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# Quantitative Analysis of Ngoma Forest in Kafue National Park, Zambia

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**Abstract:** Ngoma Forest is one of the eleven major vegetation types in Kafue National Park. Between 1997 and 2002, a study was undertaken to quantify the vegetation and landscape of Ngoma Forest. The key vegetation measurement variables taken from fourteen 20m X 20m sampling plots were: height, diameter at breast height (DBH) and crown size. In addition to vegetation measurements, data on terrain, soil, water and fire occurrence were recorded from each sampling plot. Observations regarding the presence of faunal species were done based on actual sightings and signs such as droppings, nests, foot prints, debarking of trees, feathers, hairs and sounds. Results of the study indicates that Ngoma Forest terrain is almost flat to very flat with generally straight slope of 0 to 3% and altitude ranging from 1,050m to 1,120m above sea level. The Forest occurs on strong acidic and well-drained sandy-clay and sandy-loam with pH range of 4.4 to 5.3. *Baphia massaiensis*, *Friesodielsia obovata*, *Baikiaea plurijuga*, *Pterocarpus lucens*, *Combretum celastroides C. mossambicense*, and *C. elaeagnoides* contribute more than 80% to the physical structure. The tree layer consists of tall trees in the height range of 18 to 22m and is dominated by *Baikiaea plurijuga* and *Pterocarpus lucens* with isolated stands of *Entandrophragma caudatum*, *Ficus sur*, *Burkea africana* and *Erythrophleum africanum*. The second layer consists of trees above 6m but less than 18m and is characterized by *Philenoptera violacea*, *Pterocarpus rotundifolius*, *Xeroderis stuhlmannii*, *Dalbergiella nyasae*, *Strychnos potatorum* and *S. pungens*. The third layer consist of small trees and shrubs rarely reaching the height of 6m and is characterized by *Croton megalobotrys*, *Friesodielsia obovata*, *Combretum elaeagnoides*, *C. mossambicense*, *C. celastroides*, *Duranta erecta*, *Citropsis daweana*, *Grewia flavescens*, *Dalbergia martinii*, *Pteleopsis anisoptera* and *P. myrtifolia*. The species diversity of Ngoma Forest is relatively low but comparatively higher than Mopane, Combretacea and *Acacia* woodlands. The tree / shrub density calculations indicated 1,475 stems per hectare while the mean biomass calculations were 122.6 tons per hectare and 1.5 tons per hectare for trees and shrubs respectively. The extent of Ngoma Forest in 1985 was 34km$^2$ but the Forest had shrunk to about 18km$^2$ by 2002. The Forest is likely to shrink further while the scrubland around the Forest is going to expand. This habitat shift is bound to adversely affect the habitat range of a number of ungulates, carnivores, primates, rodents and birds. Some management interventions have been suggested in order to protect this unique habitat.

**Keywords:** Ngoma, Forest, Trees, Biomass, Habitat

## 1. Introduction

Eleven major vegetation types were distinguished in Kafue National Park during the ecological landscape study which was undertaken between 1997 and 2004 (Mwima 2005). Prior to this study, there was very little information on the park's landscape and vegetation distribution, types, cover and composition. Ngoma Forest is one of the eleven major vegetation types in Kafue National Park which provides unique habitat upon which the distribution and relative densities of a diverse range of faunal communities depend.

## 2. Location of the Study Area

Ngoma Forest is located south of Ngoma Wildlife Camp within Kafue National Park (Figure 1). The national park is located in the south-central part of Zambia and covers an area of about 22,480km$^2$ and lies between longitudes 25° 13' to

26° 46' East and latitudes 14° 03' to 16° 43' South.

