Landscapes of the Gorongosa National Park


CITATIONS
14

READS
1,052

2 authors:

Marc Stalmans
Gorongosa National Park, Mocambique
47 PUBLICATIONS 443 CITATIONS

Richard Beilfuss
International Crane Foundation
92 PUBLICATIONS 551 CITATIONS

Some of the authors of this publication are also working on these related projects:

Zambia Crane and Wetland Conservation Program View project

Developing the capacity to improve private lands management for conservation. View project
PARQUE NACIONAL DA GORONGOSA, MOÇAMBIQUE

LANDSCAPES OF THE GORONGOSA NATIONAL PARK

CONDENSED VERSION

Prepared for the Gorongosa Research Center by

Dr. Marc Stalmans
International Conservation Services - South Africa

&

Dr. Richard Beilfuss
Department of Scientific Services, Gorongosa National Park

July 2008
Gorongosa National Park

A full description of the study with its methodology and additional plant community maps is available from the Carr Foundation.
# TABLE OF CONTENTS

**SUMMARY** ............................................................................................................................... 3

1. **BACKGROUND & OBJECTIVE** ......................................................................................... 4

2. **STUDY AREA** .................................................................................................................. 5

   2.1. Area of Interest ........................................................................................................... 5
   2.2. Description .................................................................................................................. 5

3. **REGIONS, LANDSCAPES AND PLANT COMMUNITIES OF GORONGOSA** ................ 9

   3.1. Regions ....................................................................................................................... 9
   3.2. Landscapes .................................................................................................................. 10
   3.3. Transformed areas ....................................................................................................... 17
   3.4. Description of landscape delineation and landscape content .................................. 18
   3.5. Plant communities ....................................................................................................... 22
   3.6. Alien plants .................................................................................................................. 27

4. **IMPLICATIONS FOR WILDLIFE** ................................................................................. 28

   4.1. Introduction ................................................................................................................ 28
   4.2. Habitat suitability ....................................................................................................... 29
   4.4. Implications ................................................................................................................ 34

5. **GAPS & SHORTCOMINGS** .......................................................................................... 35

6. **CONCLUSION** .............................................................................................................. 36

7. **ACKNOWLEDGEMENTS** .......................................................................................... 37

8. **REFERENCES** .............................................................................................................. 37
SUMMARY

The objective of the study was to produce a broad-scale landscape map of the Gorongosa National Park. A landscape is defined as ‘an area with a specific geomorphology, climate, soil vegetation pattern and associated fauna’. The landscape unit may encompass several individual plant communities.

A total of 139 plots were sampled on the ground. A total of 1,570 control points with more limited information were assessed during overflights with a helicopter and during traverses along the main roads in the Buffer Zone. Although high-resolution LISS IV imagery was acquired, problems with the images precluded the use of supervised and unsupervised classification across the whole study area.

A hierarchical approach was used to delineate mapping units. Four regions that correspond to the units originally described by Tinley (1977) were delineated. A total of 15 landscapes were defined that fit into the 4 regions:

- Gorongosa Mountain Region
  - Gorongosa Lower Montane Grassland & Woodland Landscape
  - Gorongosa Montane Grassland & Shrub-forest Landscape
  - Gorongosa Montane Forest Landscape

- Midlands Region
  - Midlands Moist Miombo Landscape
  - Midlands Dry Miombo & Mixed Woodland Landscape
  - Midlands Alluvial Landscape
  - Midlands Inselberg Landscape

- Rift Valley Region
  - Rift Valley Alluvial Fan Landscape
  - Rift Valley Riverine & Floodplain Landscape
  - Rift Valley Colluvial Fan Landscape
  - Rift Valley Lake Urema Landscape

- Cheringoma Plateau Region
  - Cheringoma Plateau Seaward Slope Landscape
  - Cheringoma Plateau Calcareous Sandstone Riftward Slopes Landscape
  - Cheringoma Plateau Argillaceous Sandstone Riftward Slopes Landscape
  - Cheringoma Plateau Limestone Gorge Landscape.

Some preliminary identification and mapping of 21 individual plant communities is provided. The focus is on ‘key elements’ in the landscape. These include dambo’s in the miombo of the Cheringoma plateau, pans and short Cynodon – Digitaria grasslands in the Rift Valley Riverine & Floodplain landscape and sodic patches of short open Acacia woodland in the Rift Valley Alluvial Fan landscape.

