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Does Illegal Harvesting of Woody Plants Influence Physiognomic Status and Woody Vegetation Dynamics in Lochinvar National Park?

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Abstract

A survey of the physiognomic status of woody vegetation types in Lochinvar National Park, was carried out to determine; i)distribution, ii)species composition, iii) incidences of tree cutting and soil erosion as a consequence of illegal uses of trees by humans. Quadrats were laid out every 100 m along transects placed 250 m apart and aligned East-West direction. Tree species encountered were identified and measured. Results showed that there were six vegetation communities; i) *Brachystegia* woodland, ii) *Diplorynchus* woodland, iii) *Combretum*/*Pericopsis*/*Xeroderris* mixed woodland, iv) Mopane, v)Thicket, and vi) Other. Tree cutting and soil erosion incidences were common 98 and 97points (36% of the sites) respectively. It was concluded that woody vegetation had experienced high illegal off-takes and measures were required to curb the trend. Further research is required to investigate the proportional impact of each human use and influence of late fires which consume tree remnants after desirable parts of the tree have been collected.

Keywords: Tree cutting, Woodland, Soil Erosion, Species Composition, Vegetation Distribution

1. Introduction

Lochinvar National Park is located on the Kafue flood plain system (Figure 1), lying between 970 – 1,038 m above sea level making it generally flat, a factor responsible for annual flooding and maintenance of a floodplain (Figure 2a). With annual flooding, woodland vegetation is restricted to a small slightly higher ground zone in the southern part of the National Park where there are fire climax woodlands. In 1979, the Government of the Republic of Zambia commissioned the Itezhi-Tezhi reserve dam to hold water for the generation of electricity at the Kafue gorge. At the time, there were no legislative frame works compelling developers to conduct an Environmental Impact Assessment (EIA). Subsequently Lake Itezhi-Tezhi was formed which disrupted the natural flooding regime that had maintained the Kafue flats dynamics at equilibrium. Major vegetation community changes were predicted and some of them have occurred and continue to take place on the Kafue Flats. The sudden disruption of the natural flooding regime and the ecological dynamics taking place on the Kafue Flats attracted attention of scholars and various studies have been carried out to determine the impact of the disrupted flooding cycle on the ecosystem. Monitoring of the impacts of the disrupted flooding regime is very important because construction of the Itezhi-Tezhi dam preceded promulgation of the legal framework on EIAs. Subsequently, no EIA was done to identify potential negative environmental consequences of damming on the natural vegetation communities and to predict and put in place mitigation measures. Since the area is generally divided into three major zones (Figure 2b), with each zone having a characteristic fauna and flora, it was expected that each zone with its unique vegetation community would respond differently to the changed flooding regime. The northern third is a flood plain and continues to be inundated annually by the Kafue River (Figure 3a). The central zone comprises termitaria grassland (Figure 3b & c), with grassy plains and scattered termite mounds. In this zone *Euphorbia candelabrum* is common and it is in this same zone woody encroachment has been recorded since the commissioning of the Itezhi-Tezhi dam. It is these and other similar changes in the dynamics of vegetation communities that have attracted numerous studies to document impacts of disrupted natural flooding cycle on the ecology of the Kafue Flats.

Woodlands are located in the southern and south-eastern corner of the park within a few kilometres from local communities (Douthwaite & van Lavieren, 1977) (Figure 2a; Figure 3d). This woody vegetation community, has in addition to the impacts of the disrupted flooding regime also experienced pressure from illegal human activities, such as late fires, illegal harvesting for timber, firewood, and other extractive uses. Widespread tree cutting and cattle grazing were reported to be among top priority concerns for park management which is why this study was commissioned to generate data necessary for adaptive management.

The effects of illegal harvesting of woody plants were especially obvious in the woodland area (Figure 3d), which as already mentioned, was near the National Park boundary close to human settlements. This pressure from illegal harvesting by humans coupled with change in vegetation accentuated by changes in flooding regime after 1979, underscored the importance of this study. This was critical for three main reasons; i) to collect baseline data for the monitoring of changes in woody vegetation communities, ii) that big trees were also important habitat for fauna in particular as nesting sites for large birds and raptors (Chomba and M'simuko, 2013 a & b), and iii) to understand the distribution pattern of large trees as an important requirement for securing nesting sites for threatened species of raptors (Chomba and Eneya, 2013a) and to protect the soil from erosion. The objectives of the study were as follows; i) to describe current distribution of woodlands in Lochinvar National Park and compare as baseline, with past distribution status, iv) to provide information on species composition and characteristics of woodlands in the south-eastern corner area of Lochinvar National Park which is under extreme pressure from illegal harvesting by surrounding local communities, and v) to understand spatial distribution of illegal activities, including grazing and tree cutting, and incidences of soil erosion.

2. Methods and Materials

2.1 Study Site Description

Lochinvar National Park covers an area of about 410 km^2 in extent, representing about 7.9% of the Kafue Flats' total area of 5, 175km^2 an extensive floodplain of the Kafue River System, situated between the Itezhi-Tezhi and Kafue Gorge dams. It is located at 15^o 40'S - 16^o 10' S and 27^o 10' E-28^o 20'E in Southern Province of Zambia. There are two National Parks on the Kafue Flats; Blue Lagoon National Park on the north bank and Lochinvar National Park in the south and between the two National Parks is the Kafue Flats Game Management Area (Figure 1). The National Park was designated a Wetland of National Importance (Ramsar Site) together with Blue Lagoon in 1991 and is home to an endemic subspecies and semi aquatic antelope the Kafue lechwe (*Kobus leche kafuensis*) and IUCN endangered bird species including wattled crane (*Grus carunculatus*) and Zambian endemic barbet (*Lybius chaplini*).

2.2 Climate

There are three main seasons; rainy season (November-March), cool dry season (April-July), and hot dry season (August –October/November). On average, annual rainfall is between 700 - 800 mm and trends have been on the decline in the last two decades. The mean annual temperature is 20.6^{o}c and increasing in the past two decades. Total evaporation is about 2,032 mm per annum.

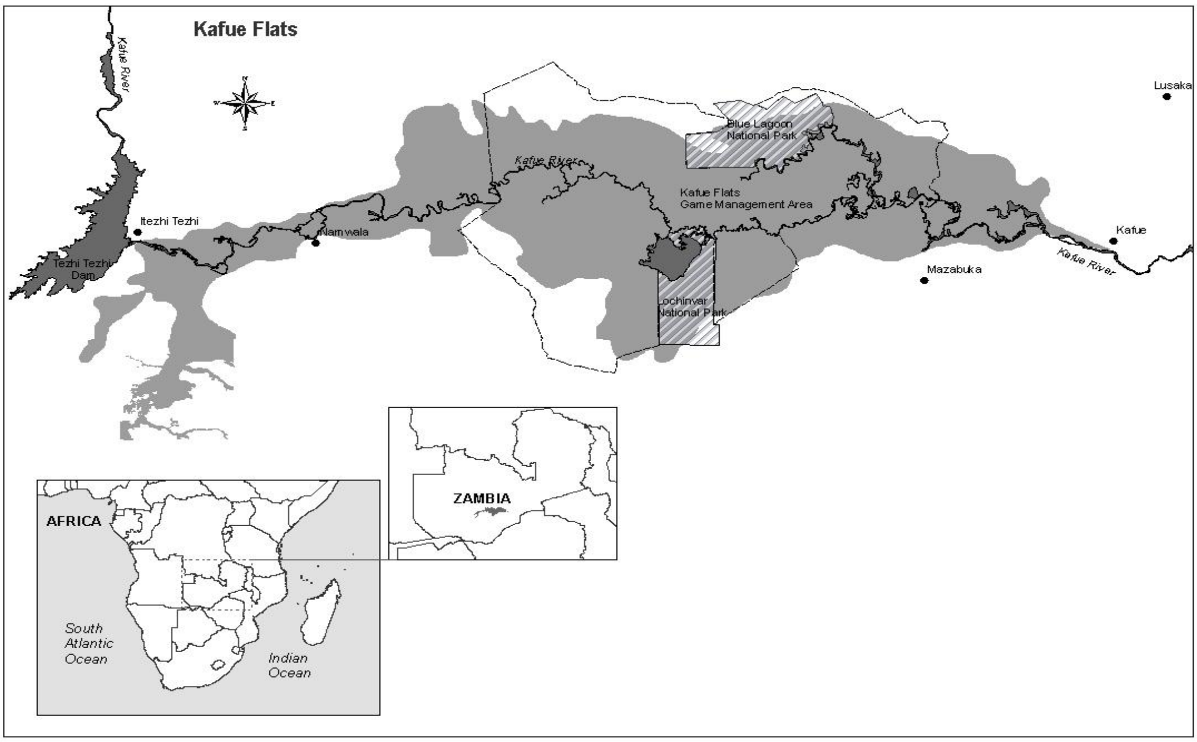

Figure 1 Location of Lochinvar National Park on the Kafue Flats, Zambia

2.3 Elevation and Major Habitats

The relief is generally flat, ranging 950 - 1,060 m above sea level (Figure 2a). Major habitats include, open water, flood plain, termitaria and woodland (Figure 3 a, b, c & d). The floodplain is situated 975 – 981 m above sea level. Swampy areas at 950 – 975 m above sea level; termitaria band at elevations of 981 - 991m above sea level and woodland mostly occurring at over 1,000 m above sea level (Figure 2 a, & b).

