

Chapter 3

Research Methods

3.1 Introduction

This study was conducted in the North-East District of Botswana, which is the second smallest district (5993 km²) of the nine in Botswana. The district shares an international border with Zimbabwe in the north and east clearly defined by the Ramokgwebana River. The North-East District borders the Central District of Botswana in the south and west with the Shashe River clearly defining this boundary. There are two further major rivers in the district, namely the Tati River and the Ntshe River. The Tati River is central to the current study.

The region has had an interesting past, which is evident from the numerous Bushman paintings found here (personal observation) and the ancient ruins known as Dombashaba within fifty kilometres of study area. Dombashaba means the “Hill of Merchants” (Maudeni unpublished, 2009). It was in this region that trading in ivory, salt, grain and other items took place. The region was rocked by instability in the 1840’s when the Ndebele, under the rule of Mzilikazi, invaded during the well documented Nfacane. During these unsettled times local tribes fled southwards. A population vacuum was created, which was filled by the now well-known Tati Company, who fenced and sold off large tracts of land, mainly for cattle farming (Maundeni unpublished, 2009).

Currently the area is a mosaic of communal farming (3,391 km²) and private freehold commercial farms (2,569 km²), with cattle farming being the main land use activity in both these areas (Maundeni unpublished, 2009).

It was with this background that the area was ideally selected for the current study.

3.2 Research framework

Literature review

- Study motivation
- Problem statement
- Desktop literature review
- Hypotheses formation

Design of dissertation

- Identification of land use types
- Point count distribution
- Duration of counts

Analysing the vegetation

- Categorising vegetation according to height and cover
- Statistical representation of vegetation structure

Collection of data

- Data collection over 10 months
- Data collection evenly spread over all 28 points

Statistical analysis

- Statistical analysis of data using various analytical programs

Conclusions and implications for management and conservation

- Testing of hypotheses
- Discussion and conclusion of results
- Impacts for land managers
- Impacts on conservation

3.3 Research area

The study area was 25 kilometres north of Francistown. The region of the study was chosen as freehold private ranches were situated along the eastern bank of the Tati River, while communal farms were found on the western side of the Tati River.

The location of the study area was chosen because of the following conditions:

- The relatively high avian species count for the area
- The close proximity of different land use types
- The near uniformity of the natural vegetation
- The uniformity of the local climate over the entire study area
- Agreement obtained from the land use managers obtained
- Stocking rates varied considerably between the land use types

Penry (1994) categorised avian distribution in Botswana into three main groups, described below. Penry (1994) explained that these groupings can be transient and may vary according to the local climate, particularly rainfall. The distribution of birds both numbers and species varies according to the described zones (Penry, 1994) and it would appear that the study area was close to the transition between the Tropical and Savannah Zone and the Interzone (Figure 3.12).

Penry (1994) divided the country into a grid with latitude and longitude degree squares used as a reference for bird counts. The current study area fell within the degree square (20° South; 27° East). Each degree square was divided into quarters with a total count recorded for each quarter. There was mean bird species richness of 153 species for the degree square .

The three primary land uses compared were the Moderate Land Management (MLM) (Farm 83 OQ), Intensive Land Management (ILM) (Farm 88 OQ) and Communal Land Management (CLM)(Farms 84 OQ & 87 OQ), as indicated below (Figure 3.3). Each of these land uses had eight evenly spaced census points (Figure 3.4).

The location of the Tati River, which ran between the land uses, offered a further opportunity to test the impacts of land use on the avian population. The Tati River followed a north to south course between the CLM, MLM and ILM. The management of the riparian

vegetation fell under the CLM as there were no fences restricting the movement of livestock from the CLM into and across the Tati River (Figure 3.8). The boundary fences on the eastern bank of the MLM and ILM were 30 metres away from the river bank (Figure 3.8)

The Riparian Land Management (RLM) only had four census points: R17, R18, R19 and R20 (Figure 3.4). R18, R19 and R20 fell within the riparian vegetation. R17 was located almost 100 metres from the Tati River. This point was located at the base of a small rocky outcrop, near to a farm with livestock and small cultivated fields and in close proximity to the river.

