

CHANGE DETECTION IN VEGETATION COVER OF HORTON PLAINS NATIONAL PARK FOR ADAPTIVE MANAGEMENT: A PRACTICAL GEOINFORMATICS APPROACH

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ABSTRACT

The Department of Wildlife Conservation (DWC), the entity which is entrusted with the mandate to conserve fauna and flora of the country, manages 14% of total land area of Sri Lanka, which is designated as Protected Areas (PA) under the Fauna and Flora Protection Ordinance (FFPO). Conservation of biodiversity and non destructive uses of wildlife resources, especially for recreational purposes within the PAs, is a challenging task for the DWC. Horton Plains National Park is a one such PA which supports higher diversity of montane fauna and flora in the country. The PA is at present also subjected to some habitat changes, which are taking place naturally. Managing such a sensitive landscape requires timely and accurate scientific information regarding the species richness of the area and their spatial and temporal distribution patterns. It is also important to understand the extent of habitat change, where it occurs and what habitats are converted into a different habitat.

In conventional wildlife management approach, thematic management plans are prepared for a ten year time frame. The review interval of such a plan is generally five years. However, in Sri Lankan context, due to the nature of the dynamics in protected areas and the target environment, DWC uses a concept called "adaptive management" where the reviewing and adjustments of the activities are done frequently depending on the previous periods' experiences, usually less than five years. In this context temporal change detection of the habitats is a task which should be carried out as frequent as possible.

This study focuses on developing classified vegetation maps for two time periods (1998 and 2008) and quantify the temporal area variation of the vegetation. Vegetation map was developed using IRS LISSA III images. The vegetation classes were classified into dense forest, open forest, carpet/*Pennisetum* grass, tussocky grass, and marsh / dwarf bamboo. The methodology was developed integrating Normalized Difference Vegetation Index (NDVI) and Tasseled Cap Transformation (TCT). Finally the landscape of the PA was classified into different vegetation types using pixel based unsupervised classification algorithm. User and producer accuracies were calculated with the field observation data.

The results clearly indicate that all the vegetation types within the PA have changed between 1998 and 2008. Open forest cover increased from 23.56% to 28.41%, marsh / dwarf bamboo cover was increased from 5.35% to 8.76% during the period of ten years. It was also noted that the dense forest area reduced from 48.19% to 47.52%, carpet grass/ *Pennisetum* dominant area reduced from 2.12% to 1.68% and tussock grass cover was reduced from 20.78% to 13.63%. In general, forest cover of the PA has increased from 71.75% to 75.93% and grass cover (carpet/ *Pennisetum* and tussock) was reduced from 28.25% to 24.07% between 1998 and 2008 period. With the user accuracies of 83% in 1998 and 82% in 2008, and producer accuracy of 87% in 1998 and 80% in 2008 it can be concluded that the methodology adopted in the study is sufficient in accuracy for practical usage. Hence, technique proposed in this study could be practiced periodically to detect the vegetation changes quantitatively and effectively for the management activities of the park.

KEYWORDS: GIS, Vegetation Mapping, Protected Area Management, Change Detection

INTRODUCTION

The Department of Wildlife Conservation (DWC), the entity which is entrusted with the mandate to conserve fauna and flora of the country, manages 14% of total land area of Sri Lanka, which is designated as Protected Areas (PA) under the Fauna and Flora Protection Ordinance (FFPO). Conservation of biodiversity and non-destructive uses of wildlife resources, especially for recreational purposes within the Pas, is a challenging task for the DWC (DWC, 2012). Horton Plains National Park is a one such PA which supports high diversity of montane fauna and flora in the country. Horton Plains was declared a National Park (HPNP) on 16 March 1988, having previously been designated as a Nature Reserve on 5th December 1969. Horton Plains is a gently rolling highland plateau 2,200 m above sea level, at the southern end of the central mountain massif of the island (DWC, 2006a).

There are two dominant vegetation types in the Horton Plains, namely upper wet pattana grasslands and upper Montane Rain forests or cloud or mossy or elfin forest (DWC, 2006c). Pattanas or plain vegetation occur above 1500 m. Tussock grasses, such as *Chrysopogon nodulibarbis* and *Garnortia tectorum*, predominate the grasslands except in damp valleys where pure stands of endemic dwarf bamboo *Arundinaria densifolia* form a thick cover. A rich herbaceous flora flourishes on the pattanas with numerous species of both temperate and tropical origin. The forest canopy grows to about 20 m and is dominated by the endemic Keena *Calophyllum walkeri*, in association with varieties of Myrtaceae (*Syzygium rotundifolium* and *S. sclerophyllum*) and Lauraceae (*Litsea*, *Cinnamomum* and *Actinodaphne speciosa*)(IUCN, 1990).

Among spectral change detection methods, Normalized Difference Vegetation Index (NDVI) image differencing emerges as one of the most widely used. NDVI is a measure derived by dividing the difference between near infrared (NIR) and red reflectance (R) measurements by their sum (Singh, 1989). NDVI relies on the principal that the healthy vegetation canopies reflects very little solar energy in the visible wavelengths (0.4 - 0.7 μ m), and the reflectance sharply increases in the near infrared wavelength region (0.7- 1.1 μ m) (Mohammad, 2011). The tasseled cap+ transformation (TCT) applied to satellite images proved to be useful in separating the different categories of land on larger areas, according to their use (ArcGIS Help 10.1, 2013).

From a biodiversity point of view, the lack of consistent and up to date information on quantity and quality of natural habitats in PAs in Sri Lanka have been identified as major constraints for the implementation of the management plans and it becomes evident that a common reference scheme is required for proper conservation management and monitoring interventions. There are a number of wildlife ecologists and biologists who have studied and surveyed Horton Plain area in different times and compiled the species data with more or less an account of the spatial distribution. Previous attempts to develop existing vegetation cover maps of this park; Survey carried out by DWC (2006a) identified 10 habitat types such as undisturbed forest, forest dieback areas, tussock grass, carpet grass, bamboo, ecotone, rock outcrop, park buildings, streams and ponds. But, definitions of some vegetation categories such as ecotone are not clear. Forest Dieback studies conducted in HPNP (2006c & 2007) categorize vegetation into tea, open forest, dense forest, marsh, grassland and pigmy forests.

But, these researches failed to produce detail maps for temporal changes of each vegetation classes.

This study focuses on developing classified vegetation maps for two time periods (1998 and 2008) and quantifies the temporal area variation of the vegetation. Vegetation map was developed using IRS LISSA III images.

METERIALS AND METHODS

A past vegetation map of Horton Plains National Park was employed as a reference. These vegetation maps were compiled in year 2006 and 2007 by DWC, based on inventory field work and Satellite images. The first detailed vegetation map in this area using remote sensing was done by DWC under the research project “Habitat Maps for Selected Areas in Sri Lanka: Horton Plain National Park” and second stage of mapping was also done by DWC (2007) under “Follow up Study of Forest Dieback in Horton Plains National Park”. Also, Google map was used for identification of training areas in the IRS (Indian Remote Sensing) satellite data interpretation. Moreover, errors were reduced by ground truth data and field experience.

The processing sequence is shown in Figure 1. The first step was to obtain qualified satellite images for this study area’s satellite Images from IRS LISS III (Linear Imaging Self Scanning Sensor) sensor and was obtained on 22nd February 1998 and 18th February 2008. The images are acceptably cloud free and spatial resolution is 23.5 m.