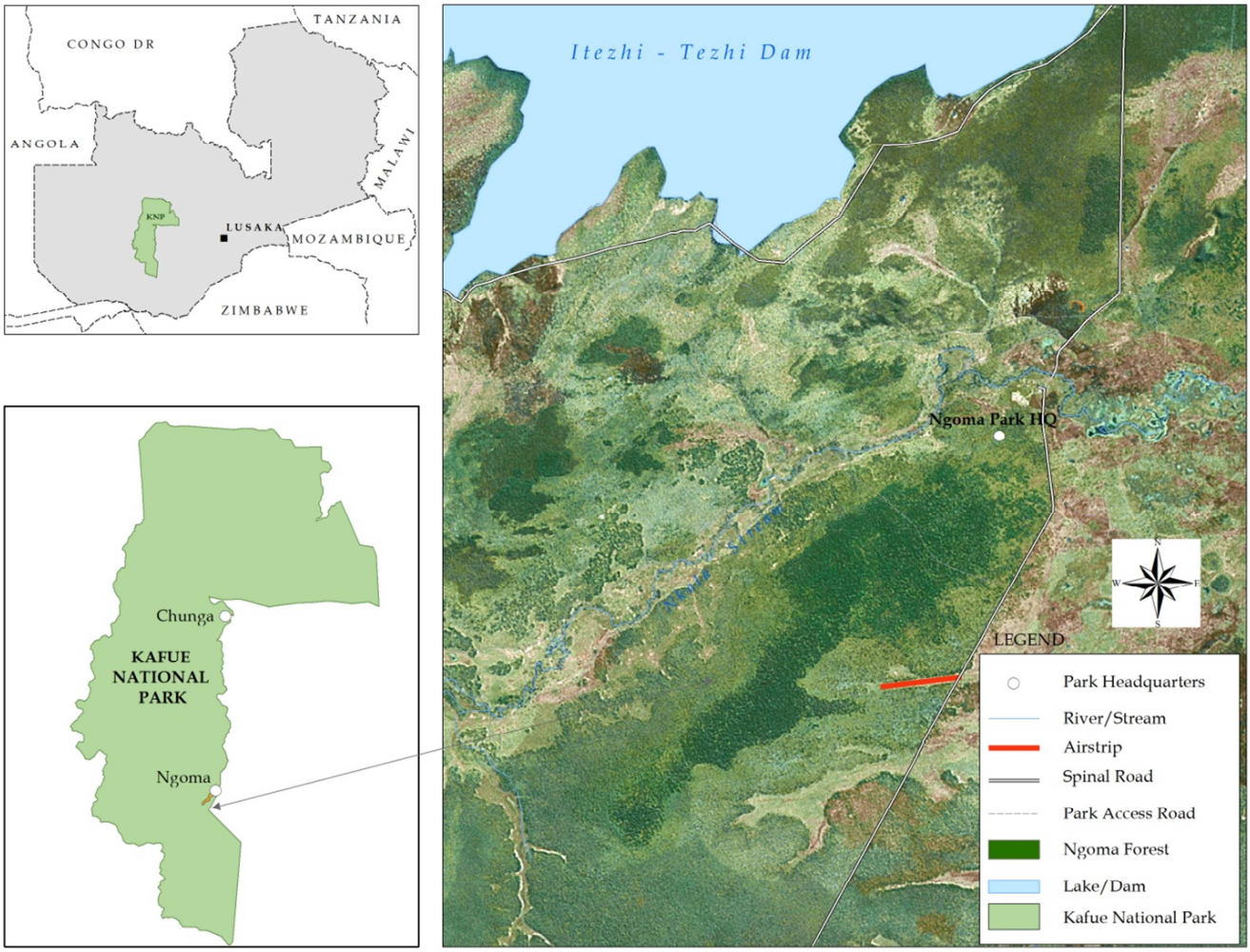


***Figure 1.*** *Location of Ngoma Forest.*

## 3. Methods and Materials

Fourteen 20m X 20m sampling plots were established in Ngoma Forest during the Kafue National Park ecological landscape study (Mwima 2005). The procedure for setting sampling plots involved placing 15cm X 15cm galvanised metal plates marked with reference codes on trees at the height of 2m along the main road between Ngoma Wildlife Camp and the Southern part of the national park. The galvanised metal plates were used as reference points for sampling transects. Using the Garmin Global Positioning System (GPS) unit, the GPS reading at the sampling transect reference point was taken and recorded on the green coded data sheet. The data sheet was colour-coded green to reduce the strain on the eyes due to sunlight reflection. The first sampling plot was set on the edge of the forest while subsequent sampling plots were set after every 1,000 meters of walking in the East - West and West – East directions along sampling transects. A magnetic compass was used for orientation along the sampling transects.

At each sampling plot, a 15cm X 15cm galvanized metal plate with the numeric sampling code written on it was placed on the tree at the height of 1.5m to mark the sampling plot. The tree on which the metal plate was placed marked the South-East (SE) corner of the sampling plot. Using a canvas measuring tape and a magnetic compass, the North-East (NE), North-West (NW) and South-West (SW) corners were determined (Figure 2).

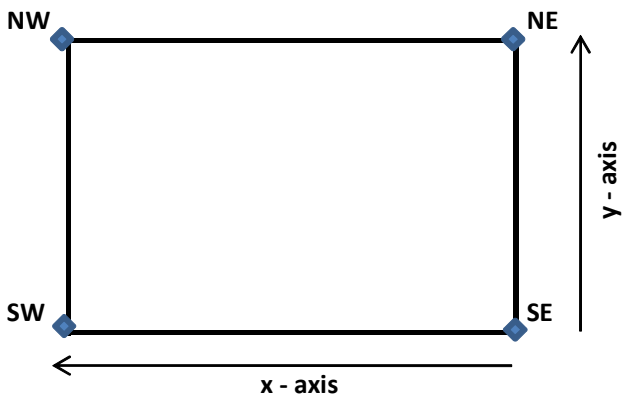


***Figure 2.*** *Sampling plot lay out showing the four corners (NE, SE, SW and NW) and orientation of x and y axis.*

## 4. Key Vegetation Measurement Variables

Before taking any measurements, the tree or shrub was identified and recorded in the data sheet. Whenever there was some doubt in the identification of any plant species, a sample was collected and kept in plant presses and thereafter taken for expert identification at the park herbarium and/or Mount Makulu Agricultural Central Research Station herbarium in Chilanga. Location of the tree/shrub was measured relative to the *x* (East-West orientation) and *y* (South-North orientation) axis.