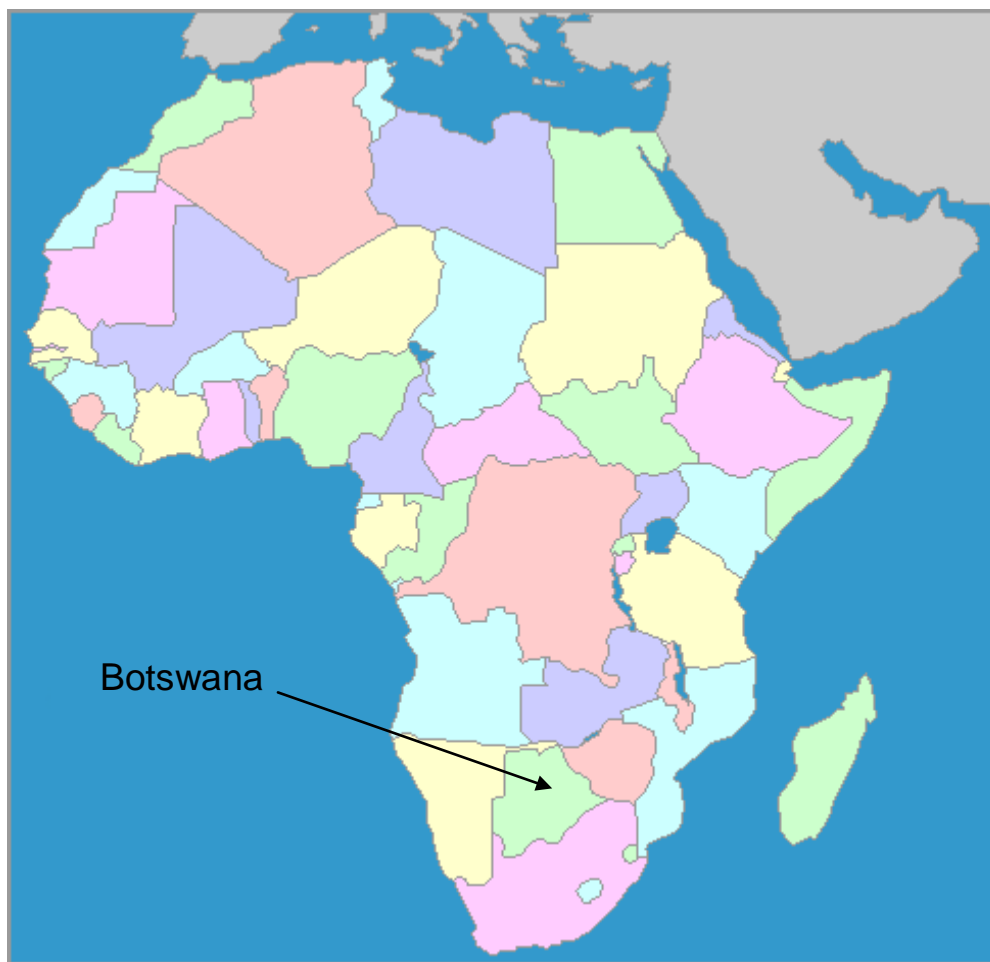


Figure 3.1 Map of Africa showing the relative position to other African states

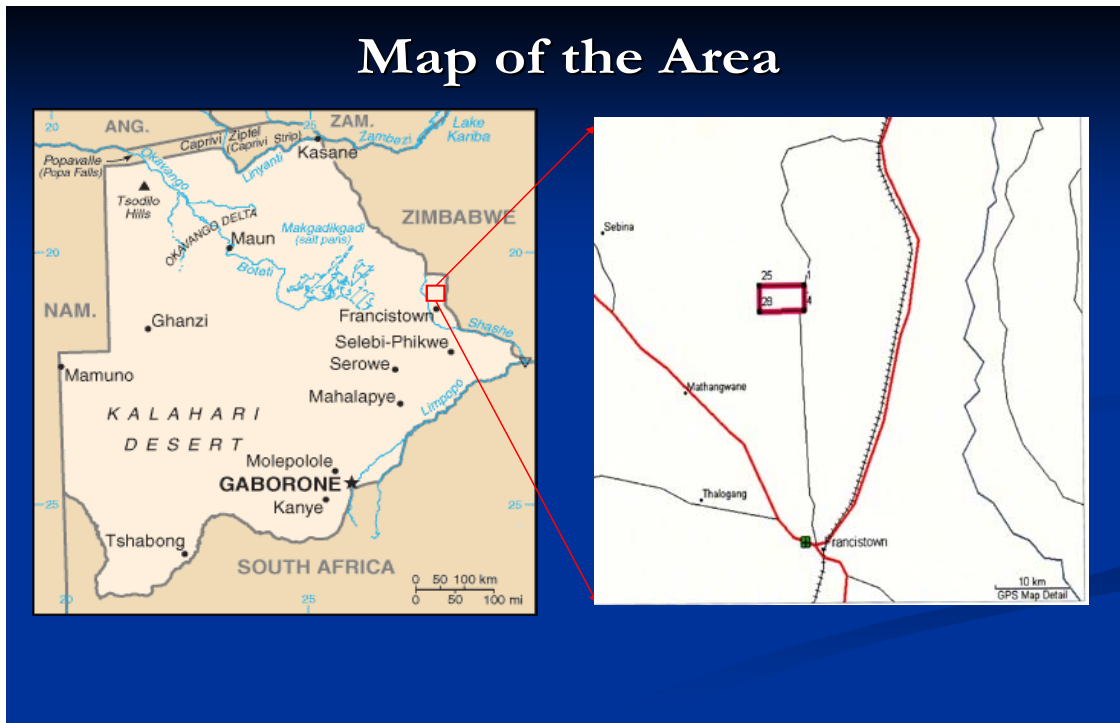


Figure 3.2 Map of Botswana with the study area indicated

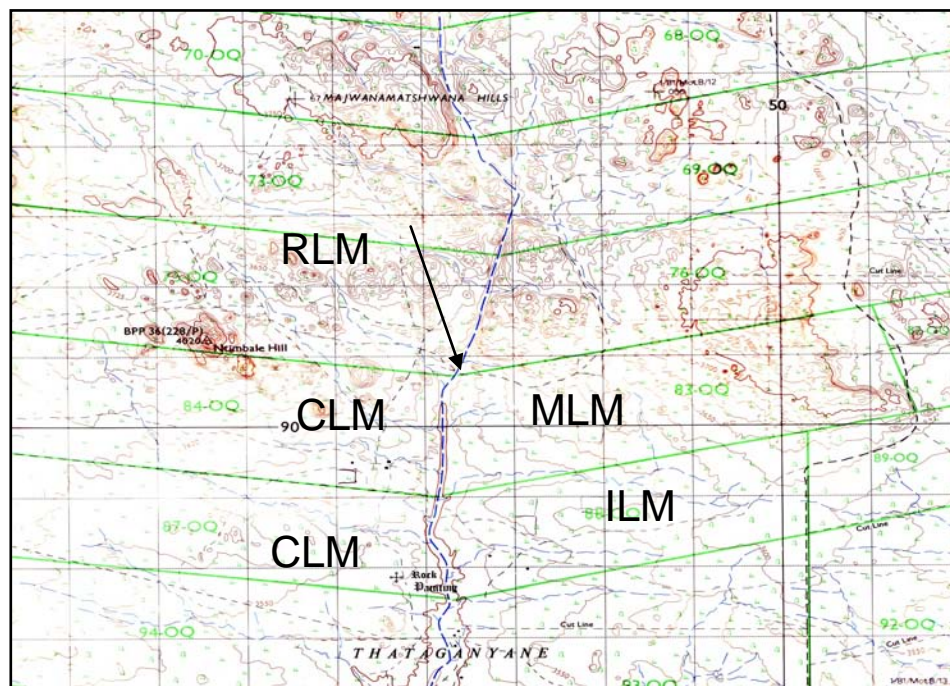


Figure 3.3 The relative position of the different land use types

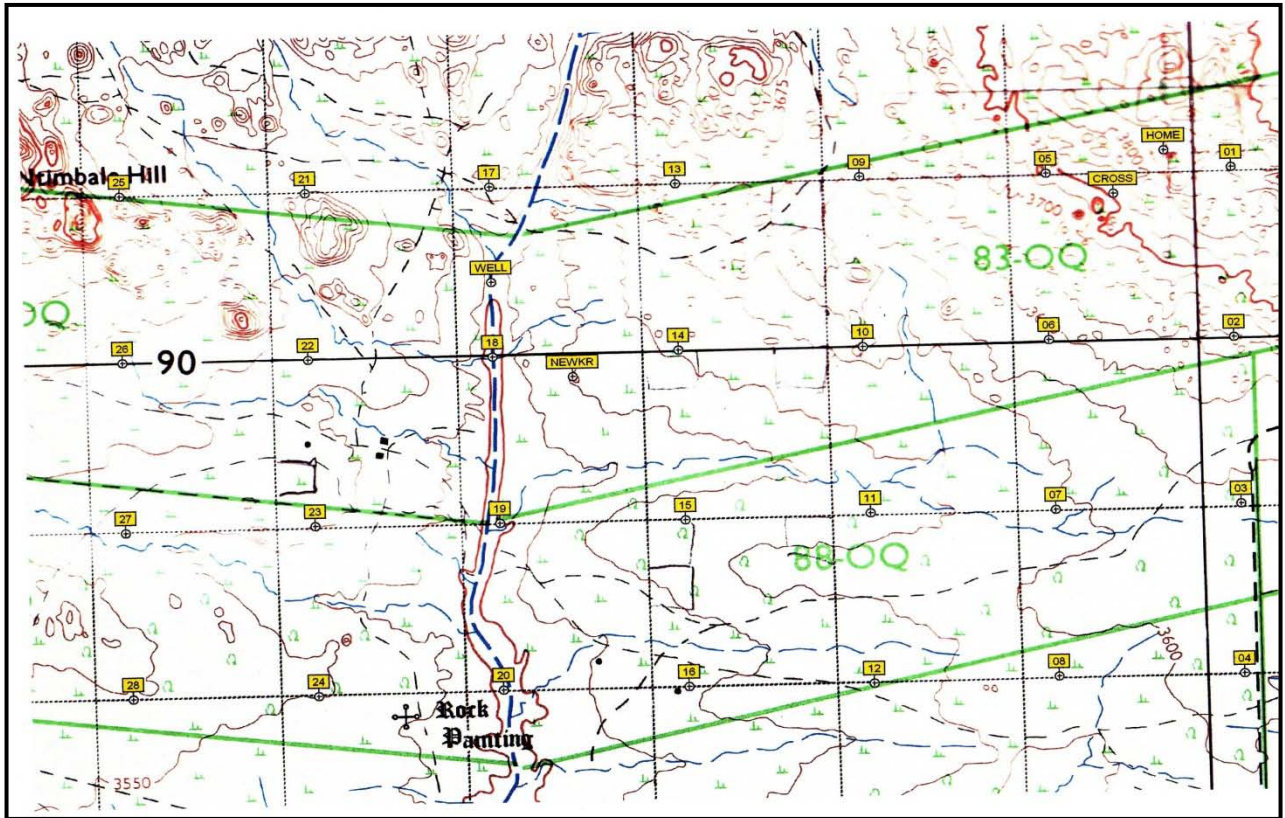


Figure 3.4 The distribution of census points as per the land use indicated in Figure 3.3 above

3.4 Location of the study area

The study area lies between $20^{\circ} 52.938'$ South and $20^{\circ} 54.564'$ South latitudes and $27^{\circ} 28.958'$ East and $27^{\circ} 25.496'$ East longitudes.