The occurrence of alien invasive plant species was recorded during the field survey. *Mimosa pigra* that occurs on the floodplain landscape is the most dangerous invader.

The landscape map was translated in terms of carrying capacity and suitability for wildlife. The habitat of the Park remains extremely suitable for grazers although the collapse of the grazing succession has led to a reduction in the extent of the *Cynodon-Dactylion* short grasslands. The carrying capacity of the Park is high and should allow for stocking rates that are comparable to historic levels.
1. BACKGROUND & OBJECTIVE

A base map of the Gorongosa National Park (henceforth GNP) was required to guide research and management. The base map not only had to provide units that could be used as a basis for more detailed biodiversity inventories, but it also had to provide an explanation of the causal factors. The understanding of the underlying factors allows for steering, manipulation and experimentation within the framework of adaptive management.

Vegetation is often used as a surrogate or building block for the definition of habitats. The use of broad habitat units defined by a combination of environmental factors and vegetation probably represents the most useful input for further biodiversity surveys.

The proposed approach must take cognisance of the large size of the area, its relative poor accessibility, the need to provide practically useful input for other surveys and the requirement of cost-effectiveness. A traditional fine-scale vegetation description and map are not achievable within a short time frame and without incurring very significant costs.

The specific objective is to produce

‘A landscape map of Gorongosa at a scale that allows for the planning of research and monitoring and that permits decision-making with regard to strategic management and land use planning.’

A landscape is defined as ‘an area with a specific geomorphology, climate, soil vegetation pattern and associated fauna’ (adapted from Gertenbach 1983). The landscape unit may encompass several individual plant communities. Yet it reflects a combination of environmental factors that gives rise to a predictable and repeatable habitat.

During the course of this study a number of other outcomes have been achieved that are based on the fieldwork (ground plots and aerial control points) and analysis that was undertaken:

- Assessment of the vegetation and carrying capacity of the Sanctuario to assist with the planning of the wildlife re-introductions (Stalmans 2006a);
- Formulating of an approach for a systematic, multi-scaled monitoring system of the landscapes and vegetation of the Park (Stalmans & Beiffuss 2007);
- Extraction from the Tinley study off all the plant species per Tinley vegetation unit (for use in the larger Gorongosa database)(Stalmans 2006b).
2. STUDY AREA

2.1. Area of Interest

Although the GNP forms the core of the Area of Interest for this study, the landscapes are being assessed for a much wider area (Fig. 1). The total area covers ca. 10,090 km² (1,009,000 ha) of which the GNP comprises 3,688 km² (368,800 ha).

This larger area covers the full geographical extent of the Gorongosa Restoration Project as per the Agreement for the Long Term Administration of the National Park of Gorongosa between the Ministry of Tourism of the Republic of Mozambique and the Gregory C. Carr Foundation. The landscapes on the borders and upstream of the GNP have a direct bearing on those within its borders. One cannot fully understand the GNP’s landscapes without a broader contextual view beyond its borders.

2.2. Description

The physical environment largely determines soil patterns, vegetation composition and structure and has direct bearing on land use and development potential. Only the most salient and general features are being summarised here (Fig. 2):

- **Physiography**
  - Gorongosa occurs at the southern end of the Great Rift Valley system that extends from Ethiopia in East Africa down into Moçambique.
  - The Rift Valley is the salient feature of the area with its 40 km wide valley floor that is situated at only 15 to 80 meters above sea level;
  - The eastern edge of the Rift Valley rises up to 300 m to form the Cheringoma Plateau;
  - The western edge of the Rift Valley is characterised by the deeply dissected Midlands region that rises to 400 m;
  - The Gorongosa Mountain is perched on the Midlands. It is a massif of 20 by 30 km in size and rises up to 1,863 m above sea level.