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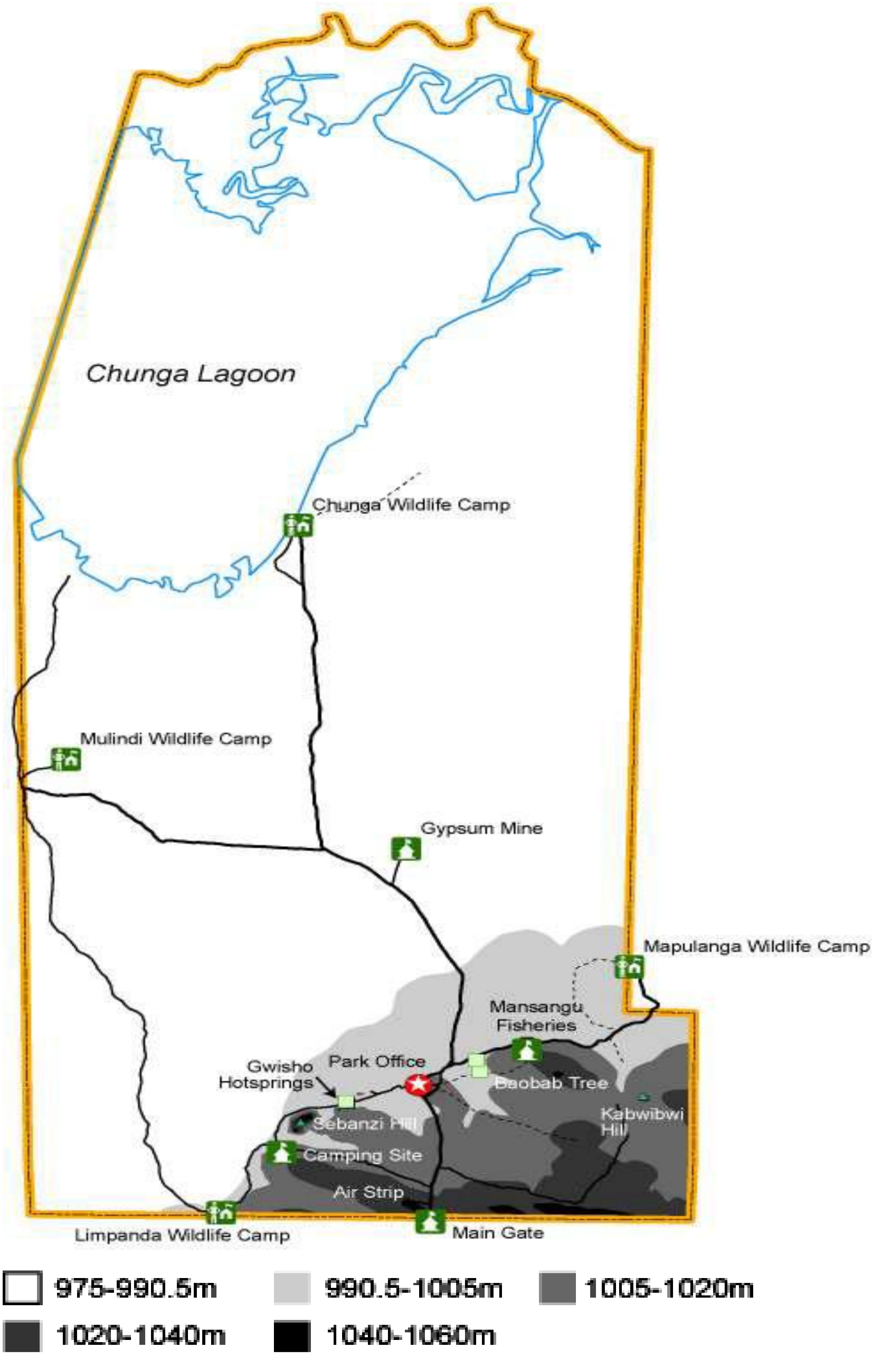

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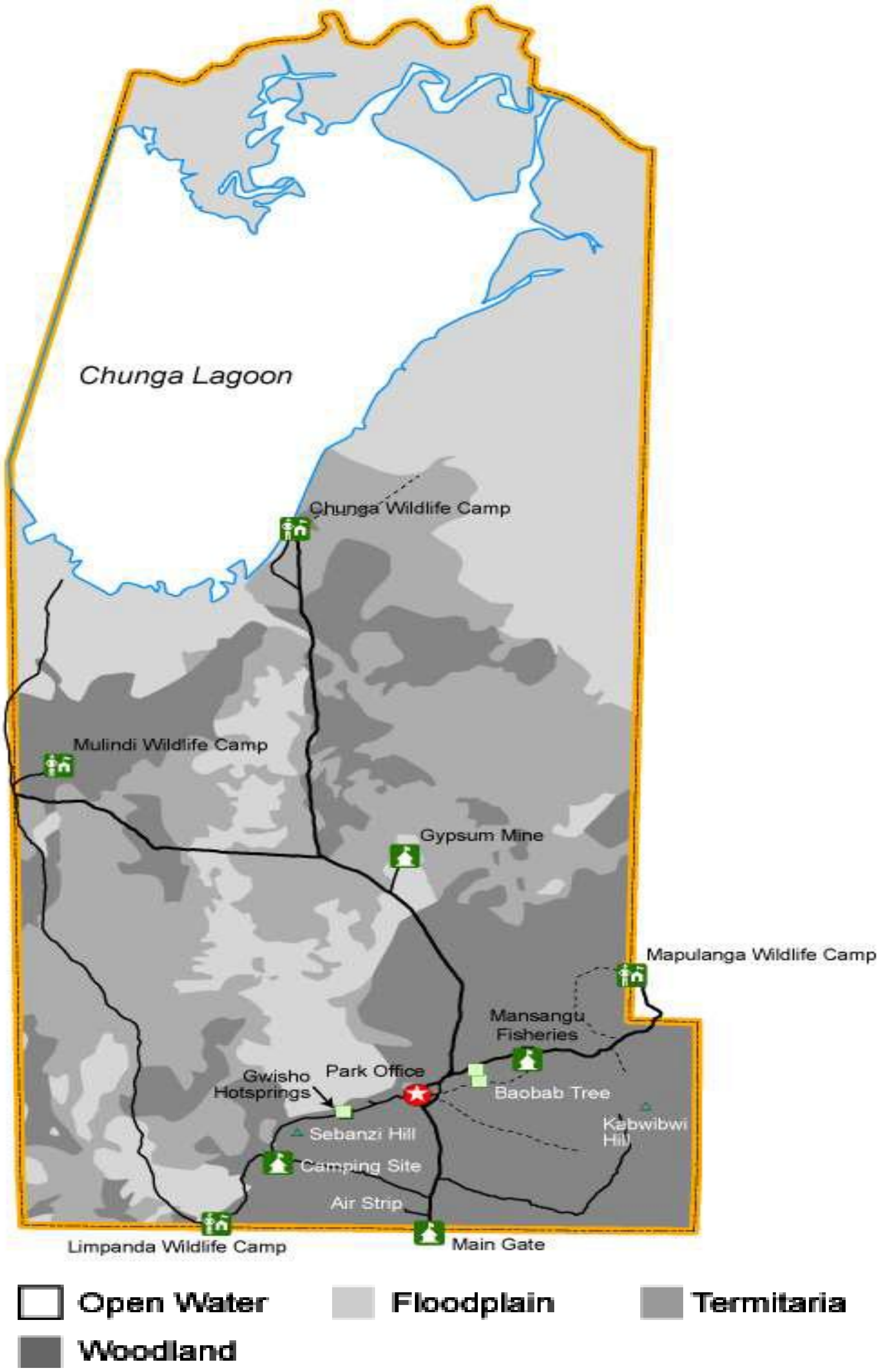


(b)

Figure 2 (a) Land elevation of Lochinvar National Park, (b) vegetation zones and proneness to flooding, Kafue Flats, Zambia

(a)

(b)

(c)

(d)

Figure 3 Major habitats in Lochinvar National Park, (a) Map showing vegetation zones, (a) open water, (b) grassland, (c) termitaria, (d) woodland, Kafue Flats, Zambia.

2.4 Data Collection

This survey was conducted in the south-eastern corner of Lochinvar National Park (Figure 2 a & b) where according to earlier surveys by Douthwaite & van Lavieren (1977), *Brachystegia* mixed with *Combretum*/*Pericopsis /Xeroderris species* and Mopane woodlands were recorded.

2.5 Transect Surveys

Transects aligned East-West direction were placed 250 m apart in the study site, considering accessibility and manpower allocated for this survey. Researchers walked along each transect and made observations at every 100 m and classified dominant vegetation encountered based on earlier work by Douthwaite & van Lavieren (1977). Other observations including dominant species, height (m) and coverage (%) of each layer, texture and colour of surface soil, sign of tree cutting, geology, and evidence of erosion were recorded. Location of transects were given by GPS receiver in advance. In addition, GPS coordinates were obtained where *Brachystegia* woodland in particular was observed during transect survey.

2.5.2 Quadrat Surveys

A total of 26 quadrats were established in the study site (Figure 4) for the purpose of collecting information on species composition of the vegetation types. Approximate locations of the plots were given in advance with reference to past studies and were placed spatially where vegetation was more or less homogenous (but excluded gaps) and where cover was representative of the surrounding areas.

In order to specify locality of the quadrats for future monitoring, coordinates were obtained with GPS receiver and each corner of the quadrat was marked by wooden peg. Marker metal or plastic plates were put on big trees for plots located particularly in *Brachystegia* woodland. At each plot, cover of each plant species was estimated by each layer of the plant community. Total cover was then estimated by visual inspection and rounded up to the nearest 5%. Soil texture, soil colour, and geology were also described. The size of the plot was 10 m x 10 m based on the description provided by Mueller - Dombois & Ellenberg (1994). At each plot all the woody plants taller than 1.5m were described based on Pratt & Gwynne (1978) and the following measurements were taken; i) Location within the quadrat, ii) DBH, iii) Height, and iv) Canopy.

Diametre at Breast Height (DBH – 1.3 metres above ground) was calculated by trunk circumference divided by circle ratio, and the trunks or branches thinner than 1cm of DBH were not measured to eliminate potential error arising from measuring small circumferences. For low branching multi-stemmed specimens (branching below 1.3 metres), diameter was measured at 15 cm above ground. If the specimen was damaged, the cause of the damage was classified and recorded as; fire, tree cutting, or grazing etc., based on visual appearance of the damaged part and experience of the researcher. At the four corners of the quadrats, 2 x 2 m sub-quadrats were set in order to obtain detailed information on spatial distribution of sprout and young trees/coppicing.