3.4.1 Site selection

Census points were selected using a Garmin Colorado 300 global positioning system (GPS) (Table 3.1 & Figure 3.4). The close proximity of the four land use types made the area ideal for the study. The managers of the MLM and ILM and the Chief of the CLM were approached regarding the study. Permission was granted by the all to conduct the survey.

The 28 census points were positioned at the crossing point of a 1x1 km grid (Figure 3.4). The evenly spaced locations on a 1x1 km grid-basis were a *priory* selected. The

systematic approach is useful for any sampling situation, provided the sampling units (locations) are far enough apart to be considered to be independent (Palmer & White , 1994; Elzinga *et al.*, 2001; Riggs *et al.*, 2008). Systematic is commonly used to sample plant and animal populations, allows for geostatistical autocorrelations with equidistant adjacent points, and no need to extrapolate outside the sample area (Christman, 2008). The positioning of the census points was located in such a way to accommodate the points for the RLM. As already mentioned, the opportunity was taken of the north-south position of the Tati River to analyse the effect of land use on the riparian vegetation. All land uses had eight census points, with the exception of the RLM, which had four census points.

The sequence of points (Figure 3.4) for each land use were 1, 2, 5, 6, 9, 10, 13 and 14 for the MLM; 3, 4, 7, 8, 11, 12, 15 and 16 for the ILM; 17, 18, 19 and 20 for the RLM; and 21, 22, 23, 24, 25, 26, 27 and 28 for the CLM. The first letter of each land use was included with the census point to assist with identification, for example M9, I7, R17 or C22.

Table 3.1: Points 1 – 28 with geographical location

Point	Degrees	Minutes	Direction	Point	Degrees	Minutes	Direction
1	20	52.938	South	15	20	54.022	South
	27	28.958	East		27	27.227	East
2	20	53.480	South	16	20	54.564	South
	27	28.958	East		27	27.227	East
3	20	54.022	South	17	20	52.938	South
	27	28.958	East		27	26.650	East
4	20	54.564	South	18	20	53.480	South
	27	28.958	East		27	26.650	East
5	20	52.938	South	19	20	54.022	South
	27	28.381	East		27	26.650	East
6	20	53.480	South	20	20	54.564	South
	27	28.381	East		27	26.650	East
7	20	54.022	South	21	20	52.938	South
	27	28.381	East		27	26.073	East
8	20	54.564	South	22	20	53.480	South
	27	28.381	East		27	26.073	East
9	20	52.938	South	23	20	54.022	South
	27	27.804	East		27	26.073	East
10	20	53.480	South	24	20	54.564	South
	27	27.804	East		27	26.073	East
11	20	54.022	South	25	20	52.938	South
	27	27.804	East		27	25.496	East
12	20	54.564	South	26	20	53.480	South
	27	27.804	East		27	25.496	East
13	20	52.938	South	27	20	54.022	South
	27	27.227	East		27	25.496	East
14	20	53.480	South	28	20	54.564	South
	27	27.227	East		27	25.496	East

3.5 Site variables

3.5.1 Moderate Land Management



Figure 3.5 Rocky outcrops (kopjes) were common in the MLM (left). Grass cover was evident in the MLM during winter (right).

The MLM was positioned north of the ILM and east of the RLM and CLM (Figure 3.3). The working population of the MLM comprised of one manager and four labourers. Only two of the labourers lived at the cattle kraal in the study area, the others lived offsite. Wood fuel for cooking, heating and the construction of the kraal were drawn from the surrounding area, which fell within the MLM. The number of livestock was 58 head of cattle that were rotated to graze in the study area in the summer and then moved to a different area of the farm, away from the study area, for winter grazing. The grazing regime was such that the grass sward was given time to seed before the onset of winter. The cattle were kraaled in the study area at night during the summer and managed by a herder who accompanied them into the field every day, returning with the cattle to the kraal in the evening. The primary reason for the herder was to manage the cattle and handle them daily, ensuring they were relatively tame. The secondary reason was that the cattle were protected by being in the kraal at night from hyena and leopard

attack and stock thieves. The cattle were watered daily with fresh water pumped from the Tati River.

The topography of the MLM was similar to the ILM and CLM, but varied somewhat with a considerable number of kopjes (Figure 3.5). These kopjes had a marked difference in vegetation when compared to the surrounding vegetation, as noted by Perkins (2006) and Trager and Mistry (2003). The vegetation between these kopjes and the riparian vegetation of the RLM appeared similar in structure to the vegetation in both the ILM and CLM however the percentages of each category varied (Figures 4.1, 4.42 – 4.45 & 4.87). Grasses (1 – 2 metres) were most evident in the MLM where grazing pressure was reduced (Figure 4.87). The fence line contrast between the MLM and the ILM (Figure 3.6) was very evident, particularly in winter.



Figure 3.6 Fence line contrast between the ILM on the left of the fence and MLM for summer (left) and winter (right)

3.5.2 Intensive Land Management



Figure 3.7 Grazing intensity in the ILM was high in summer (left) with reduced grass cover and increased broad leaf shrub. Grass cover was significantly reduced in winter (right).

The ILM was positioned south of the MLM and east of the CLM with the Tati River running between these two land uses (Figure 3.4). The private owner of the farm lived on another farm in the area. A staff of four was housed in a permanent structure on the banks of the Tati River near the cattle kraal, which fell close to I15 and I16. Wood for fuel and the construction of the kraal was taken from the surrounding area within the ILM.

The number of cattle for the farm was 293 head, which, although not confined to the study area, were watered at the kraal near the staff quarters. The cattle moved freely throughout and beyond the census points, returning only for water. These cattle were not kraaled at night, but congregated at the kraal regularly. The impact on the vegetation within the vicinity of the watering point was substantial, as Nsinamwa (2005) and Perkins and Thomas (1993) had found in their studies. As the distance from the watering point increased, so the impact on the vegetation decreased (Nsinamwa, 2005; Perkins & Thomas, 1993).

The topography of the area was similar throughout with very few isolated kopjes, generally between 2 and 5 metres in height and a significant distance apart. The vegetation of the ILM (Figures 4.1, 4.42 – 4.45 & 4.87) had a reduced number of tall trees (10–20 metres) when compared to the MLM and the RLM. Shrub cover (1–2 metres) was also reduced when compared to the MLM, although grass cover (1–2 metres) was similar to the RLM and the CLM, where grazing pressure was high and grasses were reduced.

3.5.3 Riparian Land Management



Figure 3.8 The eastern river bank was heavily grazed (left). Bare ground on the western river bank was evident. Note the well-defined cattle path leading down to the river (right). The river bed can be seen close to the horizon.

The RLM was positioned between the MLM and ILM in the east and the CLM in the west. Although the vegetation structure (Figures 4.1, 4.42–4.45 & 4.87) was very different when compared to the CLM, the RLM fell under the same livestock management practice as the CLM. The riparian vegetation followed the course of the river and included roughly 30 metres of river bank from the water's edge. Nobody lived on the RLM. There were no permanent

structures, such as housing or kraals, in the RLM area. Nevertheless, fuel for cooking and heating, and materials for housing, kraals and fencing were taken from the surrounding woody vegetation for use in the CLM. A practice observed in the CLM and the RLM was the collection of woody vegetation, which was then sold in the urban areas of Francistown for cooking and heating. The volume of this removal was unknown, but there was an increase in the winter months (personal observation).



Figure 3.9 The Tati River during the winter. Cattle droppings indicate the magnitude of cattle numbers.

The number of livestock varied throughout the year with the highest numbers recorded in winter when cattle from far a field converged on the area to access the available water in the river. Grazing intensity (Figure 3.8) and usage of woody vegetation was evident. The number of cattle recorded in winter averaged 239 head over a two week period, while small stock, mainly goats, averaged 128. There were no fences restricting access to the river and numbers of livestock may have been in excess of those observed (Figure 3.9).