- **Geology and soils**
  - The Rift Valley floor is generally characterised by alluvial deposits with colluvial material deposited at the bottom of the Cheringoma plateau. Grey soils (some of which are hydromorphic) occur in the Rift Valley and are derived from detrital fan material and from sands;
  - The Cheringoma Plateau consists of grauwackes and limestone. Weathering and eluviation has resulted in the formation of sandy permeable soils. An impermeable horizon underlies the sands at various depths - typically near the surface in the dambo’s and drainage lines. The soils are thoroughly leached with low pH and phosphorus values.
  - The Midlands are mostly underlain by gneissises and pegmatites. This area is also characterised by many dolerite dykes. This has an important bearing on the carrying capacity for wildlife. The soils are mostly sandy and fersiallitic. Brown soils are derived from gneisses and red soils are formed from the weathering of the dykes;
  - The Gorongosa Mountain is characterised by granites in its central core. Under the influence of the very high rainfall these granites weather into ferralitic soils of low fertility. Richer soils are found on the
talus that is derived from the weathering of the gabbro and dolerite igneous rocks that occur on the outer rim of the granite core.

- **Rainfall**
  - The Cheringoma Plateau experiences a relatively high rainfall (>1,000 mm). The Rift Valley to the west lies in the plateau's rain shadow and receives only 700 to 900 mm per annum. The mean annual rainfall at Chitengo is given as 840 mm (Tinley 1977). The rainfall quickly escalates with increasing elevation towards Gorongosa Mountain in the west. Very high rainfall values of over 2,000 mm occur on Gorongosa mountain. The area immediately north of the mountain lies in its rainshadow. This is not accurately reflected in the available isohyets.

- **Hydrology**
  - The GNP and its Buffer Zone are drained by a multitude of rivers and streams. Drainage is from Gorongosa Mountain, the Midlands and the Cheringoma Plateau down into the Rift Valley. Lake Urema is at the epicentre of the drainage with the overflow draining into the Pungue River on its way to the ocean. The eastern boundary of the GNP lies on the watershed on top of the Cheringoma Plateau. The extreme eastern part of the Buffer Zone is drained eastwards directly towards the ocean whereas the western slopes of the Cheringoma plateau are drained towards the Urema and then the Pungue River.
  - Large areas of the Rift valley are regularly inundated. Extreme flood levels were experienced in 2008, for the first time since 1997.

- **Vegetation**
  - Broad classifications and maps were produced by Wild & Barbosa (1967) and White (1983). Tinley (1977) provided detailed descriptions but no map. A description of the nearby but quite different Catapu logging concession was recently published (Palgrave *et al.* 2007).
Fig. 2: Environmental characteristics of Gorongosa National Park and its Buffer Zone.
3. METHODOLOGY

The most extensive and valuable source of information on the GNP comes from Tinley’s (1977) work. Tinley did not produce a map at the ‘landscape’ or plant community scale that covered the whole of the GNP. The reasons for this can only be surmised. It is likely that the lack of suitable tools, namely a Geographic information system (GIS) and high-resolution satellite images, were major impediments at that stage.

Given some problems with the newly acquired high-resolution (5.8 m) multispectral LISS IV imagery, a classic supervised or unsupervised classification approach was not feasible for this study.

A new approach relies much more on an a priori, subjective, definition of the desired outcome followed by a hybrid application of techniques to achieve the outcome. This approach takes a hierarchical view based on the fact that at a larger scale the patterns are more general and can be inferred from broad underlying environmental conditions. At a finer scale, the approach becomes much more driven by the actual content of the satellite imagery in terms of delineating specific units. However, because of the problems listed earlier with the imagery, the detailed work is limited to only a few plant communities rather than the full suite of communities.

At the highest spatial level, the GNP is made up of a limited number of ‘regions’. Tinley’s classification is followed. These ‘regions’ are mapped ‘explicitly’ (meaning that they are spatially defined). Each region is made up by a number of ‘landscapes’. A ‘landscape’ is defined as ‘an area with a specific geomorphology, climate, soil vegetation pattern and associated fauna’ (adapted from Gertenbach 1983). The landscape unit may encompass several individual plant communities. Yet it reflects a combination of environmental factors that gives rise to a predictable and repeatable habitat.

Landscapes are mapped explicitly. Each landscape is made up of several plant communities. These communities may be too difficult to distinguish from each other based on the level of available information and resources. They will thus be ‘implicit’ in the landscape map. However, some specific communities are mapped individually, mostly because they represent a ‘key element’ in either the functioning of the landscape or in terms of providing a key resource to the wildlife (eg dambo’s, pans etc.).