At each sample point tree species were identified based on field guides by Palgrave (2005), van Wyk & van Wyk (1997) and Storrs (1995). Specimens that could not be identified in the field were taken to the field herbarium at Lochinvar for identification or referred to Mr. Mike Bingham a taxonomist for identification. Grass and herb species were separated as 'grass' or 'herb' based on Vernon (1983) and van Oudtshoorn (2009).

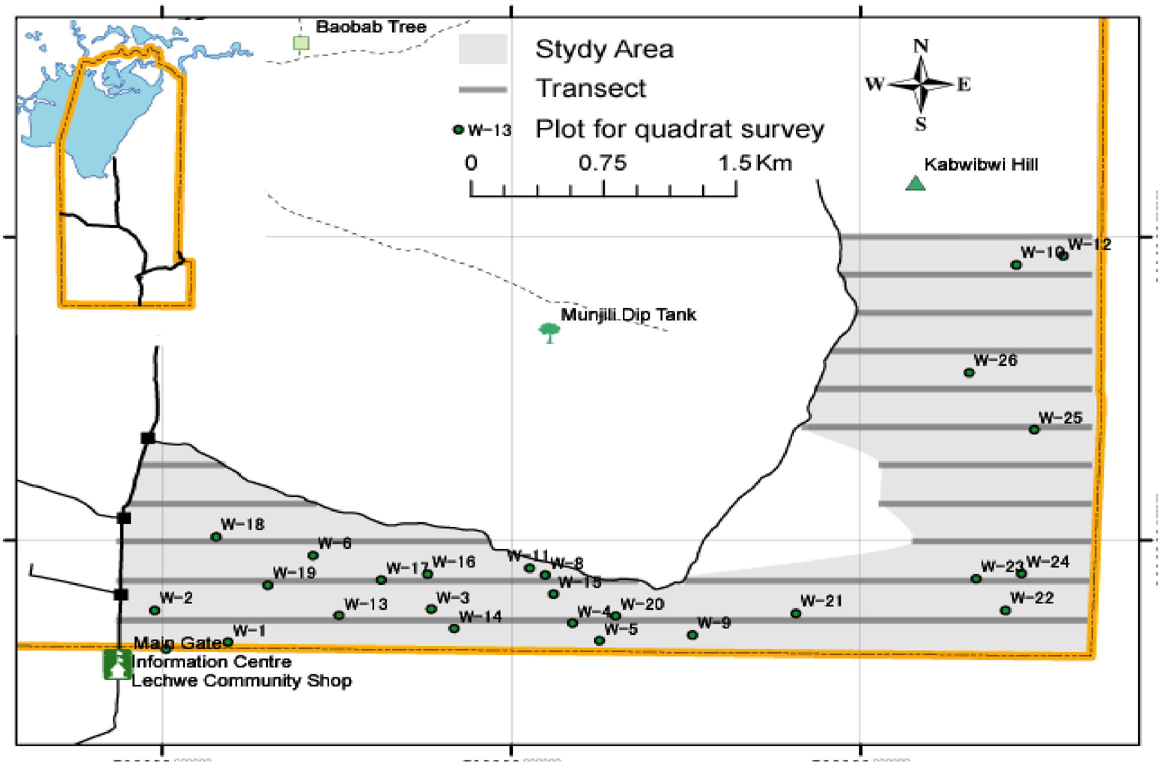


Figure 4 Location of transect lines in study site

2.6 Data Analysis

2.6.1 Distribution of the Brachystegia Woodland

Global Positioning System coordinates of *Brachystegia* woodland were plotted by GIS software Arc Map 9.1. Distribution of the coordinates was referred to the satellite image obtained from Google Map (http://maps.google.com/maps; accessed on 28th June 2012), and then the woodland area was drawn by smooth curve that included plotted points. The area of the *Brachystegia* woodland was measured by image analysis software Adobe Photoshop 7.0, and compared with the past study.

2.6.2 Vegetation Mapping and Species Composition

The same information obtained under the distribution of *Brachystegia* woodland was used to develop a vegetation map. At first, the satellite image was examined and uniform vegetation community units were outlined on the image.

Cluster Analysis using ward method was performed on a matrix of 26 plots by 78 species (excluding unidentified species) using species abundance data. This produced a similarity index among plots based on species composition. Statistical software R (R version 2.6.2, the R foundation for statistical computing) was used for this analysis.

2.6.3 Tree Cutting and Erosion Mapping

Discriminant analysis by stepwise selection was adopted on records of tree cutting and erosion. Explanatory data sets consisted of variables; i) tree cutting (vegetation type and distance from National Park boundary); ii) erosion (vegetation type, distance from National Park boundary, soil texture, geology and coverage of herbaceous layer). Categories with small sample sizes (less than three) were excluded from the analysis in order to minimize bias, thus 256 data sets were used. Statistical software R (R version 2.6.2, the R foundation for statistical computing) was used to analyse the data.

3. Results

3.1 Distribution of Vegetation Physiognomic Types

A total of 277 observations were made from which six vegetation types were distinguished (Figure 5). In addition to the six primary vegetation communities, three vegetation types were added, 1) *Acacia gerrardii* savannah woodland, 2) Dambo, and 3) *Diplorhynchus* woodland.

Brachystegia woodland was mainly distributed on higher ground in the southern and southeast boundary area. Canopy cover of this woodland type was mostly dominated by *Brachystegia spiciformis*, *Schinziophyton rautanenii, Diplorhynchus condylocarpon,* and *Pterocarpus angolensis* in that order. *Combretum/ Pericopsis Xeroderris* mixed woodland covered lower areas than *Brachystegia* woodland. Tall trees were scattered and canopy cover of the tree layer was relatively low. Species included; *Combretum apiculatum, Combretum collinum, Combretum molle,* and *Combretum zeyheri*, mixed with *Markhamia obitusifolia, Lannea discolor,* and *Schrebera trichoclada,* and *Pseudolachnostylis maprouneifolia*. This vegetation was most abundant in the study area representing 101 points (36.5%) of the total 277 points observed.

Mopane woodland covered wet and lower altitude areas on darker clay or silty soils in the eastern boundary area. The canopy was mostly dominated by Mopane (*Colophospermum mopane).* It was also abundant in the shrub layer sometimes having an almost pure stand. Other species locally mixed with Mopane included; *Dalbergia melanoxylon* and other spiny shrub species such as, *Balanites aegyptiaca, Commiphora mollis* and *Commiphora pyracanthoides.*

Riparian woodland covered narrow strips along a seasonal river in the eastern side of the National Park. Common species were; *Diospyros lycioides, Oncoba spinosa,* and *Garcinia livingstonei*. Thicket vegetation community was patchy and included various sub-types assembled together rather than comprising consistent species. The species composition varied widely depending on factors such as soil, frequency of fire and presence of termite mounds. Common trees recorded included; *Commiphora mollis*, *Peltophorum africanum, Sclerocarya caffra,* and *Albizia harveyii*. A small savannah woodland was recorded in the southern boundary area where soils were dark alluvial clays and poorly drained. This woodland was open with dotted trees in the shrub layer, and species included *Acacia gerrardii, Albizia harveyii,* and *Combretum adenogonium*. Herbaceous layer was higher than in other communities. Dambos were found on depressions, which ran from southeast to northwest. The soil was dark alluvial clay and poorly drained. Trees were scattered and common species were; *Combretum adenogonium, Acacia gerrardii, Acacia nilotica,* and *Acacia polyacantha* ssp. *campylacantha.* The herbaceous layer was high with many palatable grass species grazed by cattle and game.

The *Diplorhynchus* woodland covered a small location in the southern and eastern boundary areas, between *Brachystegia woodland* and *Combretum/ Pericopsis/ Xeroderris* mixed woodland. The soils were brownish loamy sands. Tree layers were comprised of mainly; *Burkea africana*, *Amblygonocarpus andongensis,* and *Diplorhynchus condylocarpon.* Various species of the genus *Combretum* and *Diplorhynchus condylocarpon, Pseudolachnostylis maprouneifolia, Phyllanthus engleri* consisted the shrub layer. Some species were common to *Brachystegia* woodland as well (Figure 5).