The vegetation structure of the RLM (Figures 4.1, 4.42–4.45 & 4.87) was dominated by large trees, with very little to no grass and few shrubs (Figure 3.8).

3.5.4 Communal Land Management



Figure 3.10 The enclosure (left) to protect artefacts in the CLM clearly identifies the grazing intensity. Bush encroachment was particularly evident in sections of the CLM (right).



Figure 3.11 Gully erosion (left) in the early stages. Note three roads circumventing the erosion as it deepens. The magnitude of the erosion (right) close to the Tati River in the CLM was evident.

There were three cattle posts or settlements in the CLM with 14 permanent residents, although this was not constant as numbers increased to more than twenty over weekends and holidays. CLM, compared to the other land use types (Figures 4.1, 4.42–4.45 & 4.87), had significantly fewer trees between 10-20 m and large areas of bare ground. The use of woody vegetation for construction and for sale has been mentioned above.

The number of livestock, which increased during the winter because of the influx of cattle from the surrounding area, was not constant. Fencing was non-existent, apart from around small cultivated fields. The number of cattle recorded, as indicated above for the RLM, was difficult to assess as different cattle were moved into the area, particularly in winter, to access the water from the river. An attempt was made to identify the cattle by using owner brands and photographing the cattle, however the turnover was so high that it was not possible.

3.6 Duration of study

The study took place from October 2005 to July 2006. A total of six counts were made for each of the 28 points. The counts were conducted in such a way as to give an even distribution of counts per point per season as indicated below in 3.8.4.

3.7 Climate and rainfall

3.7.1 Climate

There are two main seasons in Botswana namely winter and summer with short transition periods between them (Penry 1994). The winters are periods of long sunshine with very little to no rain with midday temperatures reaching 17⁰ C and dropping to -8⁰C in some of the coldest areas. Summers are characterized by high midday temperatures between 30 and 35⁰C with 40⁰C often being reached and night temperatures dropping to between 15 and 20⁰C (Penry 1994, Tietema, *et al.*, 1991). Soil temperatures can reach as high as 70⁰C in the summer months (Tietema, *et al.*, 1991).

3.7.2 Rainfall

The southern African region has a rainfall pattern which includes an 18 year drought cycle (Tyson, *et al.*, 1975). Bhalotra (1985) and Tyson (1979) confirm that this drought cycle is evident in Botswana.

Rainfall in Botswana is described by Tietema, *et al.* (1991) as varying between 250 mm to over 650 mm per year with an annual average between 300 to 550 mm per year. The rainfall figures for Francistown fall within the description by Tietema, *et al.* (1991). The important point made by Tietema, *et al.* (1991) was that the co-efficient of variation for this average rainfall is between 30 and 45% and within the season this co-efficient could be as high as 100% (Tietema, *et al.*, 1991). This means rainfall within the season can be erratic with long periods of no rainfall with total annual average sometime falling in a few short heavy showers over a short period.

The erratic rainfall of Botswana from season to season and within the season has a major seasonal influence on the vegetation and as a result on the distribution of avifauna (Penry 1994).

In the study of bird communities at Ruretse in southeast Botswana, Tyler (2001) found that the species recorded included a mixture of residents, migrants and seasonal or erratic visitors. Residents included those recorded in every month of the year with the migrants including both intra-Africa and Palaearctic species which were present during the summer. Erratic species were present in some months and almost absent in others. Erratic species included Marico Sunbird *Nectarinia mariquensis*, White-bellied Sunbird *Cinnyris talatala* and the Red-faced Mousebird *Urocolius indicus*, which although regarded as being common residents were often absent from the Ruretse area for some of the winter months yet these species were fairly common in the winter months in the gardens of Gaborone which was less than 50 km away from Ruretse. The often erratic rainfall of many parts of Botswana is therefore likely to have an influence of the distribution of numbers of birds and bird species (Tyler, 2001).

The rainfall figures presented by kind permission of John Solomon of Francistown Botswana (Table 3.2) confirm the rainfall patterns for the seasons as suggested by Tietema, *et al.* (1991) but the variation within the months is not evident. The rainfall figures although recorded 25 kilometers from the study area, do indicate a consistency with previous research.

Table 3.2 Rainfall figures for Francistown from 1974 to 2011

PLOT 923 FRANCISTOWN - RAINFALL FIGURES													JAN - DEC			
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year total	Year ave		
1974	120.5	150.2	17.4	27.9	14.1	0	1	0	57	0	152.1	124.5	664.7	55.4		
1975	276.9	67.3	14.7	50.9	6.5	0	0	0	0	0	18.3	149.3	583.9	48.7		
1976	78.1	137.6	68.7	31	76	0	0	0	14.8	44.9	70.2	58.6	579.9	48.3		
1977	37	154.6	100.7	0	0	0	0	8.5	44	10.9	83.1	159.5	598.3	49.9		
1978	286.6	97.4	18.1	22.8	7.4	0	0	0	10	107.7	51.8	64.4	666.2	55.5		
1979	95.6	26.3	51	0	6	0	0	0	0	80.9	80.8	101.2	441.8	36.8		
1980	53.1	106.6	2.6	30.5	0	0	0	0	27.5	35.5	198.4	61.9	516.1	43.0		
1981	179	186.6	82.5	13.9	3.1	0	0	0	0	38.7	52.5	52.3	608.6	50.7		
1982	0	0	0	0	0	0	0	0	0	92.7	96.2	60.5	249.4	20.8		
1983	35.4	22.8	54.4	14.2	8.6	0	0	0	0	6.8	52.5	42.8	237.5	19.8		
1984	14.5	25.3	151.2	11.3	0	1.7	3	0	30.6	10.7	66.2	60.6	375.1	31.3		
1985	114.6	66.7	31.8	5.3	2.8	0.8	0	0	1	46.8	24.1	21.6	315.5	26.3		
1986	6.9	24.3	65.8	93.5	0	0	0	0	15.4	46.6	97.2	100.8	450.5	37.5		
1987	62.8	42.5	11.7	0	0	0	0	0	8.5	12.6	89.7	292.8	520.6	43.4		
1988													0	0.0		
1989	59.8	155.2	0	33.7	0	5.4	0	0	0	31.2	76.3	46.9	408.5	34.0		
1990	76.3	49.2	35.6	14.3	12.4	0	0	0	0	0.2	12.1	128.9	329	27.4		
1991	110.5	82.1	0	0	0	0.3	0	0	0	2.1	25.9	42	262.9	21.9		
1992	51.1	24.6	13.3	27.6	0	6.2	0	0	0	19.1	23	24.2	189.1	15.8		
1993	55.6	9.2	10.6	15.1	0	0	8.2	0	1.3	2.3	112.6	50	264.9	22.1		
1994	73.5	152	15.5	0	0	0	0	0	0	66.5	28	31	366.5	30.5		
1995	125	71	146	13	42.5	0	0	0	0	0	149.5	109.5	656.5	54.7		
1996	162	108.5	8.5	0	20	0	0	0	0	34.6	136.2	65.5	535.3	44.6		
1997	101.7	37.6	72.1	22.1	14.4	0	0	0	0	28	129.9	102.3	508.1	42.3		
1998	140.3	66.8	41.3	0	0	0	0	0	0	57.5	133.6	111.8	551.3	45.9		
1999	105.1	60.5	39.9	0	35.8	0	0	0	0	33	150.8	110.7	535.8	44.7		
2000	363.3	367.9	130.7	18.6	2.8	64.1	2.4	0	0	8.3	100.7	46.2	1105	92.1		
2001	40.4	120.7	64	2.8	8.3	0	0	0	10.4	14.8	228.4	86.9	576.7	48.1		
2002	7.5	8.4	0	45.7	15	4.6	3.6	4.1	9.5	14.8	4.5	35	152.7	12.7		
2003	70.8	74.9	26.2	0	0.9	36	0	0	1.2	47.6	58.3	70.6	386.5	32.2		
2004	76.5	151.1	136.3	90.3	0	0	0	0	0.4	41.3	49.6	277.8	823.3	68.6		
2005	104.4	18.8	52.1	54.2	0	0	0	0	0	0	47.6	93.3	370.4	30.9		
2006	114.2	157.7	106.9	8.6	7.6	0	0	0	1.8	11.8	239	143.3	790.9	65.9		
2007	16.8	17.4	131.9	4.3	0	2.9	0	0	9.9	45.3	61.4	102.2	392.1	32.7		
2008	142.5	18.5	152.6	5.3	2.7	0	0	0	0	7.4	99.8	70.9	499.7	41.6		
2009	134.3	194.4	37.7	0	19.1	41.6	2.6	0	33	17.4	123	99	702.1	58.5		
2010	171.3	134.6	26.6	91.8	13.5	0	0	0	0	69.4	85.6	96.2	689	57.4		
2011	237.6	27.6	42.7	71.1	6.5	0	0	0	0	11.8			397.3	33.1		
2012													0	0.0		
2013													0	0.0		
2014													0	0.0		
2015													0	0.0		
Total	3902	3217	1961	819.8	326	163.6	20.8	12.6	276.3	1099	3209	3295				
Mth Ave	92.89	76.59	46.69	19.52	7.762	3.895	0.495	0.3	6.579	26.17	76.4	78.45				