A total of 139 localities were subjectively chosen and assessed (Fig. 3). Due to poor accessibility, the vast majority of the samples were selected along the roads and tracks that were accessible at the time of the survey. A total of 1,570 points were assessed from the air and the ground (Fig. 3). The quality of information recorded at those points differs from point to point as the observation time was dependent on the helicopter’s speed and altitude. GPS positions were recorded together with information on the structure and where possible the dominant woody species occurring at that spot.
3. REGIONS, LANDSCAPES AND PLANT COMMUNITIES OF GORONGOSA

3.1. Regions

The GNP and its Buffer Zone consist of 4 regions as described by Tinley (1977) (Table 1). They are:

- Gorongosa Mountain;
- Midlands;
- Rift Valley; and
- Cheringoma Plateau.

The regions are mostly defined by broad geological-geomorphological-climatic characteristics. They can be mapped based on a combination of Tinley’s initial delineation, LANDSAT satellite classification and aerial (helicopter) observations.

The Rift Valley occupies the central position of the GNP and its Buffer Zone. The Cheringoma Plateau region is found to its east and the Midlands to its west. The Gorongosa Mountain region occupies the central part of the Midlands and is defined by the 600 m elevation contour (Fig. 4).

The alluvial fans (for example for the Muaredzi River) present a particular case. The substrate may be similar to that found on the Cheringoma Plateau. However, the fact that this material gets deposited means that the terrain is flattening out and water velocity is dropping. Therefore, one is out of the Cheringoma Plateau and into the Rift Valley. Tinley (1977) used the same reasoning in his delineation of the regions.

Fig. 3: Vegetation samples (2006-2008) in the GNP and its Buffer Zone.
The boundary between the Midlands and the Rift Valley is more ambiguous. There is a difference on whether one uses the rift faulting or the dominant occurrence of alluvial material. In the northern part of the area, there are extensive alluvial deposits along the Nhamapaza River. A cut-off was selected that is located somewhat west of the faulting, but that only captures the major alluvial area and not the upstream narrow alluvial belt.

3.2. Landscapes

Whereas the underlying geological, geomorphological and climatic conditions may be fairly uniform across each region, the landscapes within a region may be very distinct. The landscapes reflect the interplay of topography, soils and water within a specific region.

The landscapes themselves are not homogeneous. Within a specific landscape, a number of plant communities will occur. These communities may be very different. It is the combination of plant communities, even if very different, that typifies a particular landscape.

The following 15 landscapes have been identified (Fig. 5)(Plates 1 – 4)(Table 1 & 2):

- Gorongosa Mountain Region
  - Gorongosa Lower Montane Grassland & Woodland Landscape
  - Gorongosa Montane Grassland & Shrub-forest Landscape
  - Gorongosa Montane Forest Landscape

- Midlands Region
  - Midlands Moist Miombo Landscape
  - Midlands Dry Miombo & Mixed Woodland Landscape
  - Midlands Alluvial Landscape
  - Midlands Inselberg Landscape

- Rift Valley Region
  - Rift Valley Alluvial Fan Landscape
  - Rift Valley Riverine & Floodplain Landscape
  - Rift Valley Colluvial Fan Landscape
  - Rift Valley Lake Urema Landscape

- Cheringoma Plateau Region
  - Cheringoma Plateau Seaward Slope Landscape
  - Cheringoma Plateau Calcareous Sandstone Riftward Slopes Landscape
  - Cheringoma Plateau Argillaceous Sandstone Riftward Slopes Landscape
  - Cheringoma Plateau Limestone Gorge Landscape.
Fig. 4: Regions of the GNP and Buffer Zone.

Table 1: Size and relative extent of the different regions in Gorongosa National Park.

<table>
<thead>
<tr>
<th>Region</th>
<th>Park &amp; Buffer Zone</th>
<th>GNP only</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Size (ha)</td>
<td>Relative extent %</td>
</tr>
<tr>
<td>Gorongosa Mountain</td>
<td>42,698</td>
<td>4.2</td>
</tr>
<tr>
<td>Midlands</td>
<td>308,224</td>
<td>30.6</td>
</tr>
<tr>
<td>Rift Valley</td>
<td>433,317</td>
<td>43.1</td>
</tr>
<tr>
<td>Cheringoma Plateau</td>
<td>222,214</td>
<td>22.1</td>
</tr>
</tbody>
</table>
Fig. 5: Landscapes of the GNP and Buffer Zone.
Plate 1: Landscapes of the Gorongosa Mountain Region.