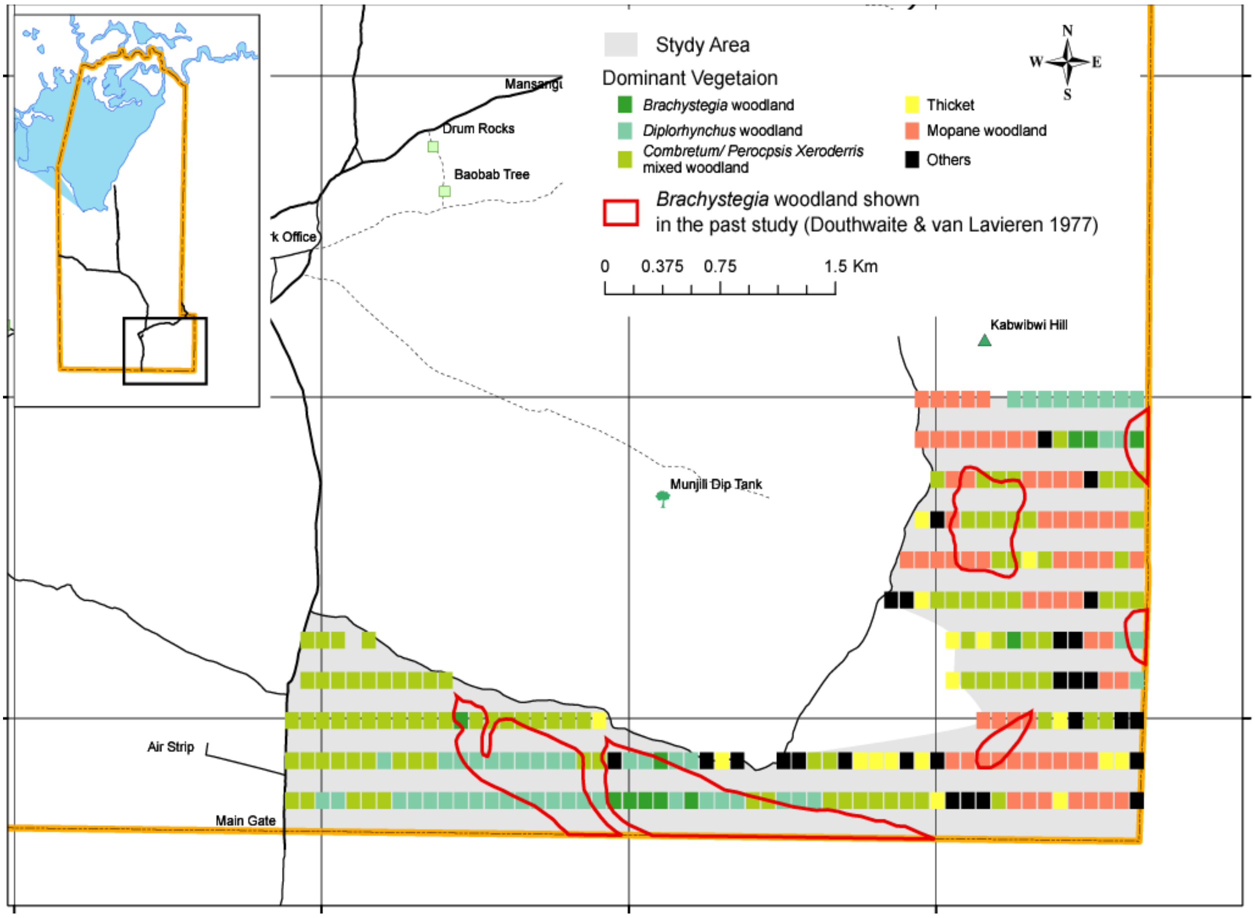
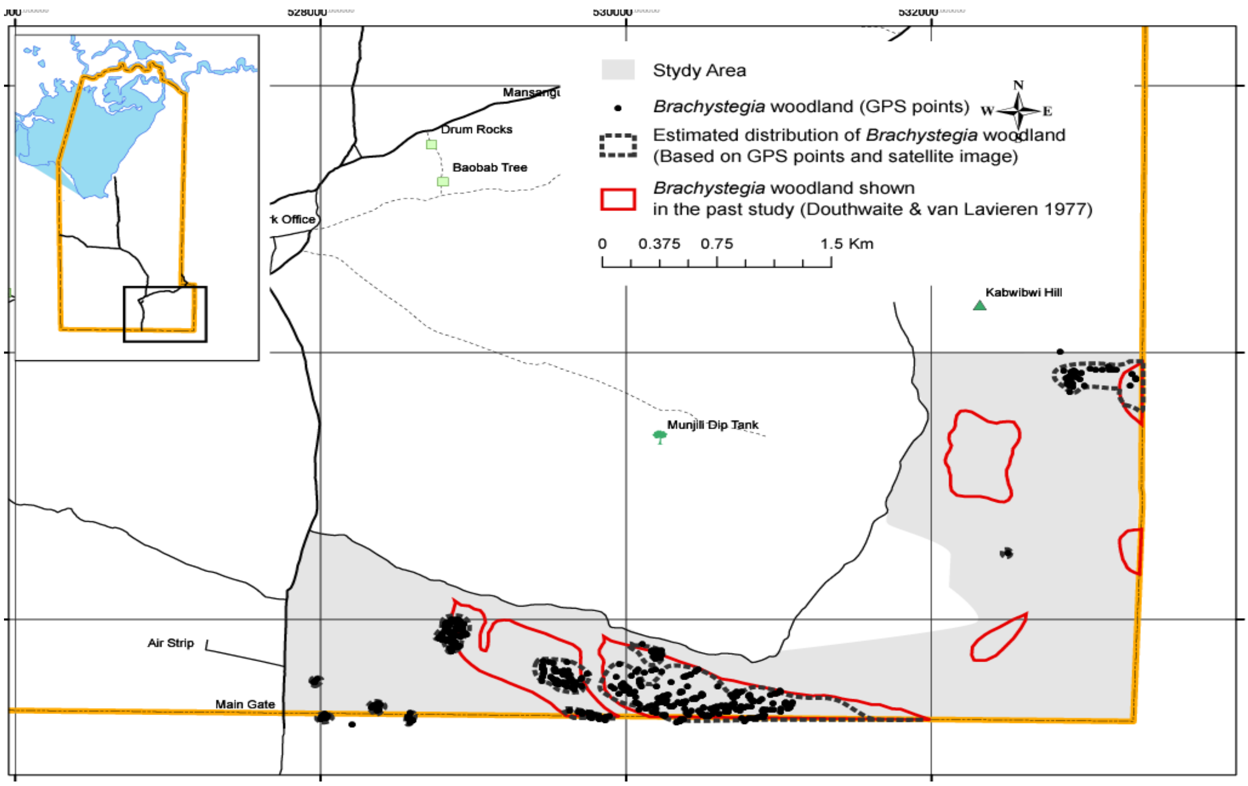


Figure 5 Dominant Physiognomic types observed during transect surveys

3.2 Distribution pattern of Brachystegia Woodland and Vegetation Mapping

The GPS points obtained showed that *Brachystegia* woodland had a fragmented distribution near the boundary (Figure 6). The area was estimated to be about 0.72km^2, a decline from the historical coverage of about 1.35 km^2 (Figure 6 & 7; Table 1), implying that its range had shrunk by 46.7% in the last 35 years (1977 – 2012).



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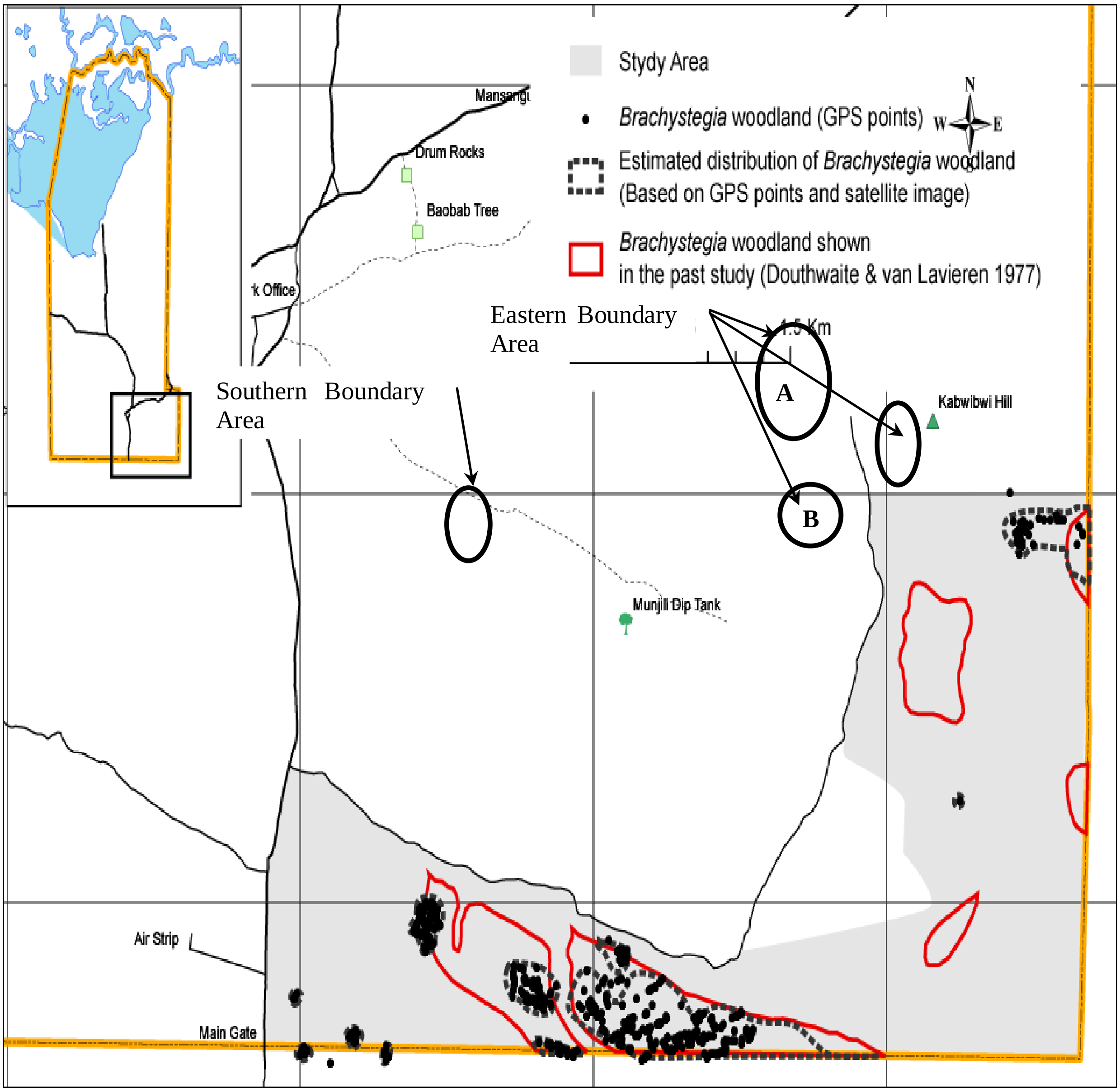


(b)

Figure 6 (a) Distribution of *Brachystegia* woodland, (b) Comparison of past and current distribution of *Brachystegia* woodland

Table 1 Comparative area coverage of *Brachystegia* woodland between past and current surveys

	Area (km^2)
Past distribution	1.35
Current distribution	0.72
Difference	0.63

Note: Past distribution was extracted by the vegetation map of past study (Douthwaite & van Lavieren 1977).