3.8 Materials and methods

3.8.1 Bird surveys

The bird counts were conducted at each census point, starting before dawn when the birds were most active. Surveys took place weekly between October 2005 and July 2006. Each point was surveyed three times during the summer and three times during the winter, totalling 168 point counts. Binoculars with a 10 x 40 magnification were used to assist with bird identification.

The point count method is the most widely used counting method in bird population studies (Ralph *et al.*, 1995). Point counts rely on the assumption that the data collected represents a constant proportion of the actual numbers over time and space (Thompson, 2002).

A maximum of four points were counted on any one morning as by mid-morning bird activity was significantly reduced. After reaching a point, 10 minutes was taken before counting began for birds to settle. Each survey took 20 minutes.

There are a number of techniques to assess avian demographics, including mist netting and nest searching, both of which are expensive and limited to small spatial extents. Point and transect counts are techniques that increase the size of the area that can be surveyed and are relatively easy and cheap to conduct, although the information gleaned will be of benefit only for relative abundances for site and habitats (Ralph *et al.*, 1993). When compared, there are certain advantages of point counts over transect counts, as suggested by Bibby, *et al.* (2000):

- Plotting point counts is easier to locate systematically or randomly selected points when compared to transects, which are difficult to design and may have a bias for certain habitats.
- Points that are designed to be well spaced will provide more effective data collection when compared to a number of transects.
- Habitats that have subtle changes will be best represented by point counts when compared to transect counts.

Bibby, *et al.* (2000) did, however, stress that point counts had the disadvantage that the data was difficult to analyse. When using point counts, the surveyed area is proportional to the square of the distance from the observer. When conducting transect counts the first dimension is the lateral distance from the observer and the second dimension was the transect length. The problem, therefore, was that for point counts the density estimates were more likely to have errors because of inaccurate distance estimations. There is a further possible complication as there could be data errors when counting moving birds using the point count technique (Bibby, *et al.*, 2000). Although Bibby, *et al.* (2000) mentioned the difficulties of analyzing point data, they did not consider geostatistical analysis non multivariant analysis to any extent. The present study will apply, geostatistical interpolations, univariant, bivariant and multivariant techniques to analyse the point data.

Birds were counted in the current study for 20 minutes using visual, auditory and behavioural cues within a radius of 100 metres from the census point. Although recording birds from auditory cues is effective in forested areas, there are limitations in the frequency of human hearing, which can result in biased results as birds with calls in a higher or lower frequency range, when compared to human limitations, may not be recorded. When tested in a 100 metre radius this bias could be between 13.8% - 20.2% greater than the actual bird population occurring within that radius (Alldredge, *et al.*, 2007).

Point count duration of five or 10 minutes would provide adequate data for modelling bird habitat relations when compared to counts which lasted 20 minutes. It was also noted that there was little or no improvement in model performance when visits to a point increased from two to three visits (Dettmares *et al.*, 1999). Detection rate differences of bird species could also have resulted in biased estimates of habitat occupation of some species, but data collection produced similar results when comparing five minute counts to 20 minute counts at the same point. However, the results need to be tested with similar studies (Dettmares *et al.*, 1999). The analysis performed by Toms *et al.* (2006) suggested that there were limitations when using avian point counts with particular reference to large territorial species. Point counts were reasonable proxy for measures of bird species, particularly species with relatively small territories and systems with high spatial or temporal variability (Toms *et al.*, 2006). However, the main aim of the study was to compare land use types and not to obtain species richness and numbers data. The point count methods were designed to obtain comparable data. It is

therefore assumed that the limitations of the point count methods were the same at all points, and that the point data can be related to each other and land use.

3.8.2 Vegetation structure

Willson (1974) suggested that there was a relationship between the complexity of the vegetation and the numbers of bird species. He concluded that as the vegetation complexity increased, particularly with the increase in the numbers of trees, there was a significant increase in bird species. This was not only due to the increase in resources, but also to the creation of an environment which had more opportunities for roosting, feeding, shelter, and breeding (Lack, 1986; Trager & Mistry, 2003; Willson, 1974). In open areas with fewer trees, there is reduced humidity and wind blows seed and arthropods away. In the more complex wooded areas, the vegetation creates higher humidity and reduces the effects of wind on seed and fruit, while creating a more suitable micro-climate for arthropods and other small animals (Lack, 1986). This will impact on bird distribution patterns.

Penry (1994) confirmed that it is the shape and character of vegetation which determines where avifauna is likely to be found. He refers to this as structure or physiogamy which may often change as a result of rainfall, fire, drought, flood or man-induced change.

Vegetation can be seen as a multi-dimensional continuum that can be divided into groups, which allow for a broad scale classification. Vegetation growth form, cover and height, amongst others, were structural characteristics that Edwards (1983) used to classify vegetation groups.

The vegetation classification described in Chapter 3 was used to classify the structural categories of the current study area using Edwards's (1983) vegetation categories, with one difference: the vegetation categories suggested by Edwards have been modified by altering his category of herbs to bare ground, as bare ground is very evident in the current study.

3.8.2.1 Vegetation and avian distribution in Botswana

Avian distribution in Botswana follows similar patterns to that of plant and animal species distribution. Penry (1994) categorised these areas of distribution in Botswana as:

- The Tropical Woodland and Savannah Zone
- The Kalahari Zone
- The Interzone lying between the above two zones (Figure 5.2)