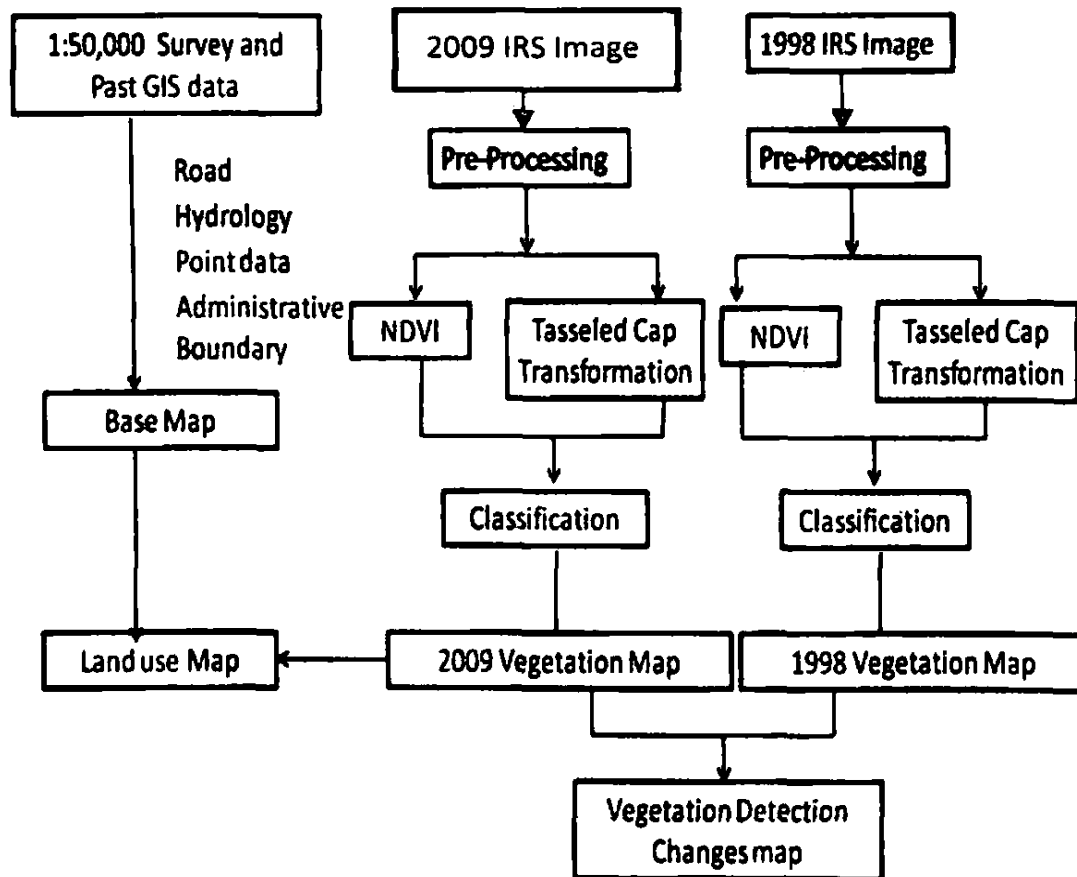


Figure 1. Conceptual frameworks for research

These images were procured and processed with the help of the image processor tools EARDS IMAGINE 9.1 and ArcGIS 9.3. Topographic map (1:50,000) from Department of Survey, existing data from DWC was used for digitizing and identifying boundary of the study area. GPS was used to take ground control points for identifying the training samples. Past literature (DWC, 2006c & 2007) was also used to identify distinct vegetation classes.

Image pre-processing

Both IRS images were geo-referenced using ERDAS Imagine software based on eight ground control points (GCPs) acquired from the 1:50,000 topographic maps of 67 (Avisawella) and 68 (Nuwara Eliya) sheets. The projection of the image was Transvers Mercator (TM) system with Kadawala map datum. It was re-sampled using the nearest neighbor method to 20 meter pixel size to create the corrected image. The study area was then subset and extracted from the output image to reduce the extraneous data outside the study area and to speed up digital image processing. The NDVI was calculated for each image using the following formula in ERDAS IMAGINE 9.1 software.

$$\text{NDVI} = (\text{NIR} - \text{R}) / (\text{NIR} + \text{R})$$

Where NDVI = Normalized Difference Vegetation Index

NIR = Near Infrared

and R = Red

The Tasseled Cap Transformation (TCT) was used to enhance separation between soils and vegetation through the determination of three indices namely, soil brightness, greenness and soil moisture, for both 1998 and 2008 IRS LISSA III images. TCT were derived using ERDAS 9.1 which transforms the four IRS bands into 3 bands of known characteristic soil brightness, vegetation greenness and wetness. Finally, NDVI and TCT images were multiplied together using ERDAS 9.1. The Unsupervised classification with Iterative Self-Organizing Data Analysis Techniques (ISODATA) digital image processing techniques was applied in the study. In the unsupervised classification approach, 50 spectral classes was classified with a specified ISODATA convergence threshold of 0, 97. The 50 classes were then reclassified, labeled and aggregated into 5 classes.

Field data collection and Assessment of Classification Accuracy

The ground reference sample points were measured during the field visit to the study area during the period from October 2013 to August of 2008. The GPS points (119 sample points) were used for classification accuracy assessment. The expected outputs from the digital classifications were mapped, representing vegetation cover patterns in the area. Several field surveys were carried out with the aid of printed maps and navigational Global Positioning System (GPS), with a 5- m positional accuracy, to identify classes and compare classified images with field data. Accuracy assessment was made by the confusion matrix procedure in which a set of random samples of classified data of the IRS images and reference data collected from the field visits were compared.

RESULTS AND DISCUSSION

Normalized Difference Vegetation Index (NDVI) Analysis Results

NDVI provides information about the spatial and temporal distribution of vegetation communities and vegetation biomass. The NDVI shows darker shades for grass dominant areas due to a lack of green vegetation. Forest areas will appear in lighter shades due to the vegetation reflectance. Figures 2 and 3 show the vegetation distribution maps using categorized of NDVI values for 1998 and 2008 respectively. Value ranges 0 to 0.46 and 0 to 0.45 indicate marsh and grass dominant areas showing low reflectance of wavelengths for

CHANGE DETECTION IN VEGETATION COVER OF HORTON PLAINS

both years respectively. NDVI value ranges 0.46 to 0.73 and 0.45 to 0.75 reflect high reflectance of wave length that indicates forest areas for each year.

