be identified as a drawback. Futhermore, the images that were used in these analyses were from 2008 the latest. Therefore, the present study (used 2017 satellite images) can be considered timely to compare the change that has occurred after about 10 years gap from the previous analysis. We observed a slight increase in the cloud forest cover (~3%) from the previous figure, and an equal decrease in the die-back/low canopy area. This could be due to differences in analysis methods or pure changes in the vegetation. Interestingly, our results suggest a considerable increase (~4%) in the carpet grass cover and a reduction in tussock cover. This could be due to the maintainace of grasses by the gracing of sambar deer (Rajapakse *et al.*, 2002) and we posit tentatively that there could be a possible increse in the sambar deer population as well. Based on the above and past literature (DWC, 2006, 2007, Abayasinghe *et al.*, 2014; Gunawardena *et al.* 2015) we propose four habitat types for HPNP; 1. Cloud forest, 2. Cloud forest die-back/low canopy, 3. Grassland, 4. Marsh/Wetland. However, in detailed investigations, there is the possibility of identifying finer scale habitat features or subhabitats based on vegetation maps provided in the present study.

The findings of our study can be used for comparisons with past and future vegetation/land cover mapping enterprises. The identification of vegetation classes and habitat types would support the future ecological research work conducted in these protected areas. The detailed maps generated through the present study can be used for management and conservation decision making. We recommend similar initiations in other protected areas of Sri Lanka and making use of the available technological tools to implement modern solutions .

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