Diameter at breast height (DBH) of the tree and shrub was measured at 1.3m height using a canvas measuring tape. If there was any irregularity at 1.3m, diameter measurements were taken above and below the irregularity and the values were averaged. For multiple or forked stems, individual stems were measured and values added up. For sub-shrubs with height less than 1.3m but above.5m, diameter was measured using callipers just above the base. The height of each tree and shrub and their respective stem heights were measured using the 7.5m fibre-glass height measuring rod. Trees higher than 7.5m were estimated by at least three team members and the estimates were averaged. Crown size was measured as length and width projections taken perpendicular to each other.

## 5. Other Sampling Variables

In addition to vegetation measurements, data on terrain, soil and water were recorded from each sampling plot. Observations regarding the presence of faunal species were done based on actual sightings and signs such as droppings, nests, foot prints, debarking of trees, feathers, hairs and sounds and these observations were not restricted to the sampling plot. Other observations such as tree cutting and presence or absence of fire were also recorded. From each sampling plot, soil samples were collected every 20cm from three locations using a soil auger to the maximum depth of 120cm (Figure 3). Two 5m X 5m sub-plots were established in each sampling plot to collect data on grasses and herbaceous vegetation. In each sub-plot, plant species were identified and thereafter, cover was visually estimated for each species relative to other species.

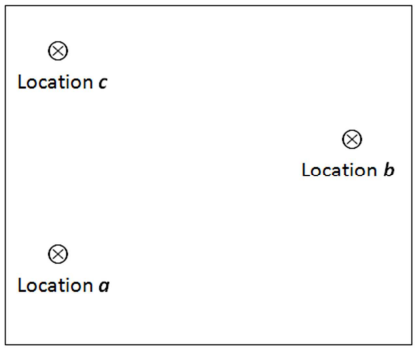


***Figure 3.*** *Layout of soil sampling locations in the sampling plot.*

Soil samples representing the same depth collected from the three locations were put in labelled black plastic bags which were immediately sealed. All soil samples were safely kept at the Ngoma Research Station and thereafter, taken to Mount Makulu Agricultural Central Research Station for analysis. The approach followed for soil analysis was similar to the one described by Gibson and Mitchell (1987) and the analysis technique followed the equation: $pH = -Log(H^+)$ or $pH = Log\ 1/(H^+)$

## 6. Data Recording, Storage and Analysis

A database known as Vegetation And Landscape Integrated Database (VALID) was designed in Microsoft Access software. As soon as data were collected, entries were made into VALID for purposes of storage and analysis. Furthermore, there was a provision in VALID to export data sets to Microsoft Excel in order to give flexibility for more and detailed data analysis.

## 7. Results

Structural variation assessment, species diversity and biomass were calculated based on equations programmed into VALID.

## 8. Structural Variation Assessment

To examine the vegetation physical structure, plant species were assigned Importance Values (IVs) based on the formula: IV = {(RD + RF + RC)/3}100 resulting in an IV index value ranging from 0 – 100%. IV calculations were based on three factors: number of individuals, distribution and size of plant species. These factors are useful in profiling the structural role of species within a particular vegetation type (Mwima 2005). These calculations were based on the following equations and symbols:

$$D_i = n_i/A;\ RD_i = D_i/\sum D_i$$

$$F_i = p_i/P;\ RF_i = F_i/\sum F_i$$

$$C_i = a_i/A;\ RC_i = C_i/\sum C_i$$

$$IV_i = \{(RD + RF + RC)/3\}\ 100$$

where: -

$a_i$ = Total canopy cover of species *i*
A = Total area sampled
$n_i$ = Total number of *i* species sampled
$p_i$ = Total number of plots in which species *i* was found
P = Total number of plots sampled
$D_i$ = Density of species *i*
$RD_i$ = Relative Density of species *i*
$F_i$ = Frequency of species *i* occurrence
$RF_i$ = Relative frequency of occurrence for species *i*
$C_i$ = Coverage of species *i*
$RC_i$ = Relative coverage of species *i*
$IV_i$ = Importance Value for species *I*

Importance Values and characteristics of the woody species are shown in Table 1 while the individual contributions to the physical structure of 15 species with the highest Importance Values in comparison with other species

are shown in Table 2 and Figure 4.