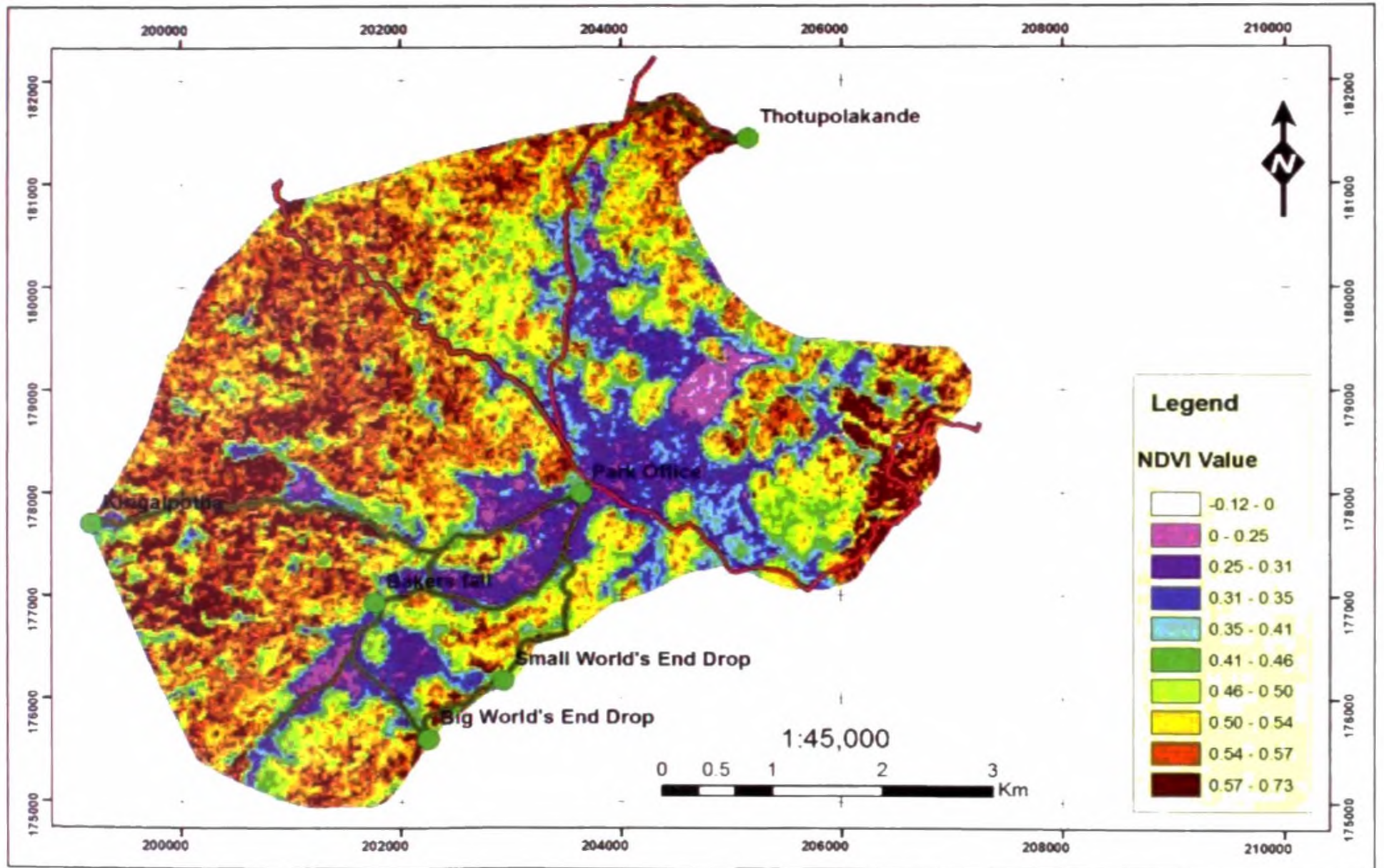


Figure 2. Vegetation distribution maps using categorized of NDVI values for 1998

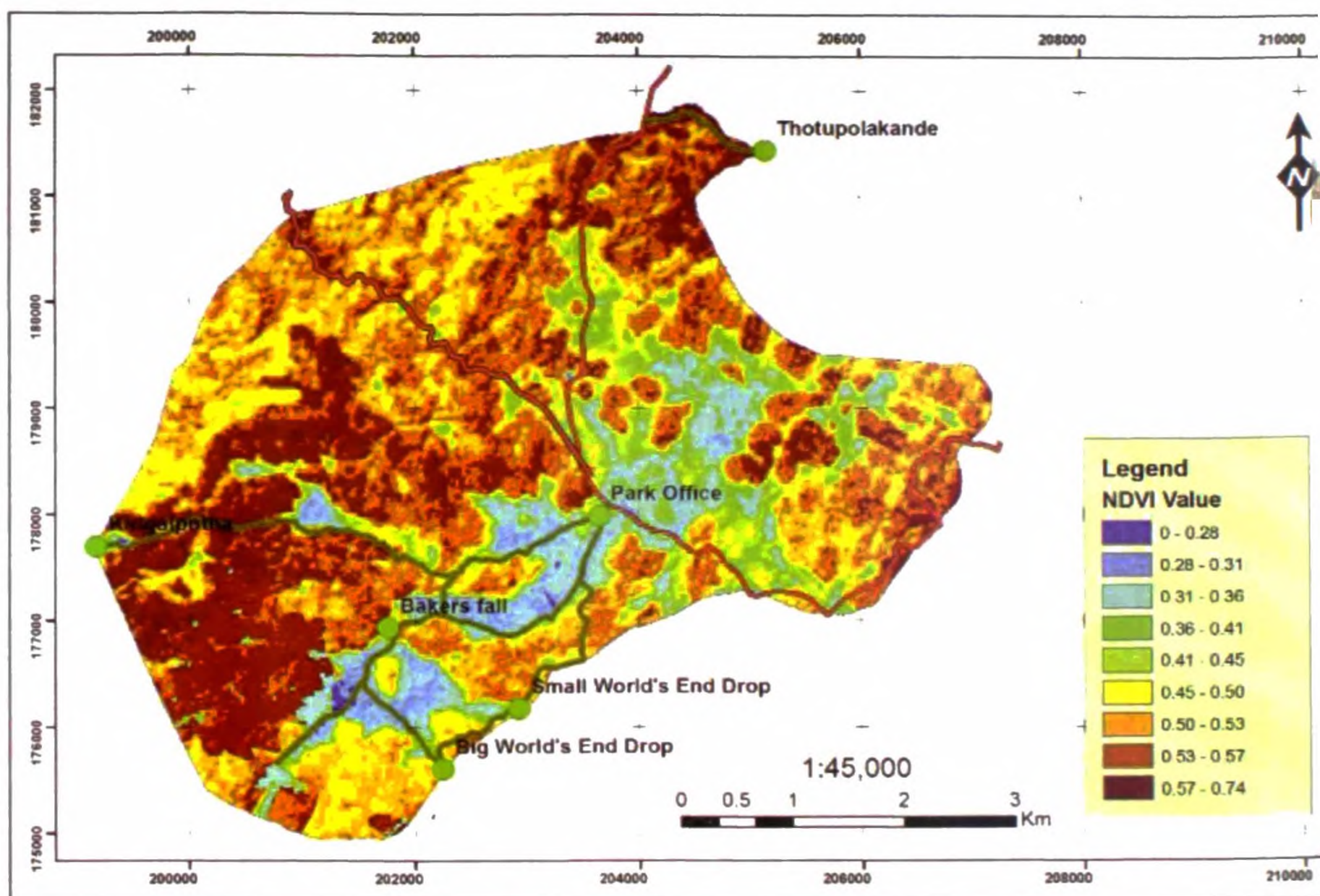


Figure 3. Vegetation distribution maps using categorized of NDVI values for 2008

Tasseled Cap Transformation (TCT) Results

TCT compressed the original four IRS reflectance bands and converted them into three indices: brightness, greenness and wetness. The brightness measure was able to outline the forest land boundary from grasslands due to the difference in brightness value. Water bodies appear dark in the brightness index because of the low reflectance property of water bodies. TCT results were used to define forest area and grass area in the unsupervised classification. Figures 4 and 5 show TCT value ranges after histogram stretch using ArcGIS 10.1. Value ranges 187.81 to 227.76 in 1998 and 342.40 to 479.36 in 2008 indicate grass and Marsh /dwarf bamboo dominant vegetation and value ranges 87.94 to 187.81 and 0 to 342.40 indicate forest cover in 1998 and 2008 respectively.