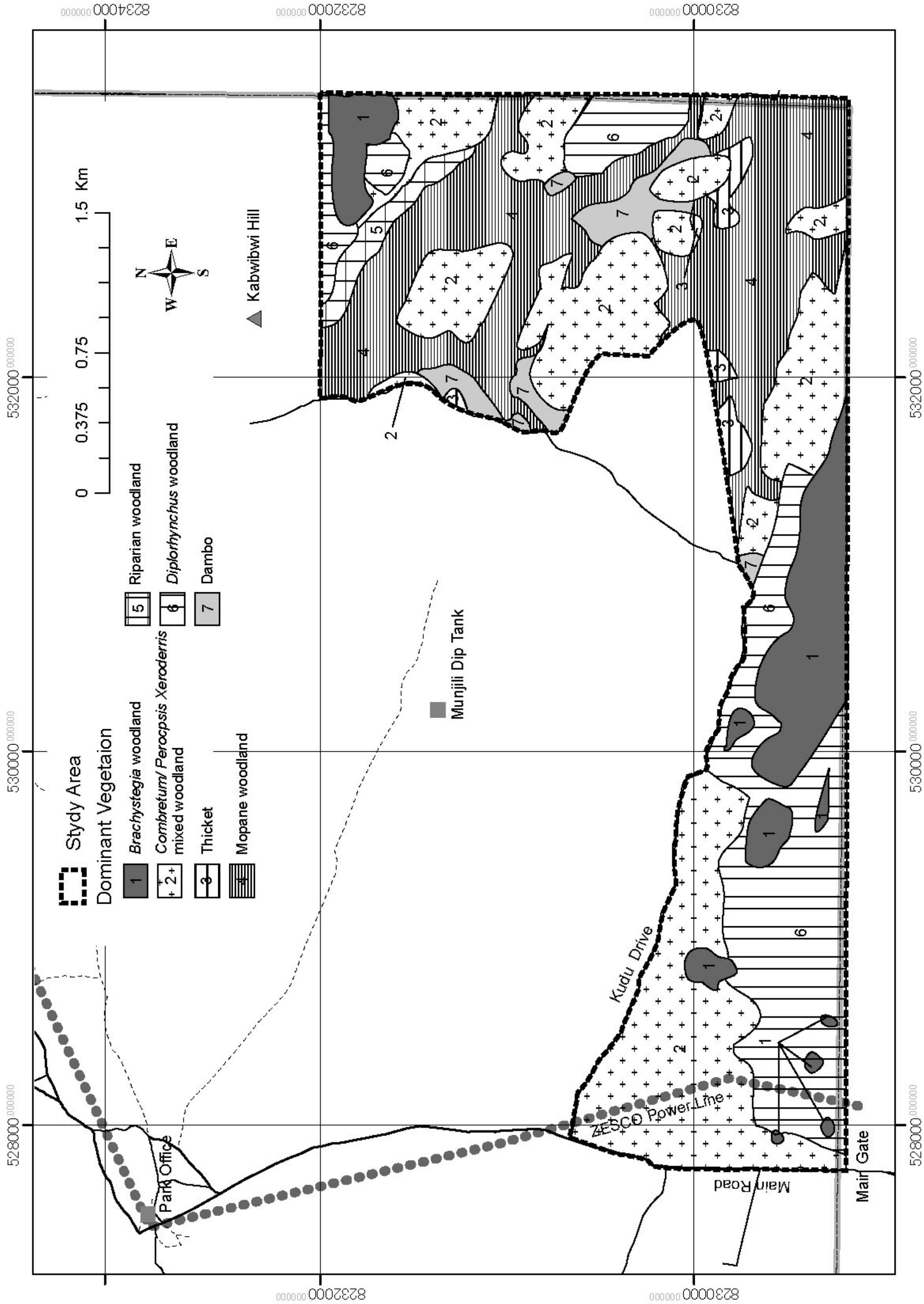
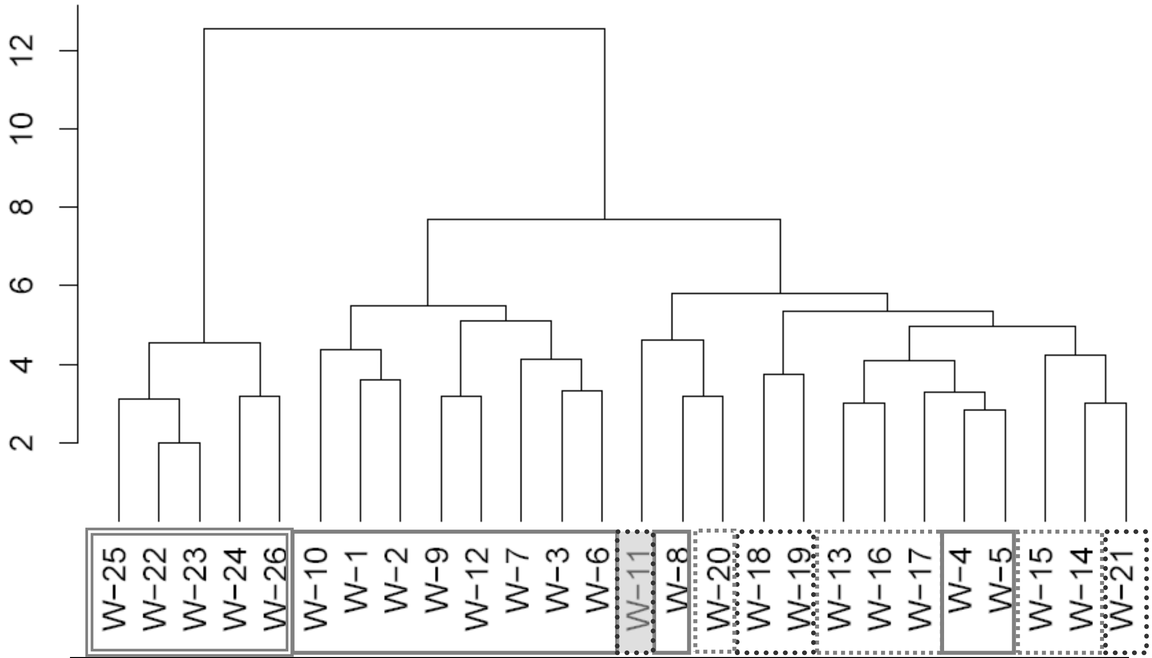


Figure 7 Composite vegetation map/ Lochinvar National Park, Zambia

3.3 Species composition

In total 78 woody plant species were recorded. Hierarchical Cluster Analysis yielded two major divisions in the vegetation communities observed (Figure 8), though certain species were shared between the two vegetation divisions.



Colophospermum mopane	*Brachystegia spiciformis*	*Schinziophyton rautanenii*	*Brachystegia spiciformis*	*D. condylocarpon & C.*	*Combretum zeyheri.*	*C. apiculatum, & P.*	*Diplorrhynchus condylocarpon*	*Brachystegia spiciformis*	*Diplorhynchus condylocarpon*	*C. apiculatum & P. engleri*
Mopane WL	***Brachystegia* WL**			**D**	**C**		**D**	**B**	**D**	**C**

Notes: Brachystegia woodland; C: *Combretum/ Pericopsis/ Xeroderris* woodland; D: *Diplorhynchus* woodland

Figure 8 Cluster analyses for major vegetation communities and species composition data

3.4 Incidents of Tree Cutting and Soil Erosion

3.4.1 Tree Cutting Incidences

Tree cutting was observed at 98 points (36 %) out of the total 273 points observed for this parameter. The distribution pattern showed that tree cutting was more common near the National Park boundary (Figure 9; Table 2 a & b). All the four variables picked by stepwise selection showed positive values, which explained that tree cutting and the four variables; (i) distribution of thicket, (ii) *Combretum/ Pericopsis/ Xeroderris* Woodland, (iii) Dambo, and (iv) distance from the boundary) related negatively. The error rates of the analysis were 21.4% (tree cutting present) and 31.6% (tree cutting absent) respectively.