***Table 1.*** *Importance Values and characteristics of woody plant species in Ngoma Forest.*

| Plant species | n*i* | p*i* | a*i* | D*i* | F*i* | C*i* | RD*i* | RF*i* | RC*i* | IV*i* | Mean Height (m) | Mean DBH (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dalbergiella nyasae | 2 | 1 | 92.0 | 0.000 | 0.071 | 0.016 | 0.002 | 0.008 | 0.005 | 0.51 | 8.5 | 72.0 |
| Combretum molle | 13 | 1 | 31.2 | 0.002 | 0.071 | 0.006 | 0.016 | 0.008 | 0.002 | 0.85 | 1.6 | 7.2 |
| Combretum zeyheri | 1 | 1 | 2.8 | 0.000 | 0.071 | 0.001 | 0.001 | 0.008 | 0.000 | 0.31 | 2.5 | 14.0 |
| Markhamia obtusifolia | 6 | 1 | 9.8 | 0.001 | 0.071 | 0.002 | 0.007 | 0.008 | 0.001 | 0.52 | 3.1 | 12.0 |
| **Friesodielsia obovata** | **242** | **11** | **653.4** | **0.043** | **0.786** | **0.117** | **0.294** | **0.087** | **0.035** | **13.88** | **2.0** | **12.6** |
| Xeroderris stuhlmannii | 2 | 1 | 78.0 | 0.000 | 0.071 | 0.014 | 0.002 | 0.008 | 0.004 | 0.49 | 8.9 | 95.0 |
| **Baphia massaiensis** | **36** | **6** | **64.8** | **0.006** | **0.429** | **0.012** | **0.044** | **0.048** | **0.004** | **3.16** | **1.7** | **6.3** |
| Kraussia floribunda | 3 | 1 | 7.5 | 0.001 | 0.071 | 0.001 | 0.004 | 0.008 | 0.000 | 0.40 | 1.7 | 5.2 |
| Rourea orientalis | 2 | 1 | 10.2 | 0.000 | 0.071 | 0.002 | 0.002 | 0.008 | 0.001 | 0.36 | 2.7 | 13.3 |
| **Croton megalobotrys** | **10** | **1** | **240.0** | **0.002** | **0.071** | **0.043** | **0.012** | **0.008** | **0.013** | **1.10** | **4.5** | **22.1** |
| Feretia aeruginescens | 1 | 1 | 4.2 | 0.000 | 0.071 | 0.001 | 0.001 | 0.008 | 0.000 | 0.31 | 2.8 | 9.2 |
| Flueggea virosa | 3 | 1 | 2.8 | 0.001 | 0.071 | 0.001 | 0.004 | 0.008 | 0.000 | 0.39 | 1.9 | 7.0 |
| **Strychnos potatorum** | **10** | **5** | **83.0** | **0.002** | **0.357** | **0.015** | **0.012** | **0.040** | **0.004** | **1.88** | **7.8** | **31.0** |
| **Duranta erecta** | **30** | **5** | **192.3** | **0.005** | **0.357** | **0.034** | **0.036** | **0.040** | **0.010** | **2.88** | **2.5** | **12.7** |
| **Grewia flavescens** | **8** | **4** | **9.6** | **0.001** | **0.286** | **0.002** | **0.010** | **0.032** | **0.001** | **1.40** | **1.8** | **5.7** |
| **Pterocarpus rotundifolius** | **12** | **3** | **1051.2** | **0.002** | **0.214** | **0.188** | **0.015** | **0.024** | **0.057** | **3.17** | **12.6** | **49.4** |
| **Combretum elaeagnoides** | **85** | **8** | **297.5** | **0.015** | **0.571** | **0.053** | **0.103** | **0.063** | **0.016** | **6.09** | **1.9** | **15.7** |
| **Philenoptera violacea** | **10** | **3** | **21.6** | **0.002** | **0.214** | **0.004** | **0.012** | **0.024** | **0.001** | **1.24** | **2.0** | **16.7** |
| **Baikiaea plurijuga** | **71** | **13** | **8233.4** | **0.013** | **0.929** | **1.470** | **0.086** | **0.103** | **0.445** | **21.14** | **19.3** | **119.7** |
| **Ficus sur** | **2** | **1** | **992.0** | **0.000** | **0.071** | **0.177** | **0.002** | **0.008** | **0.054** | **2.13** | **20.2** | **394.5** |
| Dichrostachys cinerea | 4 | 1 | 9.7 | 0.001 | 0.071 | 0.002 | 0.005 | 0.008 | 0.001 | 0.44 | 2.1 | 12.0 |
| Combretum collinum | 1 | 1 | 1.6 | 0.000 | 0.071 | 0.000 | 0.001 | 0.008 | 0.000 | 0.31 | 1.5 | 7.3 |
| Vangueria infausta | 1 | 1 | 2.2 | 0.000 | 0.071 | 0.000 | 0.001 | 0.008 | 0.000 | 0.31 | 2.3 | 12.6 |
| **Dalbergia martinii** | **6** | **2** | **126.0** | **0.001** | **0.143** | **0.023** | **0.007** | **0.016** | **0.007** | **1.00** | **2.7** | **17.8** |
| **Citropsis daweana** | **13** | **8** | **19.4** | **0.002** | **0.571** | **0.003** | **0.016** | **0.063** | **0.001** | **2.68** | **1.7** | **9.0** |
| **Combretum mossambicense** | **64** | **5** | **185.6** | **0.011** | **0.357** | **0.033** | **0.078** | **0.040** | **0.010** | **4.25** | **2.4** | **11.9** |
| **Combretum celastroides** | **53** | **8** | **217.3** | **0.009** | **0.571** | **0.039** | **0.064** | **0.063** | **0.012** | **4.65** | **2.6** | **13.8** |
| Acacia welwitschii | 2 | 1 | 2.8 | 0.000 | 0.071 | 0.001 | 0.002 | 0.008 | 0.000 | 0.35 | 1.6 | 6.9 |
| Boscia matabelensis | 2 | 1 | 77.0 | 0.000 | 0.071 | 0.014 | 0.002 | 0.008 | 0.004 | 0.48 | 7.2 | 50.9 |
| **Strychnos pungens** | **5** | **2** | **153.6** | **0.001** | **0.143** | **0.027** | **0.006** | **0.016** | **0.008** | **1.01** | **6.3** | **42.7** |
| **Pterocarpus lucens** | **39** | **9** | **4602.0** | **0.007** | **0.643** | **0.822** | **0.047** | **0.071** | **0.249** | **12.25** | **21.3** | **132.4** |
| **Entandrophragma caudatum** | **6** | **3** | **786.2** | **0.001** | **0.214** | **0.140** | **0.007** | **0.024** | **0.042** | **2.45** | **20.0** | **157.6** |
| Strychnos madagascariensis | 3 | 3 | 17.8 | 0.001 | 0.214 | 0.003 | 0.004 | 0.024 | 0.001 | 0.95 | 2.4 | 14.0 |
| Zanthoxylum trijugum | 7 | 2 | 20.3 | 0.001 | 0.143 | 0.004 | 0.008 | 0.016 | 0.001 | 0.85 | 1.9 | 11.3 |
| Canthium huillense | 8 | 2 | 24.8 | 0.001 | 0.143 | 0.004 | 0.010 | 0.016 | 0.001 | 0.90 | 2.6 | 15.0 |
| **Pteleopsis anisoptera** | **47** | **6** | **141.0** | **0.008** | **0.429** | **0.025** | **0.057** | **0.048** | **0.008** | **3.74** | **2.9** | **15.3** |
| **Pteleopsis myrtifolia** | **14** | **2** | **44.8** | **0.003** | **0.143** | **0.008** | **0.017** | **0.016** | **0.002** | **1.18** | **2.2** | **14.2** |
| | 824 | | | 0.147 | 9.000 | 3.305 | | | | | | |