CHANGE DETECTION IN VEGETATION COVER OF HORTON PLAINS

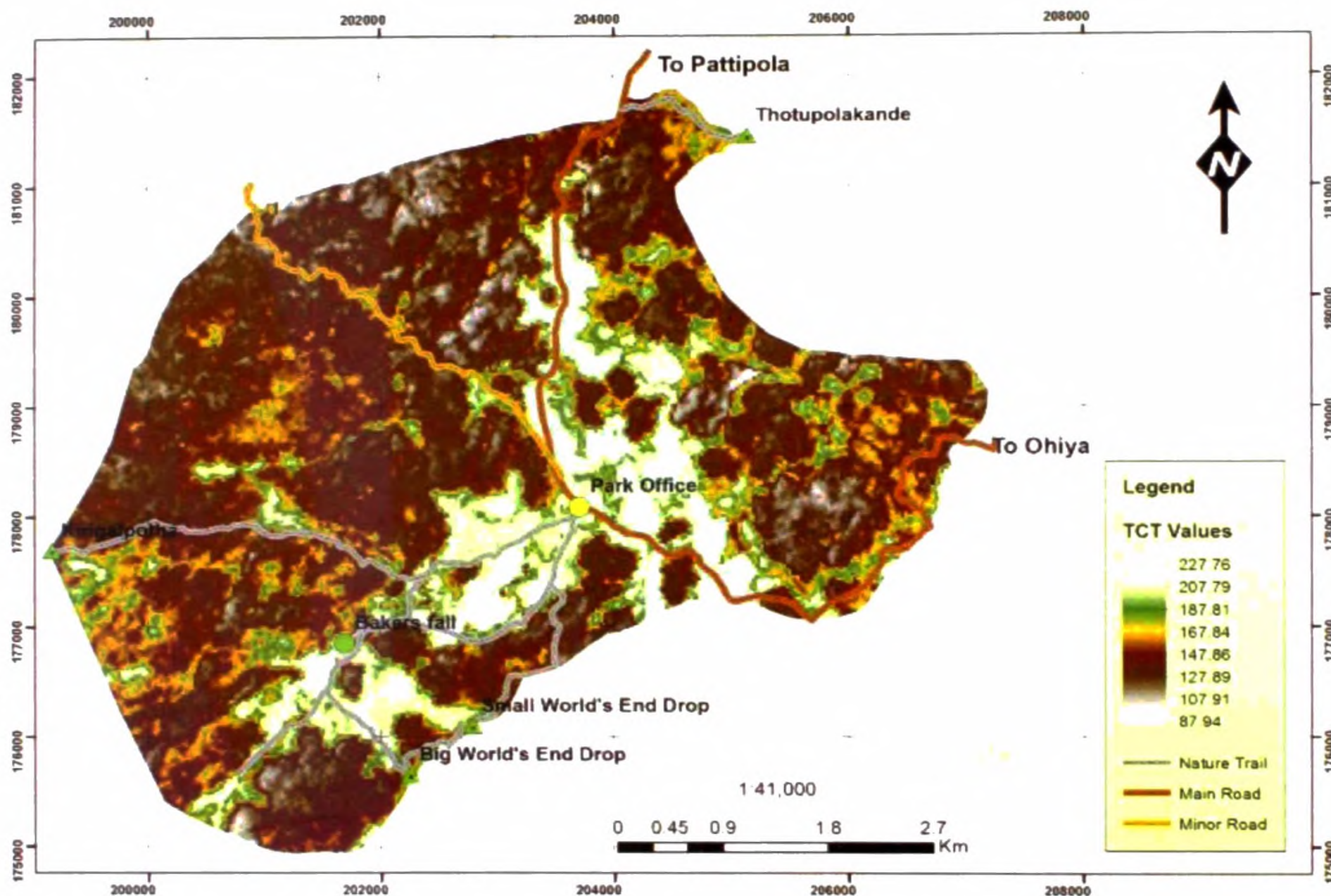


Figure 4. Separation of vegetation categories using TCT in the 1998 image

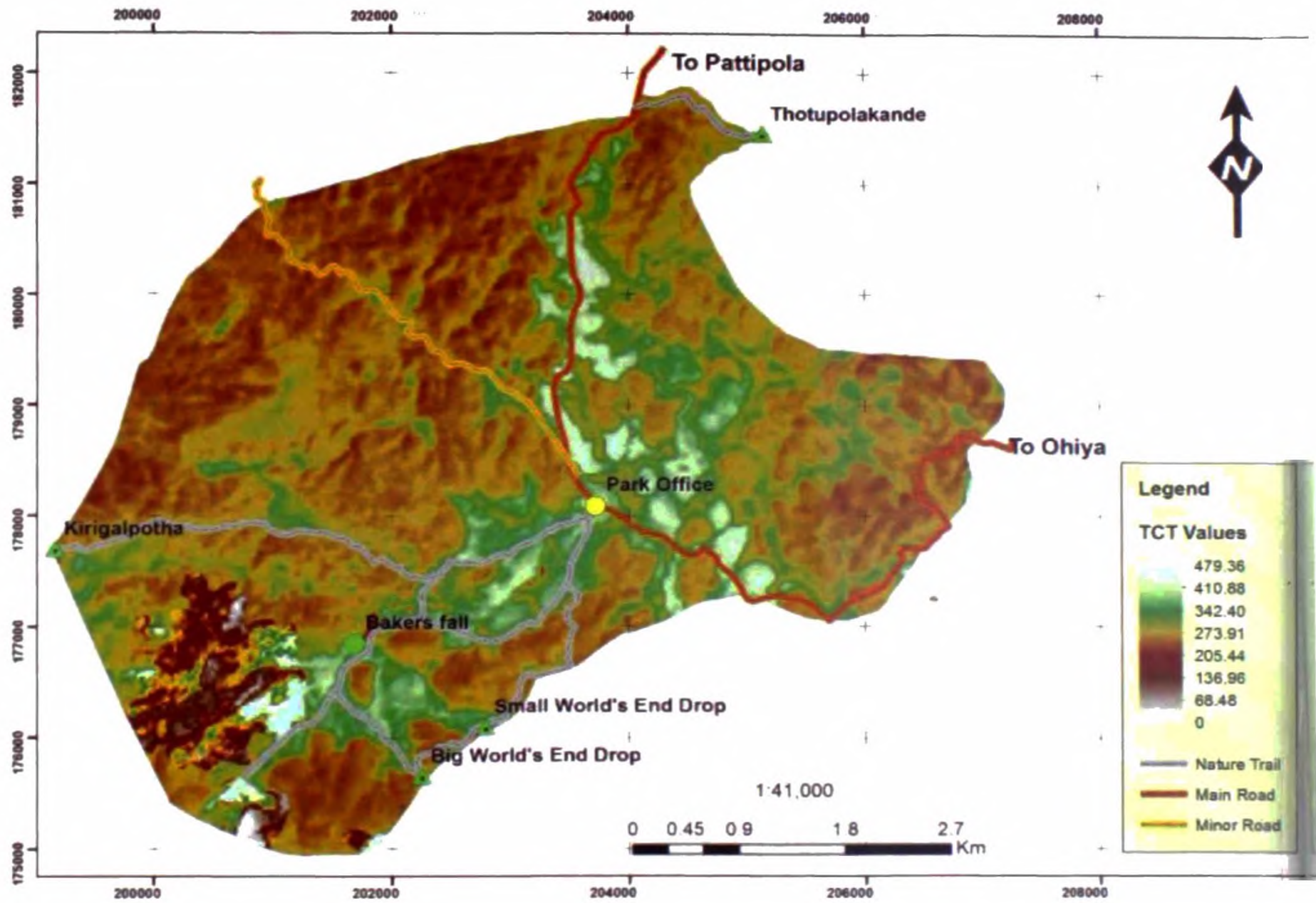


Figure 5. Separation of vegetation categories using TCT values in the 2008 image

Multification?? of TCT with NDVI image has given better classification result that was used to enhance separation between marsh area, grass and forest area in the HPNP. The dark colors indicate marsh/draft bamboo, and grassland. Light dark colors indicate dense forest area and darker bright color reflects open forest.

Vegetation Classification Maps

Prior to unsupervised classification, five vegetation class categories were distinguished as shown in the Table 1. Vegetation in the study area was classified into following cover classes based on maximum likelihood and minimum distance classifiers which are Tussock grass dominant areas, carpet grass, marsh (dwarf bamboo dominant areas), open forest, and dense forest.

Table 1. Description of vegetation classes used for analyses of changes in land use/land cover

Class Name	Description
Dense forest	Undisturbed old-growth forest is low in stature (15-20 m) and canopy trees are characteristically gnarled and twisted due to high winds. The canopy is dominated by species such as <i>Calophyllum walkeri</i> , <i>Michelia nilagirica</i> , <i>Syzygium rotundifolium</i> , <i>S. revolutum</i> , <i>Elaeocarpus montanus</i> , <i>Elaeocarpus glandulifer</i> , <i>Elaeocarpus coriaceus</i> , <i>Ilex walkeri</i> , <i>Cinnamomum ovalifolium</i> and <i>Litsea ovalifolia</i> .
Open forest	The death of aging trees may be due to pathogenic/climatic dieback or natural senescence. Access inside the forest is difficult due to dense undergrowth of species such as <i>Hedyotis</i> (Weraniya), <i>Strobilanthes spp.</i> (Nelu), <i>Sarcococca brevifolia</i> , <i>Euphorbia rothiana</i> and thorny species such as <i>Thodalia</i> (Kudumiris) and <i>Rubus</i> . In valleys and mid-slopes <i>Strobilanthes spp.</i> may dominate areas of canopy dieback sites (DWC, 2006b).
Marsh areas	The dwarf bamboo (<i>Arundinaria densifolia</i>) grows well on valley bottoms, surrounding depressions and small streams (Plate 7 & 8). In the past it occurred only close to streams but now has spread over a much larger area (DWC, 2006b). The species is endemic to Sri Lanka and found only in Horton Plains.
Carpet/ <i>Pennisetum</i> Grass	Carpet grass (<i>Axonopus fissifolius</i>) / <i>Pennisetum sp.</i> having the appearance of a lawn, has colonized abandoned potato fields. The species is thought to have been introduced via manure used to fertilize the potato fields.
Tussock Grass	Grassland that is dominated by three species of tussock or clump grasses: <i>Chrysopogon nodulibarbis</i> and <i>Andropogon polytychos</i> in drier locations; and the much broader leaved, taller and larger <i>Garnotia exaristata</i> in wetter areas. Tussock grasses are confined to lower slopes and valley bottoms. Maha Ratmal (<i>Rhododendron arboreum</i>) is commonly found scattered throughout these grasslands.

DWC (2006c & 2007) described of forest dieback areas in HPNP but did not classify vegetation in details. DWC studies were limited to interpretation of satellite image visually and digitizing according to field data without classification algorithms (Table 2). DWC (2006a) identified vegetation classes using supervised image classification and field sampling data (Table 2).