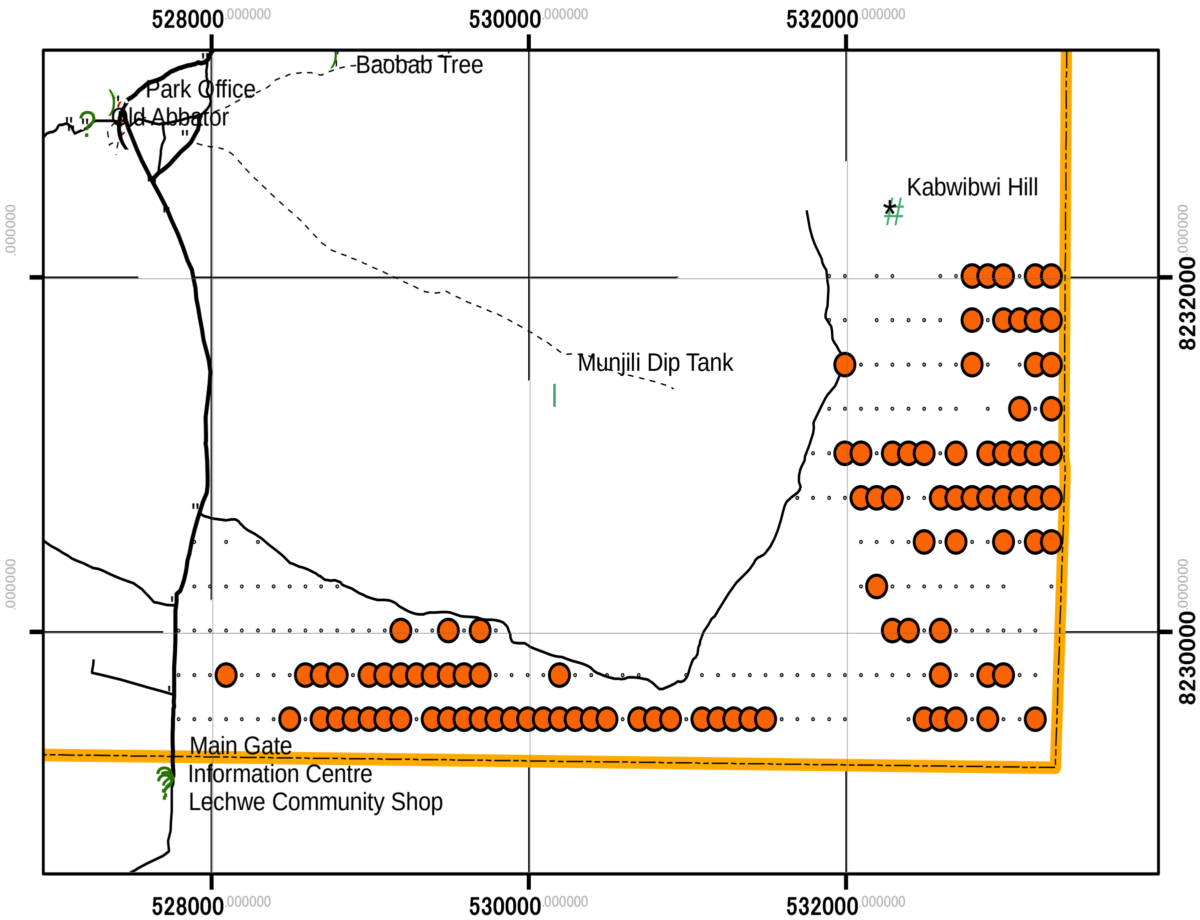


Figure 9 Occurrence of tree cutting in the study area. Orange circles show the places where the sign of tree cutting was observed.

Table 2a Results of discriminants analysis for tree cutting incidences

Explanatory variable		Coefficients of discriminants
Vegetation type	Thicket	2.771
	Combretum/ Pericopsis /Xeroderris WL	1.216
	Dambo	2.634
Distance from the boundary		0.002
Constant term		-1.974

Table2b Summary of analysis for tree cutting incidences

		Result of analysis		Error rate
		Present	Absent	
Data	Present	77	21	21.4%
	Absent	50	108	31.6%

3.4.2 Erosion

Incidents of soil erosion were recorded at 97 points (36%) out of 273 points observed for this parameter. It was most frequent near the boundary similar to tree cutting incidents indicated above (Figure 10). Of the six variables picked by stepwise selection (Table 3a & b), three variables (*Diplorhynchus* woodland, loamy sand, and loam soil) were negative of coefficient of discriminants, while the other three (thicket, coverage of herbaceous layer, and distance from the National Park boundary) gave a positive value. Negative values suggested occurrence of soil erosion, for example, places where *Diplorhynchus* woodland was distributed had more signs of erosion than other vegetation types. Positive values on the other hand suggested the opposite. The error rates of the analysis were 14.4% (Erosion present) and 26.4% (Erosion absent) respectively.

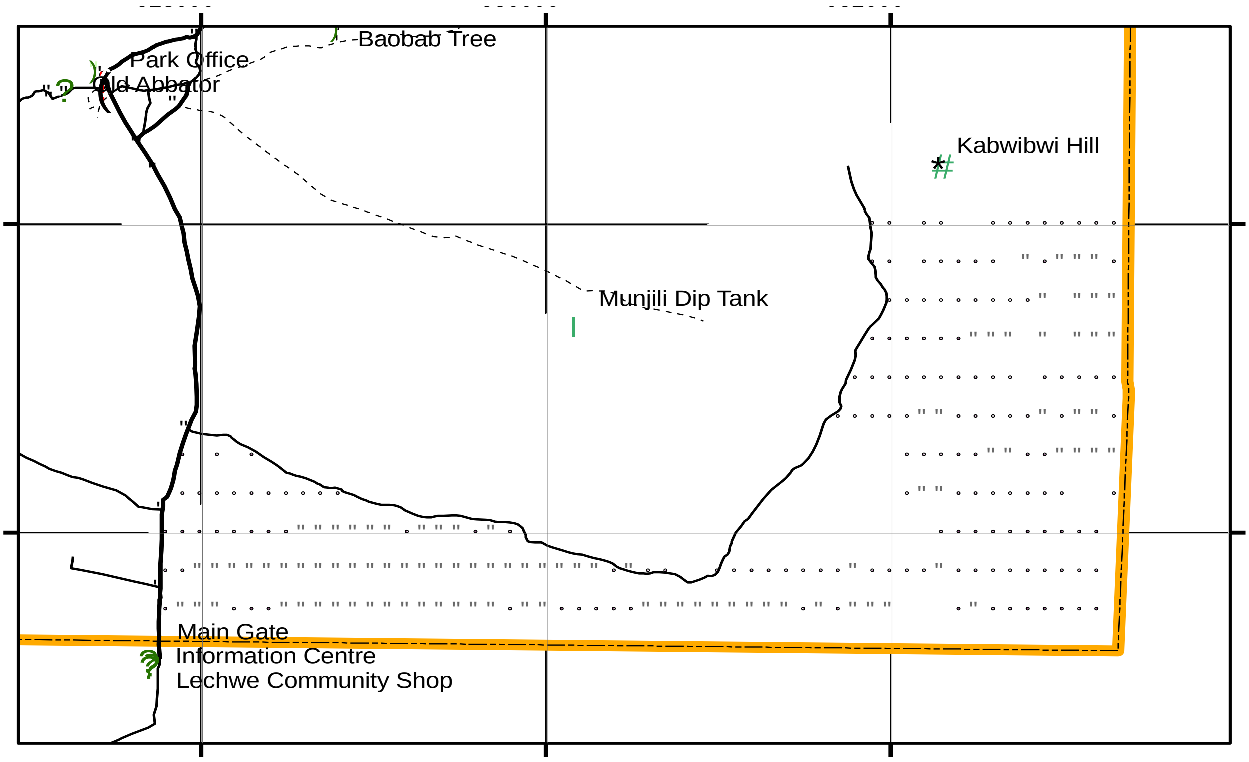


Figure 10 Occurrence of erosion in the study area. Grey squares show the places where erosion was recorded.

Table 3a Coefficients of linear discriminants for soil erosion incidences

Explanatory variable		Coefficients of discriminants
Vegetation type	*Diplorhynchus* WL	-1.287
	Thicket	2.321
Soil texture	Loamy Sand	-1.859
	Loam	-2.157
Coverage of herbaceous layer		0.030
Distance from the boundary		0.001
Constant term		-0.963

Table 3b Summary of analysis (Erosion)

		Result of analysis		Error rate
		Present	Absent	
Data	Present	83	14	14.4%
	Absent	42	117	26.4%

4. Discussion

4.1 Changes in Brachystegia Woodland Coverage

4.1.1 Area Coverage

Comparison of vegetation maps showed that *Brachystegia* woodland reduced its area coverage (Figure 6; Table 1) probably due to the wide range of uses including, charcoal, fire wood, building poles, house hold tools, medicinal (Roberts, 1990) and others. The major decline was detected in two areas: southern boundary area and eastern boundary areas which were also close to human settlements. It is easy for members of the local community to sneak into the National Park un noticed, cut trees of their choice and get out. In the southern boundary area *Brachystegia* was replaced by *Diplorhynchus* woodland, while in the eastern boundary areas were various vegetation types such as, Mopane woodland, *Combretum/ Pericopsis /Xeroderris* woodland, and *Diplorhynchus* woodland. This was because Mopane woodland and *Brachystegia* woodland grew in different soil conditions. Mopane usually grew on grey alluvial clays thinly covered by sandy clay, while *Brachystegia* woodland occurred where soils were light reddish-yellow to grey brown with sandy loams in the upper horizons and reddish loams in the lower horizons as earlier reported by Douthwaite & van Lavieren (1977). These variations in soil types may have contributed to variation in vegetation community distribution (Figure 11) as compared with Figure 6b. However, this does not fully explain why *Brachystegia* was replaced by *Diplorhynchus* woodland as it is unlikely that the soil types had changed in those areas in the past 35 years. The source of this variation between the two surveys could be that; i) in the past study, the researcher set north-south transect along Kudu drive 500 m apart (250 m apart in this study), and the eastern areas were not covered by the transects, and ii) the vegetation in the eastern areas was not distinguished by physical observation but by analysing aerial photographs (physical inspection/ground truthing were carried out in this study).

In view of the above, it is likely that some parts of eastern boundary areas were not covered by *Brachystegia* woodland in the past. If we assume that the eastern area was not covered by *Brachystegia* woodland in the 1970s and we exclude it from past distribution, the estimated area lost by *Brachystegia* could be reduced to 28.0% as given on Table 4 and not 46.7%.