Note: Highlight indicates species with highest Importance Values

***Table 2.*** *Characteristics of 15 species with highest Importance Values and other species and their contribution to the physical structure of Ngoma Forest.*

| Rank | Species | n*i* | p*i* | IV | Individual contribution % |
|---|---|---|---|---|---|
| 1 | Baikiaea plurijuga | 71 | 0.0862 | 21.14 | 8.62 |
| 2 | Friesodielsia obovata | 242 | 0.2937 | 13.88 | 29.37 |
| 3 | Pterocarpus lucens | 39 | 0.0473 | 12.25 | 4.73 |
| 4 | Combretum elaeagnoides | 85 | 0.1032 | 6.09 | 10.32 |
| 5 | Combretum celastroides | 53 | 0.0643 | 4.65 | 6.43 |
| 6 | Combretum mossambicense | 64 | 0.0777 | 4.25 | 7.77 |
| 7 | Pteleopsis anisoptera | 47 | 0.0570 | 3.74 | 5.70 |
| 8 | Pterocarpus rotundifolius | 12 | 0.0146 | 3.17 | 1.46 |
| 9 | Baphia massaiensis | 36 | 0.0437 | 3.16 | 4.37 |
| 10 | Duranta erecta | 30 | 0.0364 | 2.88 | 3.64 |
| 11 | Citropsis daweana | 13 | 0.0158 | 2.68 | 1.58 |
| 12 | Entandrophragma caudatum | 6 | 0.0073 | 2.45 | 0.73 |
| 13 | Ficus sur | 2 | 0.0024 | 2.13 | 0.24 |
| 14 | Strychnos potatorum | 10 | 0.0121 | 1.88 | 1.21 |
| 15 | Philenoptera violacea | 10 | 0.0121 | 1.24 | 1.21 |
| | Other species | 104 | 0.1262 | | 12.62 |
| | TOTAL | 824 | 1.0000 | | 100.00 |

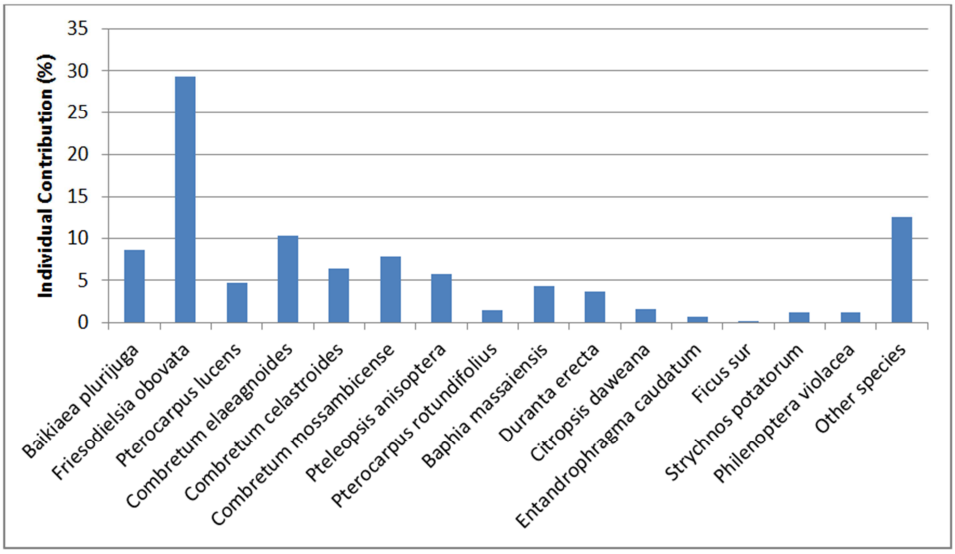


***Figure 4.*** *Contribution of 15 species with highest Importance Values and other species to the physical structure of Ngoma Forest (more details in Table 1).*

Based on the calculations of the Importance Values, it is clear that out of the thirty-seven different species recorded, *Friesodielsia obovata*, *Baikiaea plurijuga*, *Pterocarpus lucens*, *Combretum celastroides C. mossambicense*, *C. elaeagnoides* and *Baphia massaiensis* contribute more than 80% to the physical structure of Ngoma Forest.