There was no clearly demarcated ecotone between forest and grassland in HPNP. Identification of transition vegetation type between grassland and forest (ecotone) was somewhat difficult in HPNP. *Rhododendron sp.* scattered grassland could not be considered as gradual extension of forest species to the grasslands. Other problem is that 23 x 23 pixels resolution satellite image could not evaluate correct extent of water bodies and rock outcrops in the park, because most of streams are covered by forest. But, it could be evaluated with object oriented image classification with high resolution satellite images.

Vegetation class analysis of HPNP in 1998 and 2008

The spatial extent of the 1998 and 2008 vegetation map after the Unsupervised Classification yielded vegetation cover classes (Figures 6, 7 & Table 2) with the dense forest occupying the highest percentage of the area (1,523.02 ha, 48.19% and 1,501.80 ha, 47.52%). The next

vegetation class with the highest area coverage is the Open forest (744.53 ha, 23.56% and 897.80 ha, 28.41%). Tussock grass dominant area (656.81 ha, 20.78% and 430.76 ha, 13.63%) is the next highest area coverage located mainly in the center part of the park. Marsh comes next with 168.95 ha (5.35%) and 276.88ha (8.76%) and its area coverage consists of small strips along streams courses and marshy areas. Carpet/*Pennisetum* grass covers 67.02 ha (2.12%) and 53.10 ha (1.68%) in small patches scattered across the tussock grasslands where potato was cultivated earlier.