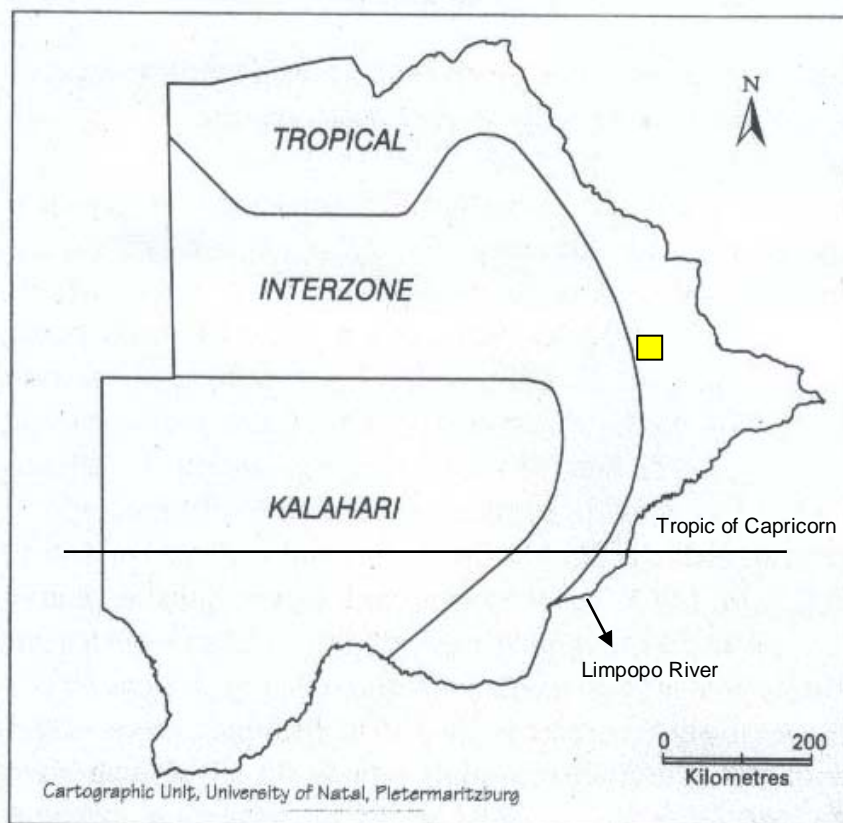


Figure 3.12 The categories of vegetation in Botswana, as described by Penry (1994), with the study area clearly marked. The yellow area indicates the location of the study area, inside the Tropical and Savanna Woodland Zone

3.8.2.1.1. The Kalahari Zone

The Kalahari Zone is characterised by dry savannah vegetation, limited primarily by the supply of water and the Kalahari sands. The resultant vegetation, when combined with the water restrictions, has a significant effect on the bird populations. There are bird species in this zone that extend into the Tropical Woodland Zone, with the converse being less frequent (Penry, 1994). Bird species common to this area are the Crimson-breasted Shrike (*Laniarius atrococcineus*), Marico Flycatcher (*Melaenornis mariquensis*), Kalahari Robin (*Erythropygia paeon*) and Shaft-tailed Whydah (*Vidua regia*).

3.8.2.1.2 The Interzone

The Interzone (Figure 3.12) is principally an area dominated by Kalahari Zone bird species. The Interzone is invaded by the Tropical and Savannah Zone bird species when the climatic conditions are more favourable (Penry, 1994). There can be an invasion of Interzone species into the Tropical Woodland and Savannah Zone when adverse climatic conditions occur. The Red-eyed Bulbul (*Pycnonotus nigricans*), for example, is a species associated with the dry conditions of the interior Kalahari Zone (Irwin, 1981) and although not recorded at any of the census points in the current study, this species was observed in the dry winter months of the study area. Irwin (1981) suggested that these seasonal movements by the Red-eyed Bulbul from the dry interior occur when water supply is reduced, significantly encouraging this species to move to more well watered areas in the Tropical Woodland and Savannah Zone (Irwin, 1981).

3.8.2.1.3 The Tropical Woodland and Savannah Zone

The Tropical Woodland and Savannah Zone is an area found across northern Botswana, stretching to the east and then following the course of the Limpopo River to the south (Figure 3.12). There is a perennial supply of water from the north, which enters the Kalahari Zone, forming the Okavango Delta. The vegetation of the western, southern and eastern boundaries of the Okavango Delta changes abruptly as the water supply ends. Bird distribution patterns change significantly at this interface. The bird species of the Tropical Woodland and Savannah

vegetation extend south of the Tropic of Capricorn as they follow the Limpopo River watershed (Penry, 1994).

The zoning suggested by Penry (1994) can be used to describe the current study area using the patterns of avian distribution. The study area could be described as being in the Tropical and Savannah Zone, where typical species of this zone are the White-browed Scrub-Robin (*Cercotrichas leucophrys*) and the Chinspot Batis (*Batis molitor*) (Penry, 1994), with both species being recorded throughout the study area. These species give way to the Kalahari Zone species, the Kalahari Robin (*Erythropygia paeon*) and the Pririt Batis (*Batis pririt*) (Penry, 1994), neither of which were recorded at any time during the census period.

The Crimson-breasted Shrike (*Laniarius atrococcineus*) and the Shaft-tailed Whyda (*Vidua regia*) however, are primarily a Kalahari Zone species (Penry, 1994), but both were recorded at a number of points in the current study.

The distribution of bird species suggests that the study area could be close to the interface of the Tropical Woodland and Savannah Zone and the Interzone, with the movement of bird species between these zones being strongly influenced by rainfall (Figure 3.12).

3.8.2.2 Vegetation survey

The vegetation for the area is described by Weare and Yalala (1971) as Mixed Mopane / Acacia tree savannah. Perkins (2006), however, believed that the description by Weare and Yalala (1971) was appropriate regionally, but did not take into account the marked changes in vegetation species as a result of changes in topography and geology.

A vegetation survey conducted for the lease area of the Mupane Gold Mine, approximately 59 kilometres south-east of the current study, was carried out by Perkins (2006). The close proximity to the current study was the reason for drawing on this study.

Both Figures 3.13 and 3.14 below have been taken from the Perkins (2006) study and are satellite images from 2000, which pre-dates current extensive mining. Remote sensing based on the spectral reflectance of the different vegetation types, combined with a field survey, was used to stratify the main vegetation communities, identifying key habitat types (Perkins, 2006).

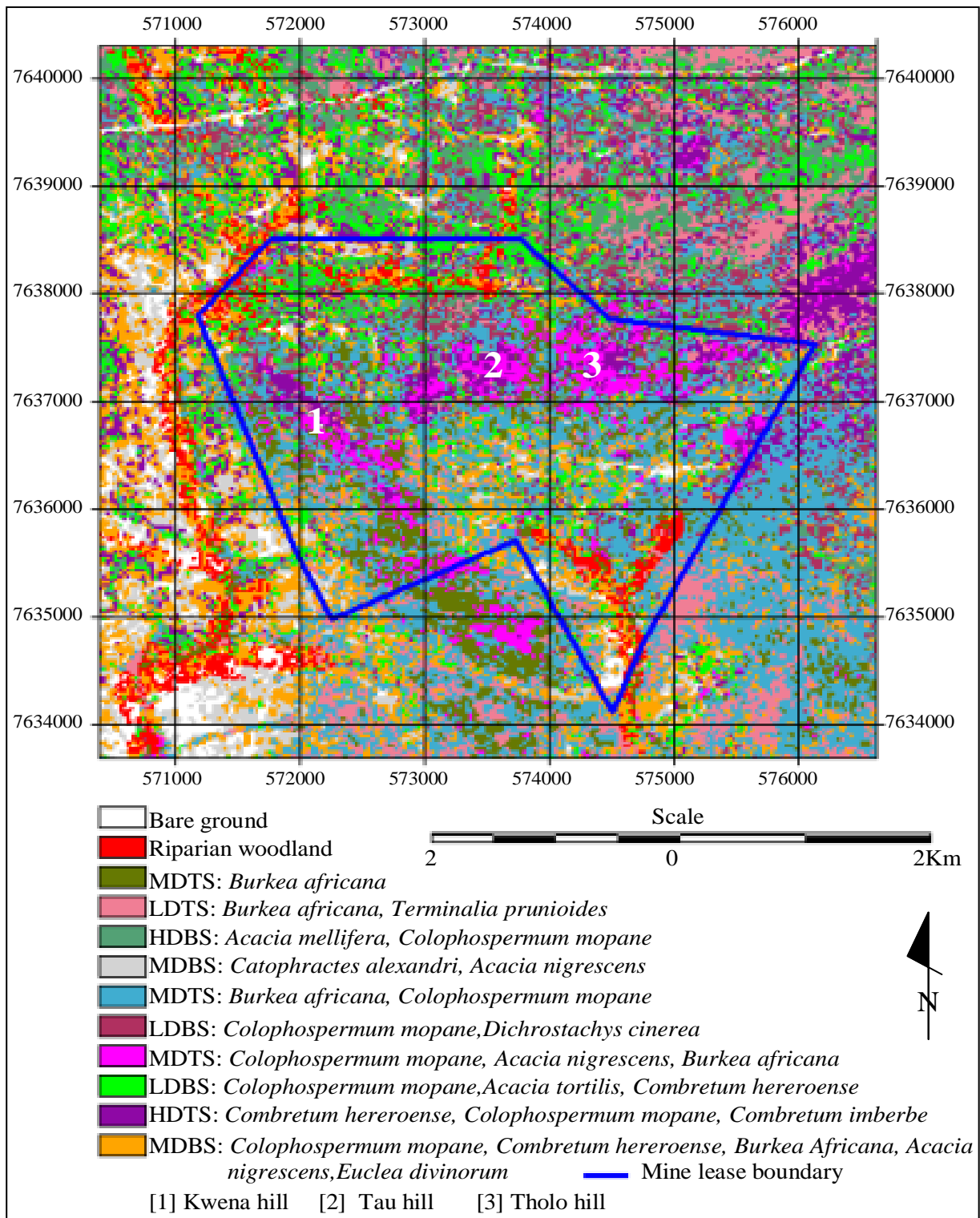


Figure 3.13 The vegetation communities of the mine lease area, which includes three hills (1. Kwena, 2.Tau & 3.Tholo) and an area outside the lease area