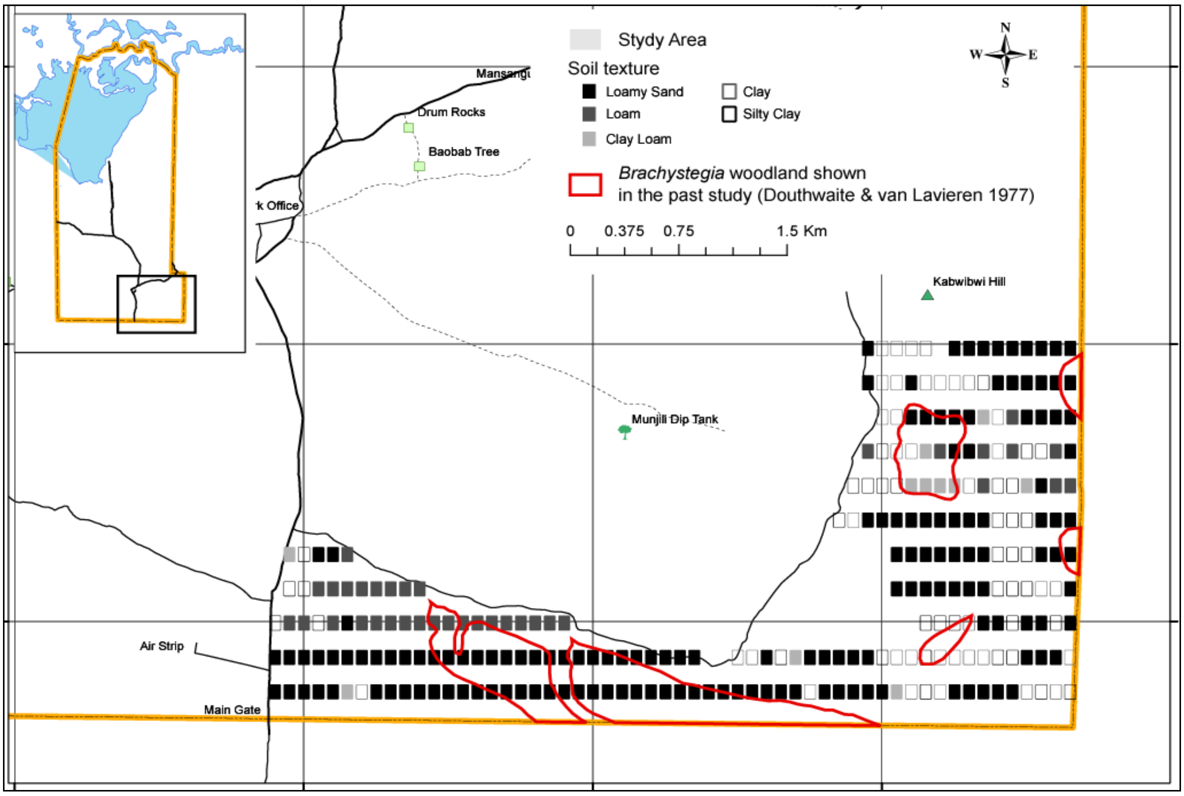


Figure 11 Distribution of soil texture in the study area

Table 4 Estimated area of *Brachystegia* woodland based on the assumption that eastern area was not covered by *Brachystegia* woodland in the 1970s

	Area (km^2)	
	Include eastern areas	Exclude eastern areas$^{1)}$
Past distribution$^{2)}$	1.35	1.00
Current distribution	0.72	0.72
Difference	0.63	0.28
Reduction rate	46.7%	28%

Note: 1) The areas A and B shown in Fig. 5.1
2) Past distribution was extracted by the vegetation map of past study (Douthwaite & van Lavieren 1977).

4.1.2 Species Composition

The methodology employed in this study was different from past study; and therefore, it was difficult to make direct comparisons between the two surveys, and this might have led to the minor variations in interpreting species composition between the current and previous study. In this study, we summed up frequency of occurrence from quadrat survey for plots W-1 to W-12 for each species; abundance rating was given by converting the occurrence of a spices as, 12 for Abundant, 10.5 for locally abundant, 9 for common, 7.5 locally common, 6 frequent, 4.5 locally frequent, 3 occasional, and 1.5 rare, which was not done in the previous study and could be responsible for some of the differences obtained.

In this study for instance, it was suggested that species composition had changed in the past 35 years. In the previous study, *Brachystegia bohemii* and *Brachystegia longifolia* were recorded as being abundant, but in this study, these species were not recorded in those same areas where they were reported to be abundant. Additionally, *Amblygoncarpus andongensis,* and *Pericopsis angolensis* were described as common in the previous study but they were occasional in this study implying that their abundance could have been significantly reduced. On the other hand, *Friesodielsia obovata,* and *Pavetta schumanniana,* both shrubs, were not recorded in the past survey but were recorded in all quadrats in this study. Fire resistant species such as; *Markhamia obustifolia, Dichrostachys cinerea,* and *Friesodielsia obovata,* also increased, which suggested that fire played an important role in the vegetation change recorded in the area, but these observations were not covered in the earlier study. Other factors could be overgrazing, especially that the frequency of *Paveta schumanniana,* which is poisonous to cattle had increased and spiny shrub *Dichrostachys cinerea* and *Catunaregam spinosa* also increased as response to over grazing (Pratt & Gwynne, 1978) (Table 5).

Table 5 Comparison of species occurrence in current and previous survey

Species	This survey	Past survey[1)]	Life form[2)]	Species	This survey	Past survey[1)]	Life form[2)]
Brachystegia boehmii	0	a	T	*Cassia abbreviata*	4	-	S
Brachystegia longifolia	0	a	T	*Markhamia obitusifolia*	4	-	Sh
Amblygoncarpus andongensis	0	la	T	*Pavetta gardeniifolia*	5	-	Sh
Ochna schweinfurthiana	0	c	Sh	*Terminaria sericea*	5	-	S
Pericopsis angolensis	0	lc	T	*Senna singueana* [3)]	6	-	Sh
Diospyros kirkii	0	f	Sh	*Catunaregam spinosa* [4)]	9	-	Sh
Securinega virosa	0	f	Sh	*Tapiphyllum discolor*	9	o	Sh
Pterocarpus angolensis	1	f	T	*Combretum zeyheri*	7	-	S
Strychnos cocculoides	1	f	Sh	*Dichrostachys cinerea*	7	-	Sh
Bauhinia petersiana	6	la	Sh	*Combretum molle*	8	-	S
Dalbergiella nyasae	5	c	S	*Lannea discolor*	8	-	S
Steganotaenia araliacea	5	c	S	*Zanha africana*	9	-	T
Schinziophyton rautanenii	1	lf	T	*Combretum collinum*	10	-	S
				Friesodielsia obovata	12	-	Sh
				Pavetta schumanniana	12	-	Sh

1) a: abundant, la: locally abuntdant, c: common, lc: locally common, f: frequent, lf: locally frequent, o: occasional, r: rare

2) T: medium ot tall tree, S: small or medium tree, Sh: shrub or small tree

3) Synonim: Cassia singueana

4) Synonim: Xeromphis obovata

4.2Tree Cutting and Erosion

4.2.1 Tree Cutting

Four variables were selected as factors to be considered in determining tree cutting incidences; distribution of thicket, *Combretum/ Perocpsis/ Xeroderris* Woodland, Dambo, and distance from the boundary. It was assumed that; thickets are usually dense and therefore people avoid it due to the difficulty of manoeuvring through it when looking for trees to cut; Dambo has fewer trees to cut than other vegetation types and so may be avoided as one requires more time to find a good quantity of trees to cut and also exposes the invader to being easily spotted by Wildlife Police Officers; *Combretum/ Pericopsis Xeroderris* woodland were usually short and small thus not very valuable and only if the people are looking for small to medium sized trees would they traverse the woodland; and distance from the boundary had the advantage of accessibility suggesting that the intruder would prefer to cut trees near their settlements. A general weakness of these assumptions is that they ignore that certain human uses such as medicinal or house hold tools may be species specific where size may not matter and therefore people would always look for such species irrespective of the vegetation community in which it grows. The assumptions did not also specify maximum distance into the National Park which would be considered risky.

The errors of the discriminant analysis given in Figure 12 showed predicted values and these were mainly near the boundary, especially near the main gate, at the south-eastern corner of the National Park and south of Kabwibwi hill, while “observed but not predicted” were distributed in two major clusters a little bit further from the boundary. This distribution suggested that; i) tree cutting did not occur near the gate where ZAWA officer were present, and ii) the distance from the park boundary was not equal to the distance from the community, as it was assumed that tree cutting could be more common near the community but in areas where law enforcement personnel are not present intruders can go deeper into the National Park to cut trees of their choice.