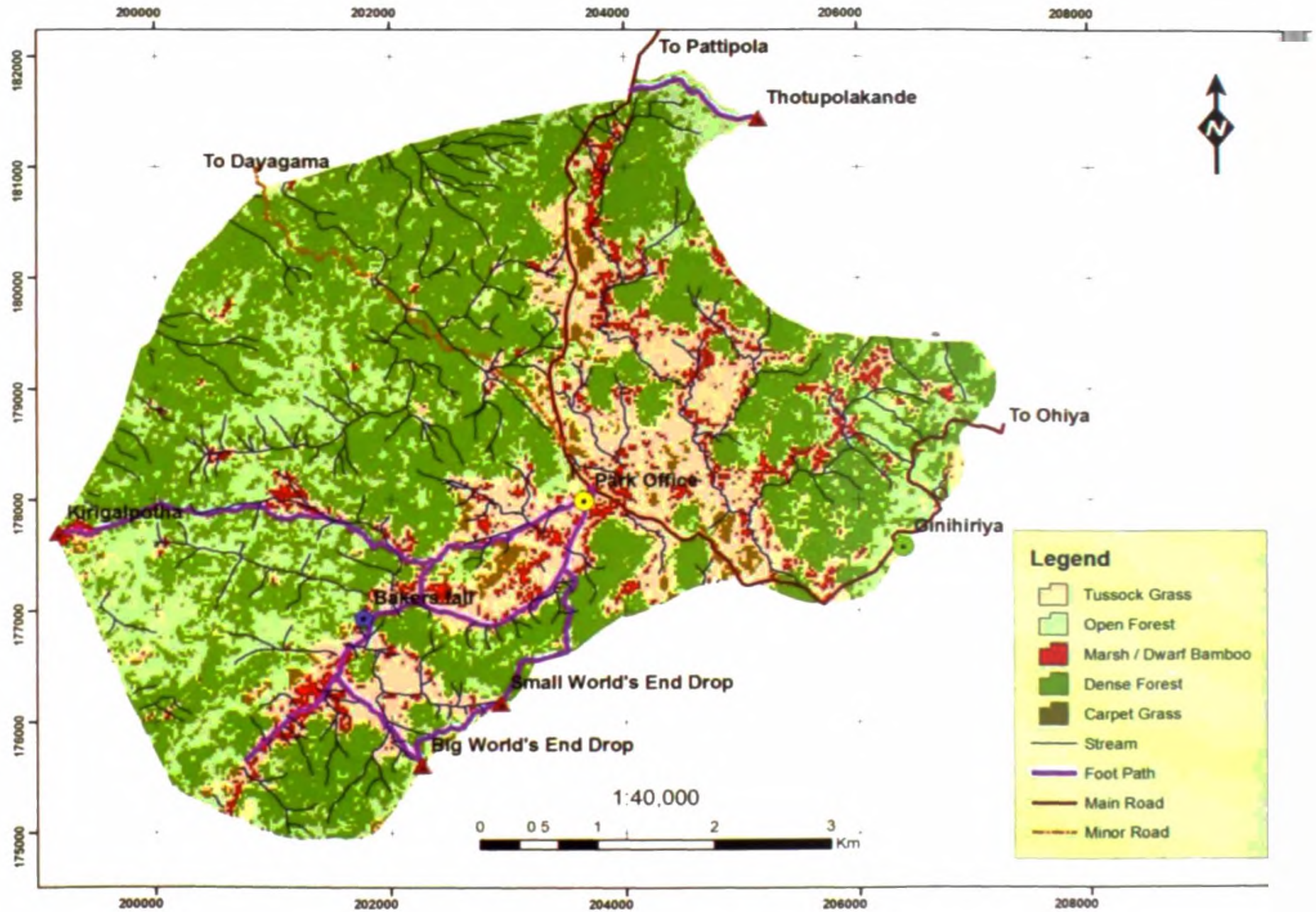


Figure 6. Major Vegetation Types in Horton Plains National Park-1998

CHANGE DETECTION IN VEGETATION COVER OF HORTON PLAINS

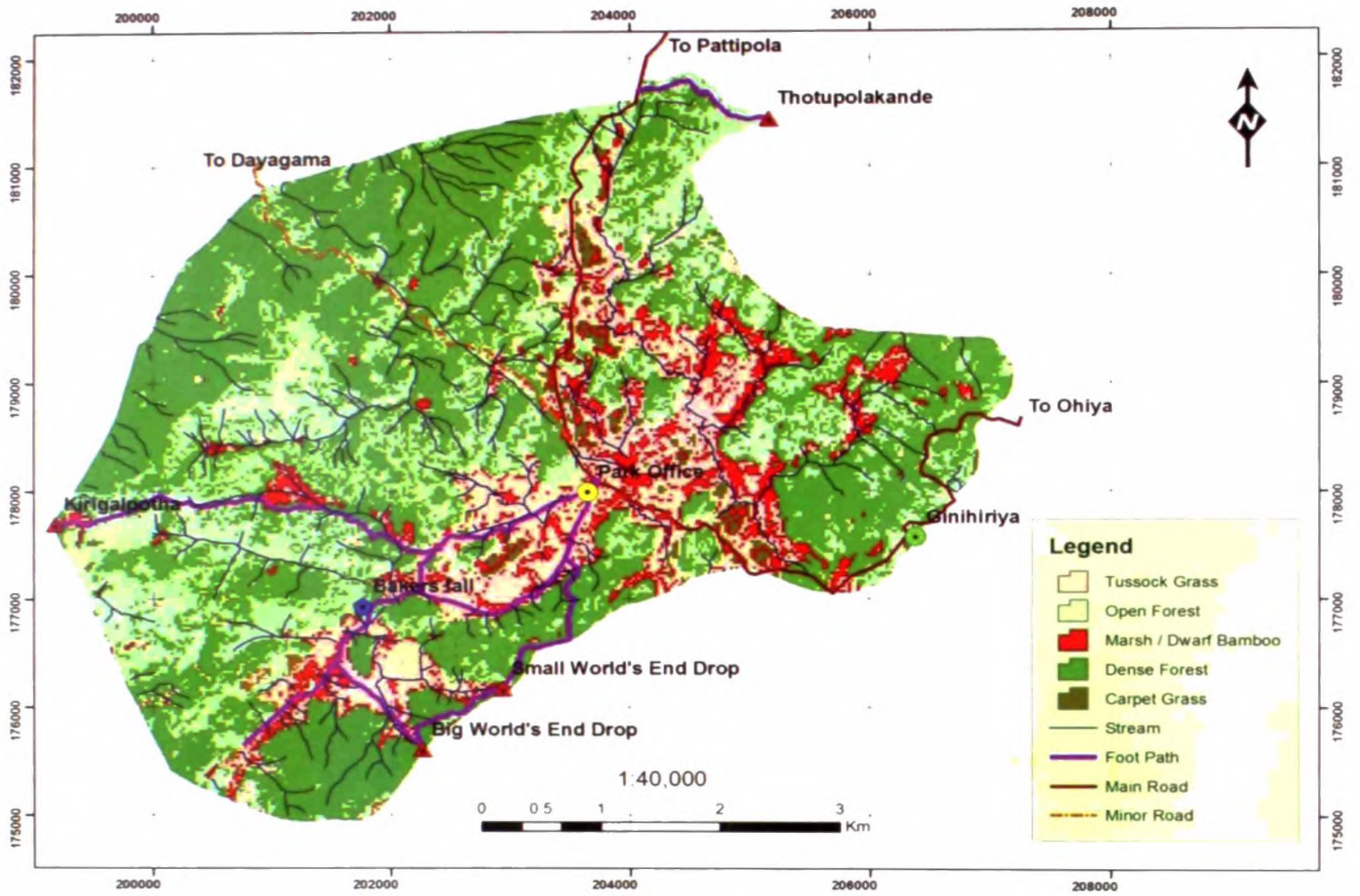


Figure 7. Major Vegetation Types in Horton Plains National Park-2008

Table 2. Comparison of extent of vegetation cover with past research studies

Vegetation Classes	DWC, 2006 research		DWC, 2007 research		Present study (1998 Satellite image classification)		Present study (2008 Satellite image classification)	
	Extent (Ha)	%	Extent (Ha)	%	Extent (Ha)	%	Extent (Ha)	%
Tea	-	-	173.03	5.21	-	-	-	-
Open forest /Forest dieback	956	30.7	255.82	7.70	744.53	23.56	897.80	28.41
Dense forest/ Undisturbed	1,236	39.7	1,920.96	57.81	1,532.02	48.19	1,501.80	47.52
Ecotone	45	1.45	-	-	-	-	-	-
Marsh /Dwarft bamboo	168	5.40	235.96	7.10	168.95	5.35	276.88	8.76
Grassland	-	-	663.41	19.96	-	-	-	-
Tussock	574	18.43	-	-	656.81	20.78	430.76	13.63
Carpet/ <i>Pennisetum</i>	64	2.06	-	-	67.02	2.12	53.10	1.68
Pigmy forest	-	-	74.66	2.25	-	-	-	-
Rock outcrop	53	1.70	-	-	-	-	-	-
Park building	3	0.10	-	-	-	-	-	-
River	14	0.45	-	-	-	-	-	-
pond	0.8	0.03	-	-	-	-	-	-
Total	3,113.8		3,322.92		3,160.34		3,160.34	

Table 2 shows a comparison of the extent of vegetation classes with past research studies. Table 2 indicates different total extents of the park area. But, it should be approximately 12.2 square miles according to Extraordinary Gazette Notification No. 497/10, dated 16th March of 1988. Therefore, present study used 3,160 ha of boundary shape file providing by DWC to extract the image.

Accuracy Assessment

A classification accuracy assessment was performed using ground control points that were collected during field studies. A classification accuracy assessment was performed on the 1998 and 2008 vegetation maps for the study area and an assessment report was obtained having an error matrix, accuracy totals and a kappa statistics (Table 3& 4). An overall Classification accuracy of 83.17% and 86.55% and a Kappa coefficient (Overall Kappa Statistics) of 0.7412 and 0.80 was achieved respectively.

CHANGE DETECTION IN VEGETATION COVER OF HORTON PLAINS

Table 3. Accuracy Assessment of the Classification of 1998 image

Field Data	Classified Data					Total	Producer Accuracy
	Tussock Grass	Carpet Grass	Marsh	Open Forest	Dense Forest		
Tussock Grass	16	0	01	01	0	18	88.89%
Carpet/ <i>Pennisetum</i> Grass	01	04	0	0	0	05	100.00%
Marsh	01	0	08	0	0	09	66.67%
Open Forest	0	0	02	21	05	28	67.74%
Dense Forest	0	0	01	09	49	59	90.74%
Total	18	04	12	31	54	119	
User Accuracy	88.89%	80.00%	88.89%	75.00%	83.05%	100%	83.17%

Table 4. Accuracy Assessment of the Classification of 2008 image

Field Data	Classified Data					Total	Producer Accuracy
	Tussock Grass	Carpet Grass	Marsh	Open Forest	Dense Forest		
Tussock Grass	15	0	02	0	0	17	78.95%
Carpet/ <i>Pennisetum</i> Grass	0	03	0	0	0	03	75.00%
Marsh	0	01	05	0	0	06	62.50%
Open Forest	04	0	0	25	06	35	92.59%
Dense Forest	0	0	01	02	55	58	90.16%
Total	19	04	08	40	61	119	
	88.24%	100.00%	83.33%	71.43%	94.83%		86.55%

According to Ayele (2011) kappa values are characterized into 3 groups: a value greater than 0.80 (80%) represents strong agreement, a value between 0.40 and 0.80 (40 to 80%) represents moderate agreement, and a value below 0.40 (40%) represents poor agreement. Therefore, this finding shows that there is strong agreement between the classification map and the ground reference information.

Vegetation Cover Change

The major vegetation classes for years 1998 and 2008 were quantitatively analyzed for the area covered by each vegetation cover categories. For a clear and informative comparison of the vegetation cover change, area values for the periods 1998 and 2009 are summarized in Table5. During the period (1998 -2008), tussock grass and carpet/*Pennisetum* grass cover decreased by 7.15% (226.05 ha), 0.67% (21.23) and 0.44% (13.92 ha) respectively, while Marsh / Dwarf Bamboo and Open Forest by 3.41% (107.92 ha), and 4.85% (153.27 ha) respectively (Figure 8 & 9).

Table 5. Change detection matrix of vegetation cover types HPNP between 1998 and 2008 (ha and %)

Vegetation class	2008					class Total
	Tussock Grass	Carpet / <i>Pennisetum</i> Grass	Marsh / Dwarf Bamboo	Open Forest	Dense Forest	
1998 Tussock Grass	311.87 ha (9.87%)	26.30 ha (0.83%)	160.79 ha (5.09%)	42.20 ha (1.34%)	115.66 ha (3.66%)	656.81 ha (20.78%)
Carpet Grass	20.18 ha (0.64%)	20.74 ha (0.66%)	11.35 ha (0.36%)	8.94 ha (0.28%)	5.81 ha (0.18%)	67.02 ha (2.12%)
Marsh / Dwarf Bamboo	63.02 ha (1.99%)	1.23 ha (0.04%)	76.35 ha (2.42%)	8.68 ha (0.27%)	19.67 ha (0.62%)	168.95 ha (5.35%)
Open Forest	16.06 ha (0.51%)	4.13 ha (0.00%)	7.46 ha (0.24%)	434.34 ha (13.74%)	282.55 ha (8.94%)	744.53 ha (23.56%)
Dense Forest	19.64 ha (0.62%)	0.71 ha (0.02%)	20.93 ha (0.66%)	403.64 ha (12.77%)	1,078.11 ha (34.11%)	1523.02 ha (48.19%)
Class Total	430.76 ha (13.63%)	91.18 ha (1.68%)	276.88 ha (8.76%)	897.80 ha (28.41%)	1,501.11 ha (47.52%)	3,160.34 ha (100%)
Class Changes	118.90 ha (3.76%)	32.36 ha (1.02%)	200.52 ha (6.34%)	463.47 ha (14.67%)	423.69 ha (13.41%)	
Image Difference	-226.05 ha (-7.15%)	-13.92 ha (-0.44%)	107.92 ha (3.41%)	153.27 ha (4.85%)	-21.23 ha (0.67%)	

In Table 5 the values on the diagonal axis are the areas 1,078.11 ha (34.11%) of dense forest, 434.34 ha (13.74%) of open forest, 76.35 ha (2.42%) of marsh / dwarf bamboo, 20.74 ha (0.66%) of carpet/*Pennisetum* grass and 311.87 ha (9.87%) of tussock grass that have not changed during the ten year period. Therefore, the image difference indicated carpet grass tussock grass cover and dense forest decreased by 226.05 ha (7.15%), 13.92 ha (0.44%) and 21.23 ha (0.67%) respectively. Marsh and open forest showed an increase of 107.92 ha (3.41%), 153.27 ha (4.85%) respectively. The vegetation cover that remained unchanged from 1998 to 2009 is 1,921.41 ha representing 60.80% of the study area. Figure 8 depicts the total percent change for each land cover to other land cover types. The marsh/dwarf bamboo class shows the least changes compared to other land cover types and the tussock grass cover shows highest changes compared to other vegetation types. Figure 9 illustrate the increase or decrease of vegetation cover classes from 1998 to 2008

The objective of this study was to accurately and effectively identify vegetation cover change information using remote sensing for the Horton Plain National Park. The image differencing techniques were crucial in determining the appropriate land cover changes. To understand the changes occurring within a period of time an approach of temporal analysis for change detection was carried out. The classified time lapse map gives a better idea of the changes occurring within a period of 10 years by visually looking at the image and inspecting the areas where vegetation classes have expanded and decreased. It also shows where the different class colors change as time goes.