What is evident from Figure 3.13 is that there are very clear differences in vegetation communities, with the hills and riparian vegetation being very distinct. The vegetation outside these two communities has varying species, which are confirmed by their spectral reflectance. Perkins (2006) made the observation that there is a marked change in vegetation communities over a very short distance, particularly between both the hill vegetation and riparian vegetation when compared to the surrounding savannah.

Figure 3.13 shows the land outside the mine lease area, which has been used for livestock farming for an extensive period, with the result that there are large areas of bare ground evident, particularly along the river courses. The domestic stock has caused the soil to become capped with sheet erosion, removing seeds, any loose vegetation and loose soil particles (Perkins, 2006). This is particularly valid when comparing the CLM with the other land use types (Figures 4.2-4.5).

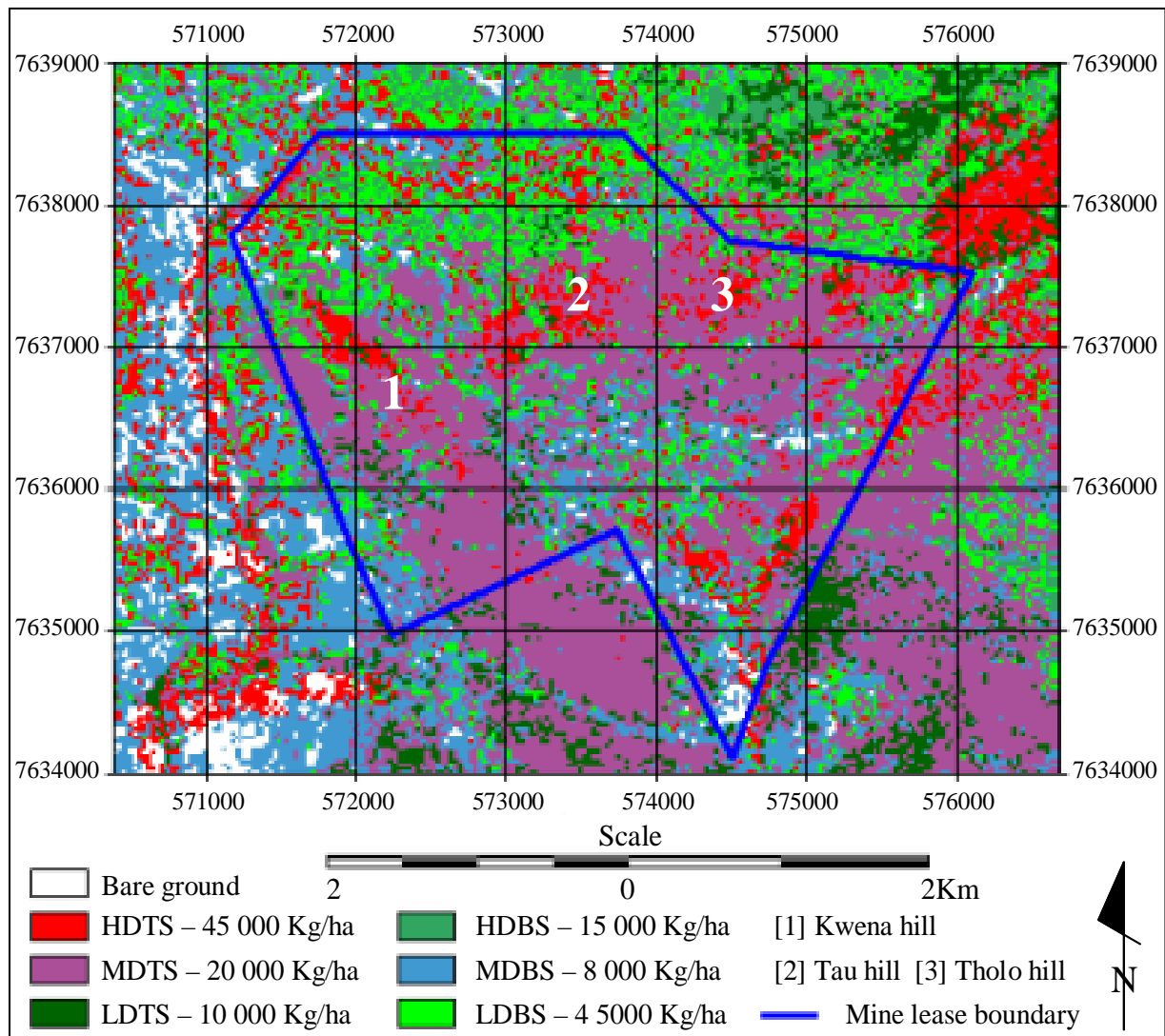


Figure 3.14 Woody biomass of the mine lease area & the surrounding area is clearly indicated

The information drawn from the Perkins (2006) study (Figure 5.3) indicates that the biomass of woody vegetation follows similar patterns to the vegetation communities (Figure 5.2). Bare ground was evident, particularly outside the lease area, while the hills and riparian vegetations had a higher woody biomass (HDTS–High density tree savannah, MDTS–Moderate density tree savannah, LDTS–Low density tree savannah). The vegetation communities between the hills and the rivers have a less dense woody biomass, being described as a bush savannah (HDBS–High density bush savannah, MDBS–Moderate density bush savannah, LTBS–Low

density bush savannah). Although the hills and riparian vegetation communities have a similar woody biomass, the species composition was different, which is confirmed by the different spectral reflectance of these two areas (Figure 5.2).

Trees that are generally found on rocky outcrops of the current study area, include Sickle-leaved Albizia (*Albezia harveyi*), Sjangbok Pod (*Cassia abbreviate*), Paperbark Commiphora (*Commiphora marlothii*), Pepper-leaved Commiphora (*Commiphora mossambicensis*), Lavender Croton (*Croton gratissimus*), Wooden-banana (*Entandrophragma caudatum*), Fig species (*Ficus spp*) and the African Star-chestnut (*Stercula Africana*) (Pulgrave, 1981).

Trees that are generally found in riparian vegetation of the current study area, include River Bushwillow (*Combretum erythrophyllum*), Tree Wisteria (*Bolusanthus speciosus*), Sweet Thorn (*Acacia karroo*) and Fig species (*Ficus spp*) (Pulgrave, 1981).

Trees and woody vegetation, generally found in the savannah vegetation between the rocky hills and riparian vegetation of the current study area, include Black Thorn (*Acacia mellifera*), Umbrella Thorn (*Acacia tortillas*), Shepherd's Bush (*Boscia albitrunca*), Mopane (*Colophospermum mopane*), Magic Guarri (*Euclea divinorum*), Transvaal Gardenia (*Gardenia volkensi*), Bastard Brandybush (*Grewia bicolour*), Brandybush (*Grewia flava*), Rough-leaved Raisin (*Grewia flavescens*), Marula (*Sclerocarya birrea*) and Small Sour Plum (*Ximenia americana*) (Pulgrave, 1981).