## 9. Species Diversity

Plant species diversity refers to the number of species and their relative abundance in a defined area. The increase or decrease of particular plant species can be an indication of more wide spread changes in the habitat. Through VALID, calculations of species diversity incorporating both features of species richness and equality of the distribution of individuals among the species were done. The species diversity index used was the Shannon Index (Usher, n.d.):

$$H' = \sum_{i=1}^{s} p_i \ln p_i$$

which is based on concepts of information theory and the Simpson Index: $p_i \ln p_i$

$$D = \sum_{i=1}^{s} p_i^2$$

where $p_i$ is the proportion of the *i*th species in the sample. $H'$ has a minimum value of 0 in a monoculture and increases to a maximum of *ln*N in a community where all individuals are in different species. $D$ has a maximum value of 1 in a monoculture and becomes smaller as the community becomes more diverse. Results of the Shannon Index and Simpson Index are summarized in Table 3. As indicated in Table 4, species diversity of Ngoma Forest is relatively low but comparatively higher than Mopane, Combretacea and *Acacia* woodlands (Mwima 2005).

***Table 3.*** *Diversity Index for Ngoma Forest.*

| Species | *ni* | *pi* | Shannon Index | Simpson Index |
|---|---|---|---|---|
| Dalbergiella nyasae | 2 | 0.0024 | 0.0146 | 0.0000 |
| Combretum molle | 13 | 0.0158 | 0.0655 | 0.0002 |
| Combretum zeyheri | 1 | 0.0012 | 0.0081 | 0.0000 |
| Markhamia obtusifolia | 6 | 0.0073 | 0.0358 | 0.0001 |
| Friesodielsia obovata | 242 | 0.2937 | 0.3598 | 0.0863 |
| Xeroderris stuhlmannii | 2 | 0.0024 | 0.0146 | 0.0000 |
| Baphia massaiensis | 36 | 0.0437 | 0.1368 | 0.0019 |
| Kraussia floribunda | 3 | 0.0036 | 0.0204 | 0.0000 |
| Rourea orientalis | 2 | 0.0024 | 0.0146 | 0.0000 |
| Croton megalobotrys | 10 | 0.0121 | 0.0535 | 0.0001 |
| Feretia aeruginescens | 1 | 0.0012 | 0.0081 | 0.0000 |
| Flueggea virosa | 3 | 0.0036 | 0.0204 | 0.0000 |
| Strychnos potatorum | 10 | 0.0121 | 0.0535 | 0.0001 |
| Duranta erecta | 30 | 0.0364 | 0.1206 | 0.0013 |
| Grewia flavescens | 8 | 0.0097 | 0.0450 | 0.0001 |
| Pterocarpus rotundifolius | 12 | 0.0146 | 0.0616 | 0.0002 |
| Combretum elaeagnoides | 85 | 0.1032 | 0.2343 | 0.0106 |
| Philenoptera violacea | 10 | 0.0121 | 0.0535 | 0.0001 |
| Baikiaea plurijuga | 71 | 0.0862 | 0.2112 | 0.0074 |
| Ficus sur | 2 | 0.0024 | 0.0146 | 0.0000 |
| Dichrostachys cinerea | 4 | 0.0049 | 0.0259 | 0.0000 |
| Combretum collinum | 1 | 0.0012 | 0.0081 | 0.0000 |
| Vangueria infausta | 1 | 0.0012 | 0.0081 | 0.0000 |
| Dalbergia martinii | 6 | 0.0073 | 0.0358 | 0.0001 |
| Citropsis daweana | 13 | 0.0158 | 0.0655 | 0.0002 |
| Combretum mossambicense | 64 | 0.0777 | 0.1985 | 0.0060 |
| Combretum celastroides | 53 | 0.0643 | 0.1765 | 0.0041 |
| Acacia welwitschii | 2 | 0.0024 | 0.0146 | 0.0000 |
| Boscia matabelensis | 2 | 0.0024 | 0.0146 | 0.0000 |
| Strychnos pungens | 5 | 0.0061 | 0.0310 | 0.0000 |
| Pterocarpus lucens | 39 | 0.0473 | 0.1444 | 0.0022 |
| Entandrophragma caudatum | 6 | 0.0073 | 0.0358 | 0.0001 |
| Strychnos madagascariensis | 3 | 0.0036 | 0.0204 | 0.0000 |
| Zanthoxylum trijugum | 7 | 0.0085 | 0.0405 | 0.0001 |
| Canthium huillense | 8 | 0.0097 | 0.0450 | 0.0001 |
| Pteleopsis anisoptera | 47 | 0.0570 | 0.1634 | 0.0033 |
| Pteleopsis myrtifolia | 14 | 0.0170 | 0.0692 | 0.0003 |
| | 824 | 1.0000 | 2.6443 | 0.1252 |