CHANGE DETECTION IN VEGETATION COVER OF HORTON PLAINS

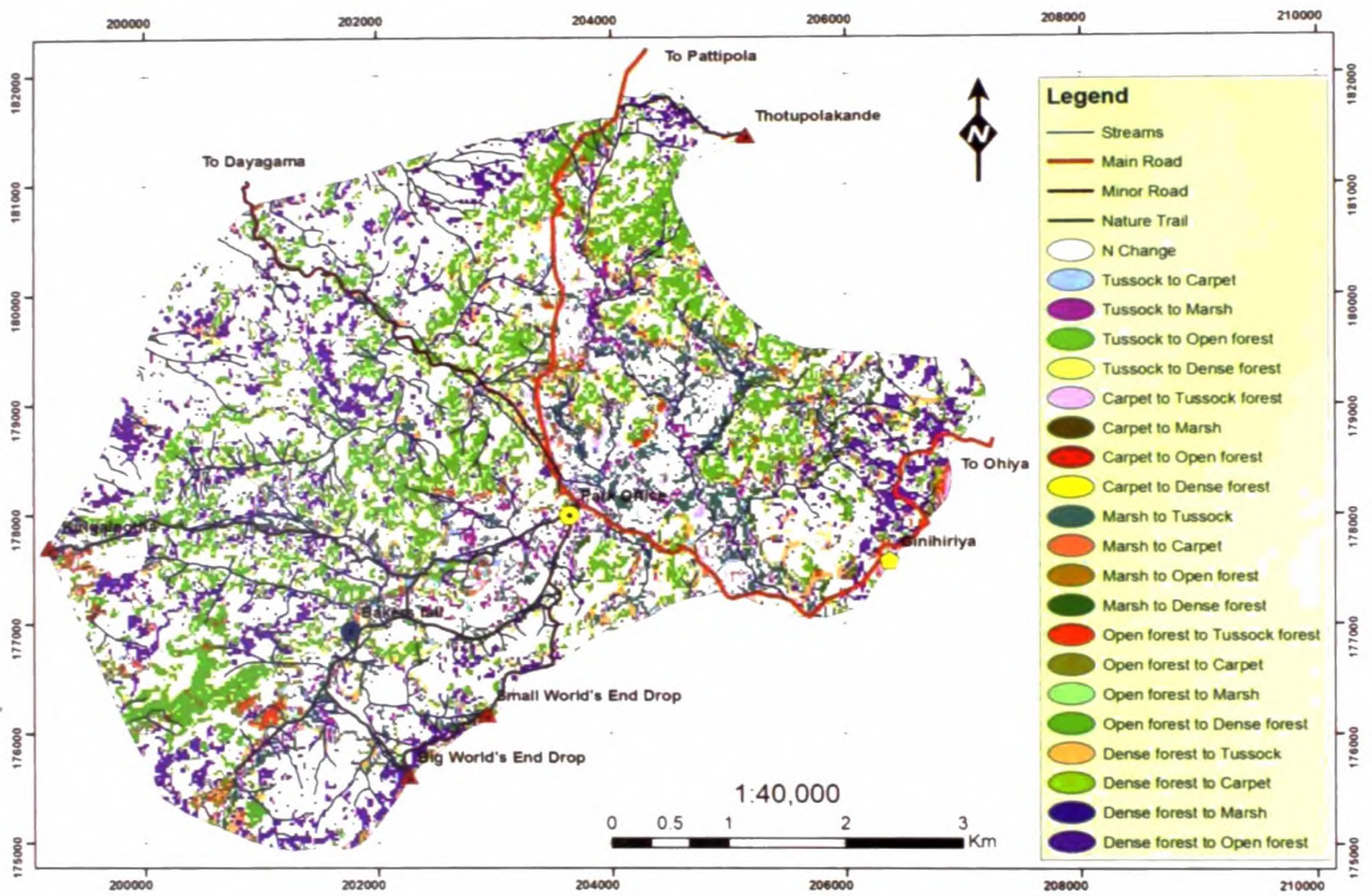


Figure 8. Vegetation Changes between 1998-2008 in Horton Plain National Park

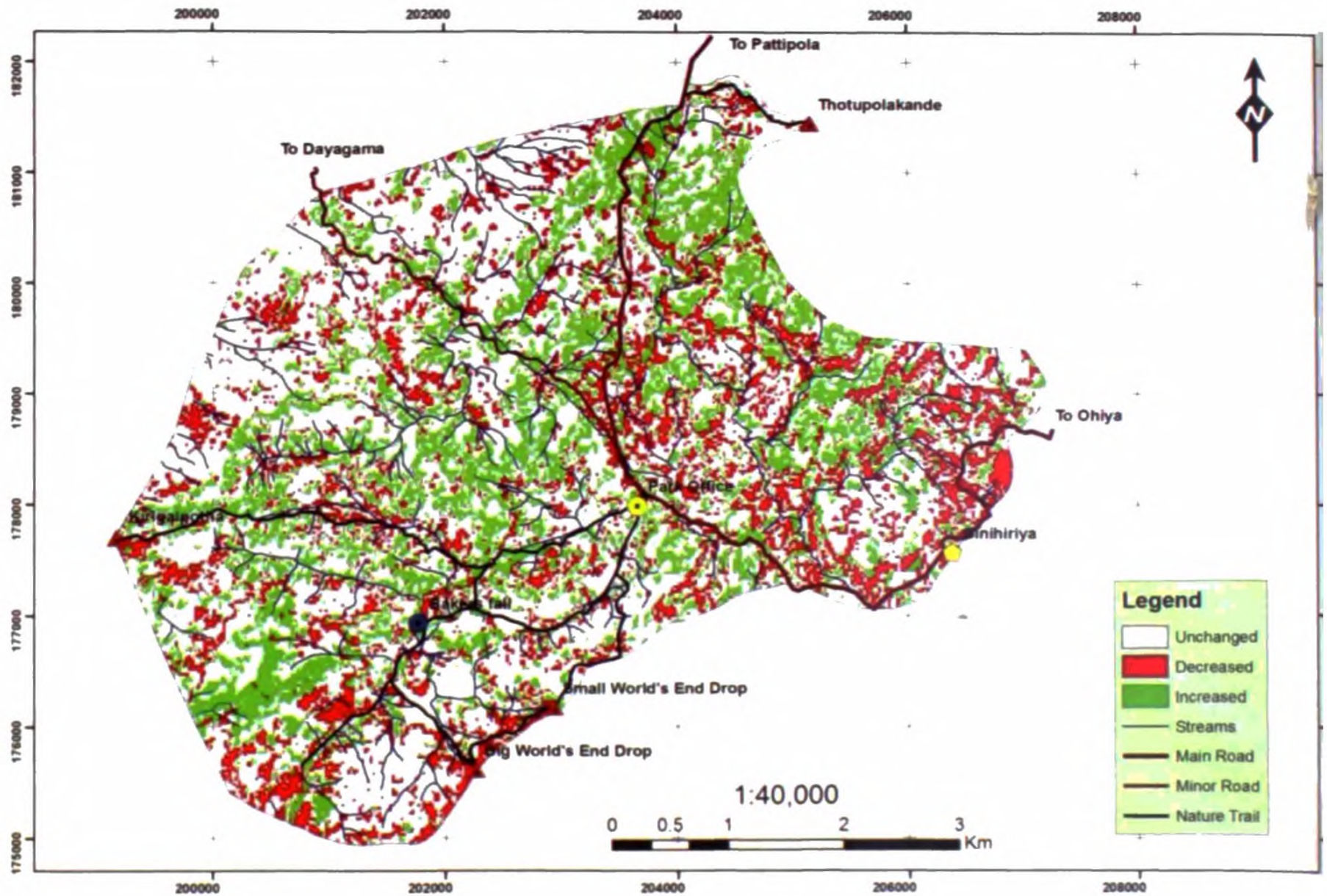


Figure 9. Decreased, increased and unchanged vegetation cover between 1998-2008

Extents of the two major vegetation types, namely forest and grass, in the Horton Plains NP in the years 1998 and 2008 are shown in Figures 10 and 11. The study showed that the forest cover (including open forest and dense forest) increased from 71.75% to 75.93% and grass cover including carpet grass, tussock grass and dwarf bamboo dominant vegetation cover was reduced from 28.25% to 24.07% between 1998 and 2009 period.