3.8.2.3 Determining the vegetation cover for the four land use types

Edwards's (1983) broad-scale classification of vegetation was used to categorise the vegetation, with the major categories being trees, shrubs, grasses and herbs. Bare ground was added in the place of herbs as a vegetation category as the land use of the study area had significant impact on the amount of bare ground present. Perkins and Thomas (1993) suggested in their study in western central Botswana, that there was a decrease in grass cover resulting in bare ground being very evident after periods of intensive grazing by livestock.

The vegetation of the different land use types was described using four criteria: trees, shrubs, grasses and bare ground.

The trees were categorised into three classes:

- Trees between 10-20 m
- Trees between 5-10 m
- Trees between 2-5 m

Shrubs were categorised into three classes:

- Shrubs between 1-2 m
- Shrubs between 0.5-1 m
- Shrubs less than 0.5 m

Grasses were categorized into three main classes:

- Grasses between 1-2 m
- Grasses between 0.5-1 m
- Grasses less than 0.5 m

Bare ground was categorised as a percentage of total cover for land use at each point. Each land use type had the four categories combined to create a composite vegetation structure.

The structural pattern was generated by a combination of the growth forms (trees, shrubs or grasses) and the cover these generated. The height class of each group was combined for each structural growth form to generate a vegetation structure at each survey point.

The vegetation was described by Weare and Yalala (1971) as mixed Mopane / Acacia tree savannah. Woody vegetation is dominated by Mophane *Colophospermum mopane*, with other common genera being *Acacia*, *Combretum*, *Commiphora*, *Terminalia* and *Grewia* with common grass genera being *Aristida*, *Eragrostis*, *Digitaria*, *Tragus* and *Urochloa*. The uniformity of the vegetation made the study area ideal for the comparison of the different land use types. However, on closer examination, changes in topography in parts of the study area resulted in different vegetation structure over short distances which may have impacted on the results of the analysis. These differences will be elaborated on in Chapter 5.

3.8 Guild classification

Each species was categorised according to their feeding and nesting guild (Tables 3.2 & 3.3)

Table 3.3: Bird feeding guild categories

Feeding Guild	Guild description
Frugivores	Adults of species that feed predominantly on fruit
Granivores	Adults of species that feed predominantly on seed
Omnivores	Adults of species that feed predominantly on a mix of different food
Scavengers	Adults of species that feed predominantly on carrion
Carnivores	Adults of species that feed predominantly on meat
Insectivores	Adults of species that feed predominantly on insects

Table 3.4: Bird nesting guild categories

Nesting guild	Description of the nest
Tree-nesting	Species nesting in trees
Shrub-nesting	Species nesting within the shrub layer
Structure-nesting	Species nesting on rocky outcrops or man-made structures
Ground-nesting	Species nesting in a scrape or hole in the ground
Brood-parasites	Species that lay their eggs in the nests of another bird species
Extralimital breeders	Species that breed outside Southern Africa

3.10 Data analysis

The method used in this study to assess avian distribution was the point count method already described. The data analysis was performed using various programs listed below.

3.10.1 Microsoft Excel

Microsoft Excel spreadsheets were used extensively throughout this study, with many of the tables generated from information from the bird counts for the different land uses. Spreadsheets required for PC Ord were imported from Microsoft Excel.

3.10.2 Geostatistical analysis for Environmental Sciences (GS) Version 9

One of the programmes used to statistically represent the data gathered was GS⁺ Version 9 (Figure 4.6-4.62). Each census point had an X and Y co-ordinate for the geographical location, while the Z value was for the bird number for that point. The technique used in GS⁺ to create these figures was interpolation, which estimates the unknown values of an area from the known values of the nearest points.

There are a number of different approaches to interpolation, including simpler techniques that take an average of the unknown value of a point compared to the known value at nearby points. Kriging, a more advanced form of interpolation, was used, which uses the average value at the neighbouring points and includes the spatial variation of the data set from the nearest neighbour, which is weighted by distance. The use of the semi-variance provides the information about the underlying relationship of the data set and reduces the variance of the information, thus producing a more accurate result. The graphs were constructed by using actual values versus the estimated value for each census point of the domain (Robertson, 1987). Indicator kriging was used to generate the maps.

3.10.3 Mapviewer 6

Mapviewer 6 was used in conjunction with GS⁺ to create the boundaries between the land use types and to indicate the main river course of the Tati River and its tributaries pertaining to the study area (Figure 4.6 to Figure 4.62).

3.10.4 Graphpad Prism 4

Graphpad Prism 4 was used to perform the analysis of variance (ANOVA), which works well if the data does not follow the exact Gaussian bell-shaped distribution, particularly for large samples (Motulsky, 2003). ANOVA was used to assess the effects of an environmental impact (land use) on the different categories of birds. The one-way ANOVA can be used to compare the means of three or more groups when the data of each of these groups is one category, in this case birds, with figures represented as scatter plots (Motulsky, 2003)(Figure 4.63 to 4.71). The Bonferroni post-test which is a modification of *t*-tests, was used to compare all pairs of

columns (land use). The probability value, or p-value, and standard deviation were important when assessing the effect of land use on a particular group of birds, for example species richness. If the $p < 0.05$ when comparing the means of any two land uses, this indicates that there was a 5% possibility of recording the same difference if the two land uses had the same mean (Motulsky, 2003). When the probability value is small it is likely that random sampling was not the cause of the differences that were observed (Motulsky, 2003).

Two-way ANOVA was used to determine how two factors (land use and season) can affect a particular response by addressing the following questions (Motulsky, 2003):

- Are the results affected by the first factor?
- Are the results affected by the second factor?
- Are the results affected by an interaction of these two factors?
- Is residual variation unrelated to differences between rows and columns?

The null hypothesis is that there would be no interaction between the columns and between the rows (land use and seasons). The probability value will assist in ascertaining if there is any interaction between the rows and columns (Motulsky, 2003).

3.10.5 PC-Ord Version 5

PC-Ord was used as a Windows-based programme for multi-variant analysis of ecological data using spreadsheets (Beals, 1984). Multi-variant analysis is an important modern tool as many researchers of ecological issues are faced with numerous variables of community data when assessing environmental impacts (Gauch, 1982). This form of analysis is a branch of mathematics that examines a number of variables simultaneously (Gauch, 1982).

The information in the form spreadsheets generally contains a species data set of information, which is the first matrix, while the second matrix contains an environmental data set, vegetation, for example. These matrices can be interchanged, but it is the main matrix which is the subject of most of the operations of PC-Ord.

Non-metric Multidimensional Scaling (NMS) is an ordination method that is well suited to ecological studies as it permits suitable graphical representation. The use of this method allows for the discovery of properties, qualities or characteristics of a data set, scaled against

another set of data at a particular time to display the relationship in an appealing fashion Clarke (1983).

The ordination procedure used was Sorenson (Bray-Curtis), which locates the major axes of variation, reducing the dimensions with a minimum loss of information. Ordination creates a two- or three-dimensional map using multi-dimensional data, enhancing the important shapes of variation, but reducing the less important variation whilst maintaining the integrity of the map (Beals, 1984).

Perhaps one of the most useful goals when assessing community analysis is to detect and describe how individual species can be used to describe environmental conditions. Indicator Species Analysis was performed using Dufrene and Legendre's (1997) method. The results showed a combination of the abundance of a species and the occurrence of that species, as well as a probability value indicated for each species

A challenge of statistical analysis is the representation of the data in a graphic format. Two-way cluster dendrograms were used to show the relationship between individuals and groups. The main reason for two-way cluster analysis was to expose the relationship between the individual avian species and the relationship with the cluster itself. The resulting graphs show the relationship, both similarities and differences, between individual species in rows of the same and different groups, and columns of the same and different groups.