N (Total number of different species recorded) = 37

***Table 4.*** *Species Diversity for ten major vegetation types in Kafue National Park.*

| Vegetation type | N | n | Shannon Index | Simpson Index |
|---|---|---|---|---|
| Termitaria | 63 | 591 | 3.5222 | 0.0487 |
| Miombo Woodland | 129 | 4,414 | 3.5692 | 0.0637 |
| Shrubland | 47 | 641 | 3.1100 | 0.0626 |
| Thicket | 69 | 3,331 | 3.1415 | 0.0781 |
| Riparian Forest | 71 | 1,684 | 3.0061 | 0.0926 |
| Wooded Grassland | 23 | 80 | 2.7235 | 0.1038 |
| Ngoma (*Baikiaea*) Forest | 37 | 824 | 2.6443 | 0.1252 |
| Mopane Woodland | 24 | 166 | 2.4494 | 0.1477 |
| Combretacea Woodland | 36 | 525 | 2.4291 | 0.1708 |
| Acacia Woodland | 6 | 108 | 1.0650 | 0.4174 |
| | | 12,364 | | |

N = Total number of different species recorded
n = Total number of species sampled

# 10. Biomass

To quantify ecosystem processes and disturbances, plant biomass calculations were incorporated into VALID. Tree and shrub density expressed as stems per hectare were calculated using the following formulae used by Guy (1981) and Smith (1998):

$$\text{Tree Biomass (kg)} = 0.0549 \times (\text{diameter})^{2.5101}$$

$$\text{Shrub Biomass (kg)} = 1.2102 \times (\text{canopy volume})^{0.9138}$$

Analysis of the results revealed that the tree / shrub density in Ngoma Forest was 1,475 stems per hectare while the mean biomass was 122.6 tons per hectare and 1.5 tons per hectare for trees and shrubs respectively.

Ngoma Forest terrain is almost flat to very flat with generally straight slope of 0 to 3% and altitude ranging from 1,050m to 1,120m above sea level. The Forest covers about 18km$^2$ which is less than 1% of the total national park area and occurs on strong acidic and well-drained sandy-clay and sandy-loam with pH range of 4.4 to 5.3. These soils are locally known as Kalahari Sands (Arenosols and Ferralsols). The tree layer consists of tall trees in the height range of 18 to 22m and is dominated by *Baikiaea plurijuga* and *Pterocarpus lucens* with isolated stands of *Entandrophragma caudatum*, *Ficus sur*, *Burkea africana* and *Erythrophleum africanum*. The second layer consists of trees above 6m but less than 18m and is characterized by *Philenoptera violacea*, *Pterocarpus rotundifolius*, *Xeroderis stuhlmannii*, *Dalbergiella nyasae*, *Strychnos potatorum* and *S. pungens*. The third layer consist of small trees and shrubs rarely reaching the height of 6m and is characterized by *Croton megalobotrys*, *Friesodielsia obovata*, *Combretum elaeagnoides*, *C. mossambicense*, *C. celastroides*, *Duranta erecta*, *Citropsis daweana*, *Grewia flavescens*, *Dalbergia martinii*, *Pteleopsis anisoptera* and *P. myrtifolia*. *Baphia massaiensis* is mainly found within the third layer and is principally concentrated on the forest fringes. Climbers include *Baissea wulfhorstii*, *Cucumis anguria*, *C. metuliferus* and *Hippocratea parviflora*. Herbs, sub shrubs and grasses constitute fragmented strips within the third layer with occasional open areas. Herbs and sub shrubs include *Abutilon angulatum*, *Acrotome inflata*, *Aneilema johnstonii*, *Asystasia gangetica*, *Cleome* spp., *Cycnium adonense*, *Euphorbia heterophylla*, *Hibiscus meeusei*, *Ocimum canum*, *Oxygonum sinuatum*, *Thunbergia crispa*, *Tithonia rotundifolia*, *Triumfetta annua* and *Vernonia* spp. The characteristic grasses which occur in patches across the Forest are *Setaria homonyma*, *S. verticillata*, *Panicum maximum*, *Dactylotenium* spp, *Digitaria velutina* and *Eleusine coracana*.

Details of the faunal species recorded during the study are included in Table 5.