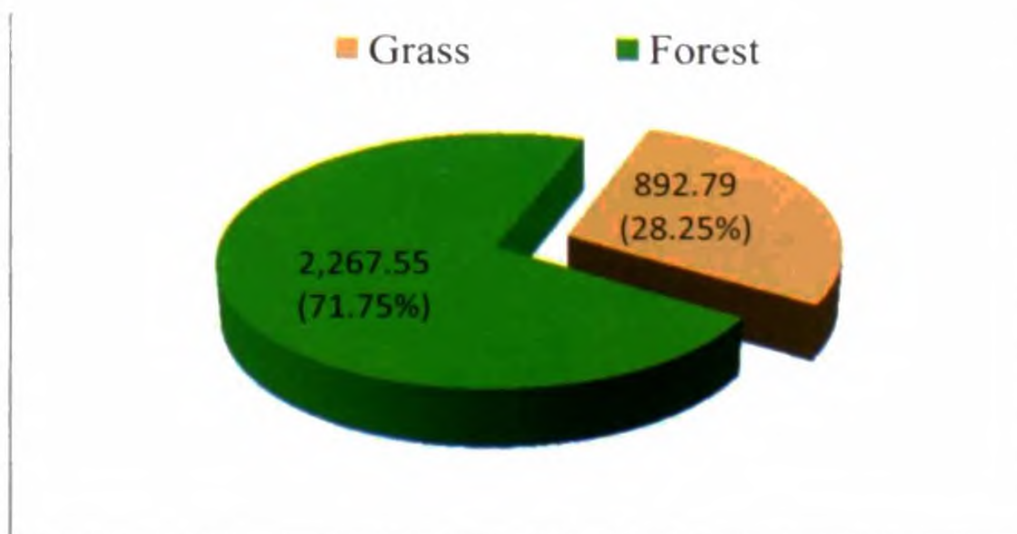


Figure 10. Major vegetation cover types in Horton Plains in 1998

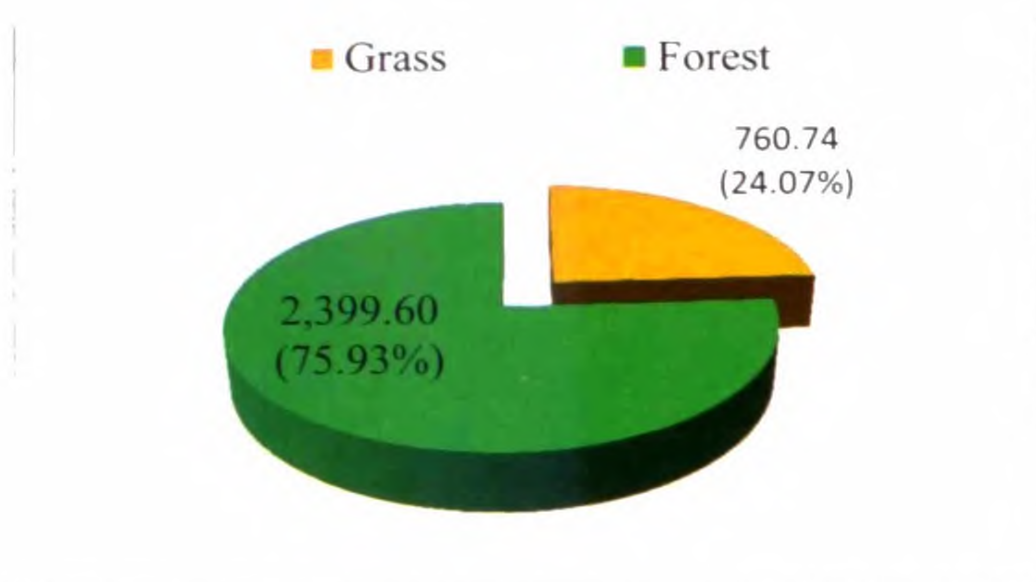


Figure 11. Major vegetation cover type in Horton Plains in 2008

According to the classification, open forest is increased as a result of spreading forest dieback in Thotupolakanda, Kirigalpotha areas and areas near Anderson wildlife bungalow. DWC, 2007 revealed that heavy dieback sites (Totupolakande) as well as the moderately dieback sites (Anderson) are exposed to heavy winds than healthy sites. Therefore, occurrence of dieback condition in Horton Plains could be triggered by winds of changing temperature and speed. In addition, water stress due to drought (not an annual phenomena), climate stress soil and air pollution, pathogens, browsing by herbivores (Sambur -*Cervus unicolor*), forest fires have been proposed as causative factors for dieback (DWC, 2007). This may also be due to the natural senescence of old growth cloud forest without natural regeneration of canopy species. The seedlings or saplings of canopy species are not found in dieback areas. *Stobilanthus* sp. in valleys and mid-slopes and *Osbeckia* sp, *Knoxia hirsute*, *Hedyotis* sp, *Rubus* sp, *Sarcococca brevifolia* have invaded the canopy-dieback areas in ridges (Ediriweera *et al.* 2007).

Grass cover decreased by an estimated 4.81% which is an area of approximately 132.04 hectares. The significant decrease in grass area may be a result of forest cover expanding toward grassland and bamboo spreading to grasslands from the stream banks.

Hoffman (1988) provided relatively the closest picture as to how upper montane rain forest of Horton Plains looked like before 1950. When he first visited Horton Plains in 1947, the low, dense, slow-growing forest had always appeared healthy and vigorous, the crowns of trees formed closed canopies and only here and there an old dying or dead tree was observed which was not noticeable to the casual observation. But at present, dead or dying tree branches and trunks can be seen clearly in southern and western part of the park including Thotupolakanda. Therefore, it was indicated as low reflectance in satellite images than dense forest canopy that was classified in to open forest category. According to DWC, (2006c) estimates, the extent of the dieback in the park is about 316.2 ha (20.1%) and most of the forest areas of the park is subjected to some degree of dieback. The survey has also revealed that 46.5% of the park area is covered by forests while grasslands cover only 19% of the park area.

CONCLUSIONS AND RECOMMENDATIONS

The main vegetation cover types identified in the HPNP are open forest, dense forest, marsh /dwarf bamboo, tussock grass and carpet grass (DWC, 2006a, 2006c and 2007). The study used post-classification comparison approach with resulting maps for the vegetation cover classes change within HPNP. The analyses revealed that the composition and configuration of the vegetation cover classes within the park had changed significantly over the 10 year period.

Maps drawn from the spatial extent of vegetation cover and changes in the study area indicate that the method of change detection was very useful in monitoring changes in each vegetation types. The image classification detected changes attributed to the decline of grass cover and increased forest cover. The method of change detection yields acceptable results and the potential for using this as a future method for detecting changes of forests vegetation. In addition, dwarf bamboo cover has expanded into marsh areas within the ten year period. Therefore, the research findings of this study could be useful in making management decisions and conservation of habitats in the HPNP.

The pattern of the changes in vegetation cover is identified using a new approach, and all the vegetation types show changes between 1998 and 2008. Particularly, Open forest cover increased from 23.56% to 28.41%, marsh / dwarf bamboo cover was increased from 5.35% to 8.76% during the period of ten years. It was also noted that the dense forest area reduced from 48.19% to 47.52%, carpet grass/ *Pennisetum* dominant area reduced from 2.12% to 1.68% and tussock grass cover was reduced from 20.78% to 13.63%. In general, forest cover of the PA has increased from 71.75% to 75.93% and grass cover (carpet/ *Pennisetum* and tussock) has reduced from 28.25% to 24.07% between 1998 and 2008 period.

In managing wildlife habitats one need to understand the extents of habitat change, where it occurs and what habitats are converted into other habitats. So the technique used in this study could be effectively used in day to day management activities of the park and the changes could be observed subjectively. Since the remote sensing is comparatively cheap techniques, this evaluation can be done each year and the annual change could be easily monitored. Rather than using rigid management plans with five year time frame, adaptive management style could be practiced in managing parks.

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CHANGE DETECTION IN VEGETATION COVER OF HORTON PLAINS

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