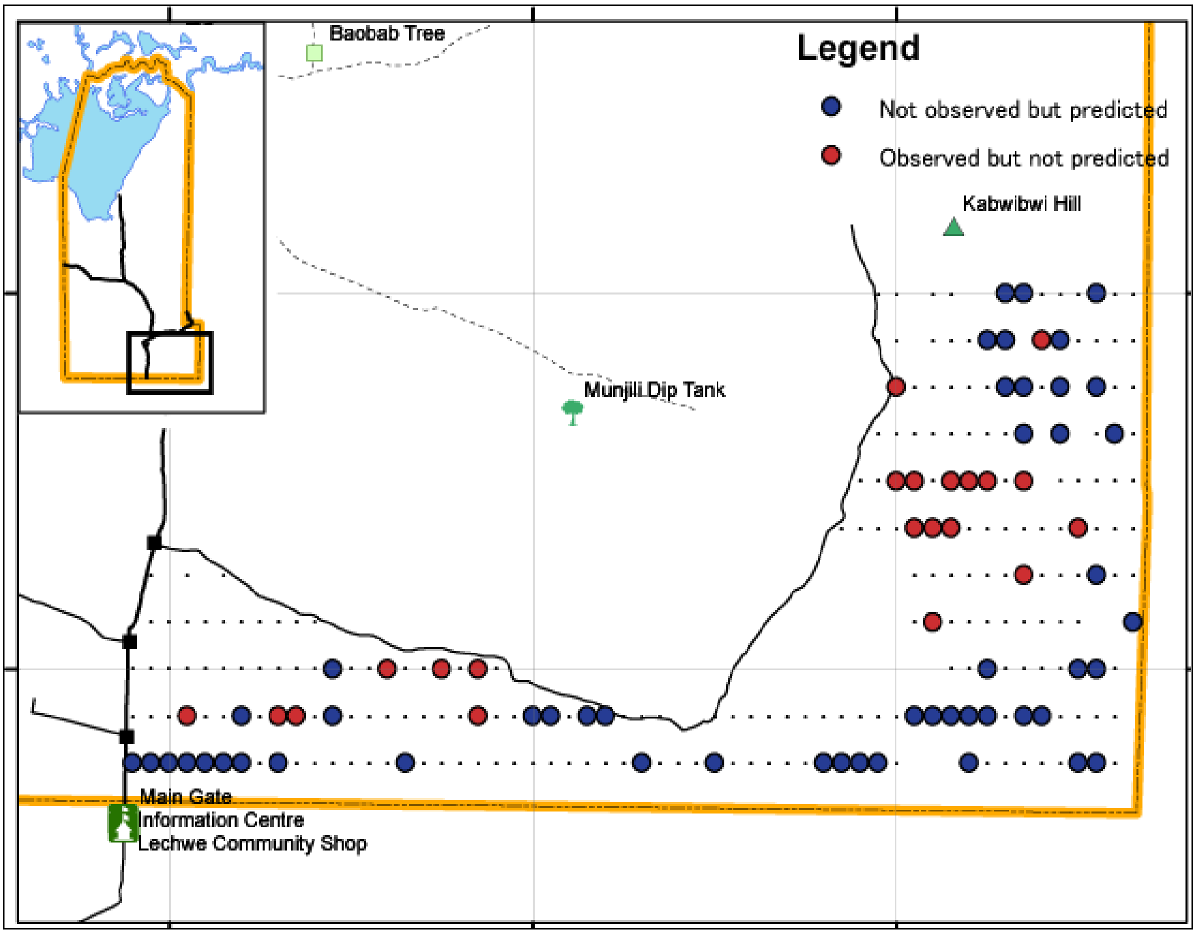


Figure 12 Errors of the discriminant analysis for tree cutting

4.3.2 Erosion

Six variables were selected for soil erosion; vegetation types (*Diplorhynchus* woodland, thicket) soil texture (loamy sand, and loam soil), coverage of herbaceous layer, and distance from National Park boundary. Distribution of thicket, ground cover of herbaceous layer, and distance from the boundary were used to determine presence of extractive human activities. Soil texture, loamy sand and loam, and distribution of *Diplorhynchus* woodland were used to explain underlying geological factors.

Errors of discriminant analysis given in Figure 13 were for “Not observed but predicted” and these were distributed mainly near the eastern boundary, probably because the southern boundary area experienced more erosion than eastern boundary area. While “observed but not predicted” were distributed in the eastern area closer to the boundary, implying that closeness to the National Park boundary alone was not a factor unless accompanied by adjacent human settlements.

The reason of this difference in the south and east was not known, but it could be explained if some more factors were considered in the analysis, for example angle of inclination, intensity of cattle grazing, and occurrence of fire could be important ecological attributes. In addition, the distance from the National Park boundary was not equal to the distance from the community, as earlier mentioned.

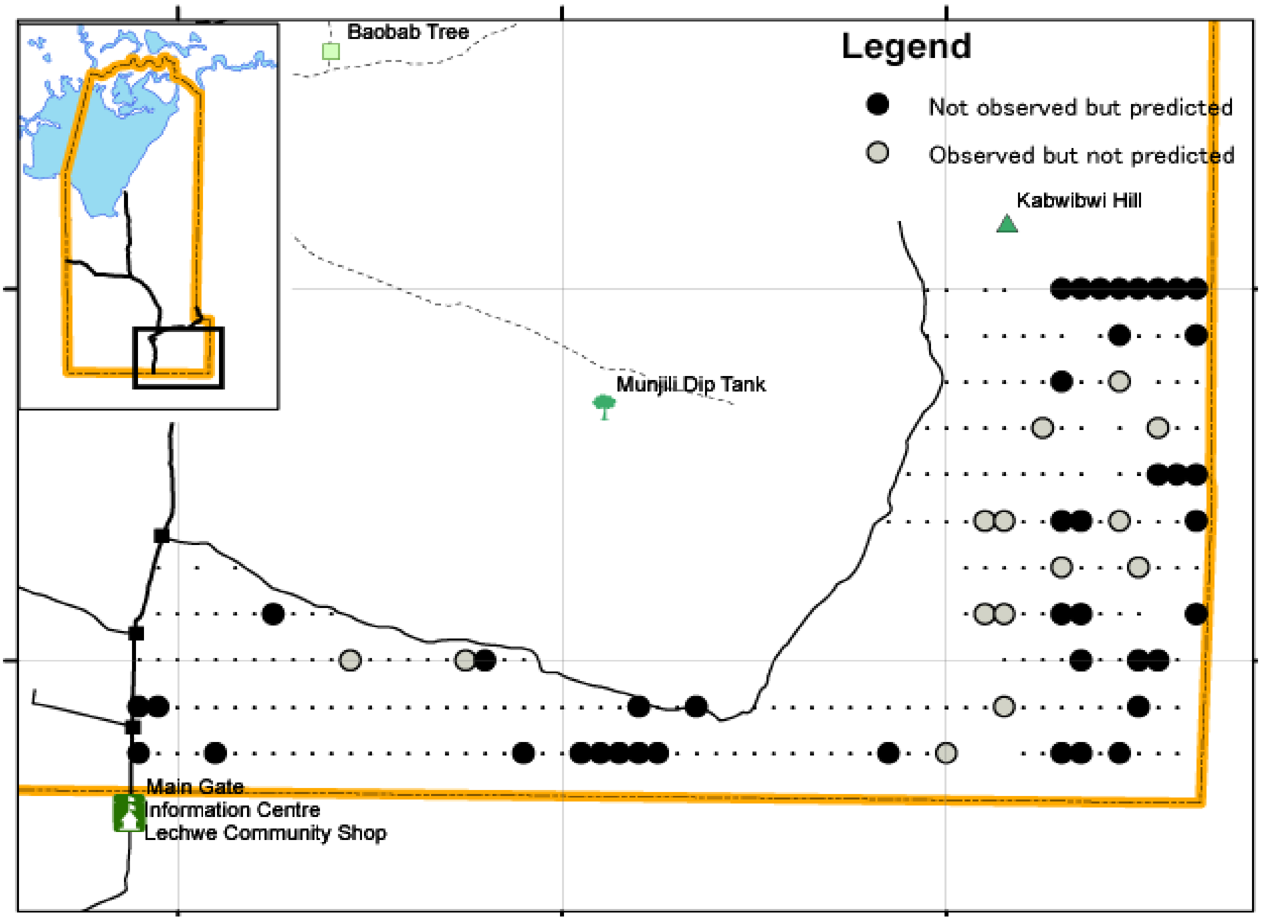


Figure 13 Errors of the discriminant analysis for erosion

4.4 The Factors Influencing Change

4.4.1 Tree Cutting

It was obvious that *Brachystegia* woodland had experienced heavy tree cutting through illegal human uses. The result of discriminant analysis for the occurrence of tree cutting, showed negative value for the distributions of thicket, *Combretum/ Pericopsis /Xeroderris* woodland, instead more tree cutting was observed in *Brachystegia*, *Diplorhynchus*, and Mopane woodlands in that order. The change in species composition, decline of canopy-forming tree species, also supported the idea that tree cutting contributed to the change in area coverage. Unlike the other factors, tree cutting can directly destroy trees growing in canopy layer and can change vegetation type in the short period of time. It was therefore, suspected that tree cutting was one of the major factors causing change in species composition, cover and physiognomy. For instance, *Brachystegia* woodland was replaced by *Diplorhynchus* woodland.

4.4.2 Grazing

Cattle grazing also contributed to vegetation change in the study area. Cattle grazing had been recorded in the area and signs of overgrazing were obvious as could be deduced from the presence of spiny and poisonous plants (Storrs & Piearce, 1982; Storrs, 1995; van Oudtshoorn, 2009) found in areas subjected to grazing. However it was also argued that while grazing is an important factor in vegetation dynamics on the range, its effect is limited since it can only change species composition of the shrub or herbaceous layers but not of trees. Although others still argue that grazing can disturb the germinations of seeds and survival of saplings for many tree species by browsing or trampling the ground, it usually takes long time to change the vegetation community, and for the purpose of this study it was considered to be some how insignificant in changing woody vegetation community. In fact by removing herbaceous layer, it reduces amount of litter to burn there-by protecting trees from late fires.

4.4.3 Others

1) Succession or natural death

It could be explained that canopy-forming trees may have died naturally in the past 35 years, but still this remains debatable as it is unlikely to happen that some species would die of natural causes while others including *Brachystegia* *spiciformis* and *Schinziophyton rautanenii* still remained.

2) Fire

In Savannah regions of Africa, fire plays a very important role in the vegetation dynamics. In this study, it was assumed that the increase in the occurrence of fire resistant tree species in *Brachystegia* woodland was indicative of regular wildfires and could be one of the contributing factors responsible for the recorded vegetation change. This interpretation however, is not holistic as time series data on fire were lacking making it difficult to assess the effect of fire in the area. Comparison of satellite imagery taken in between two surveys could enable us analyse in detail the effect of fire but this was not done.

5. Conclusion

The results of this study show that, illegal human harvesting of woody plants have influenced vegetation dynamics in the Lochinvar National Park. It was henceforth concluded that: i) area coverage for *Brachystegia* woodland had declined from approximately 28% to 47% in the last 35 years (1977-2012), ii) *Brachystegia* woodland previously recorded in the southern part of the National Park boundary had been replaced by *Diplorhynchus* woodland, iii) occurrence of canopy-forming species could decrease while the shrub species increased, iv)tree cutting, grazing and fire accentuated vegetation change in the study area, v) while fire could be a major factor behind the observed vegetation change, further data collection and analysis would be required to examine its proportional effect, vi)species composition in *Combretum/ Pericopsis /Xeroderris*, *Diplorhynchus* woodland, and parts of *Brachystegia* woodland were somehow similar, but species composition in Mopane woodland was clearly divided from other vegetation types.

It was recommended that comprehensive vegetation monitoring and fire management programmes be established to provide data required for adaptive management of the National Park and its biodiversity.

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