A: Lower Montane Landscape – note encroachment by cultivation on slopes.
B: Settlement and cultivation in Lower Montane Landscape
C: Montane Forest and Montane Grassland & Shrub-forest Landscapes
D: Montane Forest Landscape
E: Montane Grassland & Shrub-forest Landscape with pure grassland communities
F: Clearing in Montane Forest Landscape for cultivation.
Plate 2: Landscapes of the Midlands Region.

A: Midlands Moist Miombo Landscape – note steep terrain and rocky riverbeds.
B: Midlands Moist Miombo Landscape – largely cleared for the cultivation of sorghum
C: Midlands Dry Miombo & Mixed Woodland Landscape – in the rainshadow northwest of Gorongosa Mountain.
D: Midlands Dry Miombo & Mixed Woodland Landscape – mixed woodland without miombo elements.
E: Midlands Inselberg Landscape with miombo.
F: Midlands Alluvial Landscape – Boa Maria ruins (with miombo) and cultivated areas
Plate 3: Landscapes of the Rift Valley Region.

A: Rift Valley Alluvial Fan Landscape – dense palm and *Piliostigma* communities
B: Rift Valley Alluvial Fan Landscape – tall mixed woodland
C: Rift Valley Riverine & Floodplain Landscape – flooded grasslands
D: Rift Valley Riverine & Floodplain Landscape – short grasslands with recent burns
E: Rift Valley Lake Urema Landscape – hippo house with Lake Urema in background
F: Rift Valley Lake Urema Landscape – flooded grassland around Lake Urema.
Plate 4: Landscapes of the Cheringoma Plateau Region.

A: Cheringoma Plateau Calcareous Sandstone Landscape – dense miombo cover
B: Cheringoma Plateau Calcareous Sandstone Landscape – dambo in miombo woodland
C: Cheringoma Plateau Argillaceous Sandstone Landscape – open Combretum woodland
D: Cheringoma Plateau Argillaceous Sandstone Landscape – naturally eroded area
E: Cheringoma Plateau Limestone Gorge Landscape – gorges surrounded by miombo
F: Cheringoma Plateau Limestone Gorge Landscape – riverine elements in gorges.
Table 2: Extent and proportion of the Park and of the study area covered by the individual landscapes.

<table>
<thead>
<tr>
<th>Landscape</th>
<th>Park &amp; Buffer Zone</th>
<th>GNP only</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Size (ha)</td>
<td>Relative extent %</td>
</tr>
<tr>
<td>Gorongosa Lower Montane Grassland &amp; Woodland</td>
<td>19,180</td>
<td>1.90</td>
</tr>
<tr>
<td>Gorongosa Montane Forest</td>
<td>22,026</td>
<td>2.18</td>
</tr>
<tr>
<td>Gorongosa Montane Grassland &amp; Shrub-forest</td>
<td>1,492</td>
<td>0.15</td>
</tr>
<tr>
<td>Midlands Moist Miombo</td>
<td>193,810</td>
<td>19.20</td>
</tr>
<tr>
<td>Midlands Dry Miombo &amp; Mixed Woodland</td>
<td>89,708</td>
<td>8.89</td>
</tr>
<tr>
<td>Midlands Alluvial</td>
<td>23,147</td>
<td>2.29</td>
</tr>
<tr>
<td>Midlands Inselberg</td>
<td>1,820</td>
<td>0.18</td>
</tr>
<tr>
<td>Rift Valley Alluvial Fan</td>
<td>212,396</td>
<td>21.05</td>
</tr>
<tr>
<td>Rift Valley Riverine &amp; Floodplain</td>
<td>144,797</td>
<td>14.35</td>
</tr>
<tr>
<td>Rift Valley Colluvial Fan</td>
<td>74,740</td>
<td>7.41</td>
</tr>
<tr>
<td>Rift Valley Lake Urema</td>
<td>1,760</td>
<td>0.17</td>
</tr>
<tr>
<td>Cheringoma Plateau Seaward Slope</td>
<td>45,338</td>
<td>4.49</td>
</tr>
<tr>
<td>Cheringoma Plateau Calcareous Sandstone Riftward Slopes</td>
<td>87,868</td>
<td>8.71</td>
</tr>
<tr>
<td>Cheringoma Plateau Argillaceous Sandstone Riftward Slopes</td>
<td>76,004</td>
<td>7.53</td>
</tr>
<tr>
<td>Cheringoma Plateau Limestone Gorge</td>
<td>15,009</td>
<td>1.49</td>
</tr>
</tbody>
</table>