***Table 5.*** *Fauna species recorded in Ngoma (Baikiaea) Forest during the study (other habitats in Kafue National Park where the same species were recorded are also indicated).*

| | | | Habitat | | | |
|---|---|---|---|---|---|---|
| **UNGULATES** | | | | | | |
| 1 | Buffalo | *Syncerus caffer* | GLD | MBW | SHB | BKF |
| 2 | Bushbuck | *Tragephus scriptus* | TKT | RPF | BKF | |
| 3 | Greater Kudu | *Tragephus strepsiceros* | CBW | BKF | | |
| 4 | Eland | *Taurotragus oryx* | MBW | WDG | SHB | BKF |
| CARNIVORES | | | | | | |
| 1 | African Wild Dog | *Lycaon pictus* | MBW | TKT | BKF | |
| 2 | Banded mongoose | *Mungos mungo* | BKF | MBW | TKT | GLD |
| 3 | Common genet | *Genetta genetta* | BKF | | | |
| 4 | Lion | *Panthera leo* | GLD | MBW | BKF | |
| 5 | Spotted hyena | *Crocuta crocuta* | GLD | MBW | BKF | |
| 6 | African civet | *Civettictis civetta* | BKF | MBW | TKT | |
| PRIMATES | | | | | | |
| 1 | Chacma Baboon | *Papio cynocephalus ursinus* | GLD | MBW | MPW | BKF |
| 2 | Lesser Bushbaby | *Galago senegalensis* | BKF | | | |
| 3 | Vervet Monkey | *Cercopithecus aethiops* | MBW | RPF | BKF | |
| REPTILES | | | | | | |
| 1 | Common African python | *Python sebae* | ACW | BKF | | |
| RODENTS | | | | | | |
| 1 | Bush squirrel | *Paraxerus cepapi* | MBW | MPW | BKF | |
| 2 | Mole rat | *Cryptomys damarensis* | GLD | MPW | MBW | BKF |
| 3 | Mouse | *Mastomys spp* | GLD | MPW | MBW | BKF |
| 4 | Porcupine | *Hystrix africaeaustralis* | BKF | TKT | | |

| UNGULATES | | | Habitat | | | |
|---|---|---|---|---|---|---|
| OTHER ANIMAL SPECIES | | | | | | |
| 1 | Aardvark | *Orycteropus afer* | BKF | | | |
| 2 | Elephant | *Loxodonta africana* | SHB | MBW | BKF | |
| 3 | Hare | *Lepus victoriae* | MBW | BKF | | |
| BIRDS | | | | | | |
| 1 | Bearded Woodpecker | *Thripias namaquus* | MBW | BKF | | |
| 2 | Crested Francolin | *Francolinus sephaena* | GLD | MBW | SHB | BKF |
| 3 | Crowned Hornbill | *Tockus alboterminatus* | MBW | RPF | BKF | |
| 4 | Gabon Nightjar | *Scotornis fossii* | BKF | | | |
| 5 | Greater Honeyguide | *Indicator indicator* | BKF | | | |
| 6 | Red-billed Hornbill | *Tockus erythrorynchus* | ACW | MBW | BKF | |
| 7 | Southern Ground-Hornbill | *Bucorvus cafer* | WDG | MBW | BKF | |
| 8 | Swainson's Francolin | *Francolinus swainsonii* | WDG | MBW | SHB | BKF |

***Table 6.*** *Explanation of habitat abbreviations.*

| | | | |
|---|---|---|---|
| ACW: | Acacia Woodland | MPW: | Mopane Woodland |
| BKF: | Ngoma (*Baikiaea*) Forest | RPF: | Riparian Forest |
| CBW: | Combretacea Woodland | SHB: | Shrubland |
| GLD: | Grassland | TKT: | Thicket |
| MBW: | Miombo Woodland | WDG: | Wooded Grassland |

# 11. Discussion

Although Ngoma Forest represents less than 1% of the total area of Kafue National Park, the Forest provides unique habitat upon which the distribution and relative densities of a diverse range of faunal communities depend. In 1985, Ngoma Forest was estimated to be 34km$^2$ while in 2004, the Forest had shrunk to 18km$^2$ (Mwima, 1986; 2005). The Forest is likely to shrink further while the scrubland mainly dominated by *Baphia massaiensis, Croton megalobotrys*, *Duranta erecta*, *Citropsis daweana*, *Grewia flavescens*, *Dalbergia martinii*, *Pteleopsis anisoptera*, *P. myrtifolia* and *Combretum* spp is going to expand. This habitat shift – although not considered to be drastic in the immediate future - is bound to adversely affect the habitat range of a number of ungulates, carnivores, primates, rodents and birds.

It is acknowledged that fire has a dramatic effect on vegetation (WWF-SARPO 2004) and is an important factor in the evolution of African savannah ecosystems and influences biomass, cover, height, species and relative proportion of woody to herbaceous species (Trapnell 1959; Kruger 1984; Chidumayo 1988; Hough 1993). Zimba (1986) has reported that late fires destroy about 1,600 hectares of *Baikiaea* Forest and based on the observations made during the study, fire constitutes the major factor in the shrinkage of Ngoma Forest. More frequent and intense fires as a result of climate change are likely to occur and if not controlled, these fires will accelerate the alteration rate of Ngoma Forest. It is, therefore important that a fire management plan is developed and implemented for the entire Kafue National Park. Furthermore, more detailed vegetation measurements should be undertaken in order to record damage and structural changes. Such studies may include tree species composition, investigating the impact of fire on regeneration and monitoring relatively slow changes through fixed photography.

# 12. Conclusion

It is important to keep track of vegetation and landscape changes in Ngoma Forest because these natural attributes are very important in providing faunal species with essential habitat elements necessary for maintenance of viable populations. Furthermore, vegetation and landscape monitoring will offer an opportunity for Park management to determine timely and effective wildlife habitat management interventions.

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