3.3. Transformed areas

Transformed areas have been added to the landscape map. In certain areas, the degree of transformation of the vegetation (mostly through clearing and cultivation) has been such that much of the character of the original landscape has been lost. The coverage of transformed areas is important in terms of biodiversity, wildlife potential and land use planning.

The transformed areas cover almost 72,500 ha that is spread across different landscapes (Table 3). The true extent of transformation must be considerable higher. The slash-and-burn nature of cultivation in the miombo area means that significant portions can consist of secondary vegetation that may not have been picked up from the satellite imagery. There is also much evidence of current clearing of land which would not be observed on the satellite imagery.

The extent of transformation within the Park is limited to some 2,489 ha (or less than 0.7%). Whereas the absolute extent of the transformation is limited, it is the position of some of the cultivated areas within the Rift Valley Region that has a relatively large impact. This impact is direct (in terms of immediate disturbance and potential source of illegal hunting) as well as indirect (in terms of curtailing restoration potential and tourism development options).
Table 3: Transformed areas in the different landscapes of the Gorongosa National Park and Buffer Zone.

<table>
<thead>
<tr>
<th>Landscape</th>
<th>Transformed area</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Size (ha)</td>
<td>Relative extent</td>
<td>Relative extent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>of landscape (%)</td>
<td>of landscape (%)</td>
</tr>
<tr>
<td>Gorongosa Lower Montane Grassland &amp; Woodland</td>
<td>2,577</td>
<td>13.44</td>
<td></td>
</tr>
<tr>
<td>Gorongosa Montane Forest</td>
<td>1,313</td>
<td>5.96</td>
<td></td>
</tr>
<tr>
<td>Midlands Moist Miombo</td>
<td>49,867</td>
<td>25.73</td>
<td></td>
</tr>
<tr>
<td>Midlands Dry Miombo &amp; Mixed Woodland</td>
<td>3,434</td>
<td>3.82</td>
<td></td>
</tr>
<tr>
<td>Midlands Alluvial</td>
<td>4,586</td>
<td>19.81</td>
<td></td>
</tr>
<tr>
<td>Rift Valley Alluvial Fan</td>
<td>77</td>
<td>4.26</td>
<td></td>
</tr>
<tr>
<td>Rift Valley Riverine &amp; Floodplain</td>
<td>3,408</td>
<td>1.60</td>
<td></td>
</tr>
<tr>
<td>Rift Valley Colluvial Fan</td>
<td>5,925</td>
<td>4.09</td>
<td></td>
</tr>
<tr>
<td>Cheringoma Plateau Seaward Slope</td>
<td>329</td>
<td>0.44</td>
<td></td>
</tr>
<tr>
<td>Cheringoma Plateau Calcareous Sandstone Riftward</td>
<td>165</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>Cheringoma Plateau Argillaceous Sandstone Riftward</td>
<td>461</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL TRANSFORMED</strong></td>
<td><strong>72,488</strong></td>
<td><strong>7.15</strong></td>
<td></td>
</tr>
</tbody>
</table>

3.4. Description of landscape delineation and landscape content

The landscapes of Fig. 5 have been delineated and can be shortly described as follows (see also Plates 1 to 4):

- **Gorongosa Lower Montane Grassland & Woodland Landscape**
  - The boundary between the lower-montane and montane landscapes is found between 1,100 and 1,200 m;
  - This landscape corresponds to Tinley’s Upland Savanna which is an altitudinal tailing off of the surrounding miombo woodlands (of the Midlands Moist Miombo landscape). It also contains Tinley’s Shrub-Thicket formations in areas long subjected to shifting cultivation. It contains a mix of grassland, shrub, woodland and thicket communities with riverine elements along the drainage lines;
  - It also contains the following miombo units described in Muller *et al.* (2008): *Brachystegia tamarindoides* Woodland on the north-western slopes of the Monte Nhassacassa section, and *Brachystegia spiciformis* Woodland on the upper western slopes.
  - The limited extent of this remaining miombo woodland is of particular conservation value (Muller *et al.* 2008).

- **Gorongosa Montane Forest Landscape**
  - This landscape is located above the Lower-montane landscape in the higher-rainfall zone of the mountain;
  - Although there is a substantial difference in the size of the area above 600 m elevation (60 km² according to Tinley and 43 km² according to the GIS), the relative proportion of montane forest is very similar (43% according to Tinley and 45% according to the present mapping);
• Gorongosa Montane Grassland & Shrub-forest Landscape
  o This landscape occurs mostly as large glades within the Montane Forest landscape;
  o The transition from forest to grassland is mostly abrupt with a very sharply defined ecotone;
  o The grassland needs frequent fires for the maintenance of its vigour and species diversity whereas the forest (when undisturbed) is not subjected to fires (except on its margins);
  o Contrary to often-held popular opinion, the grassland communities of this landscape represent the more species diverse and the more ancient communities compared to the forest.
  o This landscape also holds shrub-forest communities such as the Ericoid Scrub and the Erica hexandra – Rhytidosperma macowanii Open Scrub described by Muller et al. (2008).

• Midlands Moist Miombo Landscape
  o The Midlands Moist Miombo Landscape occurs in a concentric ring at the base of Gorongosa Mountain and extends southwards along the westward flank of the Rift Valley;
  o The ‘ring’ is not complete for the Midlands Dry Miombo & Mixed Woodland Landscape is found in the rainshadow to the north-west of Gorongosa Mountain;
  o Drainage lines are generally fairly narrow and rocky (see eg Vundudzi River);
  o The vegetation consists of a mix of miombo communities which correspond to Tinley’s ‘Moist Brachystegia savanna woodlands’ (Tinley Fig. 1.3. Salient landscape features);
  o This is the most transformed landscape of the study area, both in absolute and relative terms.

• Midlands Dry Miombo & Mixed Woodland Landscape
  o This landscape occurs in the rainshadow to the northwest of Gorongosa Mountain as well as in the lower-lying part of the Midlands north-east of the mountain;
  o The vegetation is mostly characterized by mixed Acacia-Combretum communities and corresponds to Tinley’s ‘Mesic and dry savanna woodland and thickets’ (Tinley Fig. 1.3. Salient landscape features). Milletia stuhlmannii is very prominent. Miombo elements are generally limited. Where they do occur, Julbernardia globiflora is conspicuous rather than Brachystegia which is dominant in the previous landscape;
  o Drainage lines are generally fairly wide and sandy (see eg Muera River).
• Midlands Alluvial Landscape
  o This landscape is found on alluvial soils along the larger rivers in the Midlands, including upper Pungue (where not constrained in a rocky bed) and Nhamapaza River;
  o The vegetation consists of a mix of open to closed woodlands and species commonly associated with riverine forests and thickets;
  o This landscape has been subjected to much transformation in the form of cultivation. It is ranked second in transformation after the Midlands Moist Miombo landscape.

• Midlands Inselberg Landscape
  o This landscape occurs as small discrete units on the inselbergs that occur as outcrops north and east of Gorongosa Mountain;
  o The vegetation consists mostly of closed miombo woodland with a more open canopy on rock outcrops.

• Rift Valley Alluvial Fan Landscape
  o This landscape dominates the western part of the Rift Valley region;
  o It is not normally subject to prolonged flooding;
  o The vegetation consists of a complex mix of open to closed woodlands and dry forest/thickets reflecting the structural soil characteristics and moisture regime of the alluvial fans;
  o The Acacia – Combretum Open to Closed, Short to Tall Woodland is the most extensive community in this landscape.

• Rift Valley Riverine & Floodplain Landscape
  o This landscape occurs in the central section of the Rift Valley along its north-south axis;
  o This can be considered as a ‘supra landscape’ with distinct elements such as the areas along the Nhamapaza, Nhandue, Vunduzi, Pungue and Urema River. The problem is that these are all interconnected and it would be difficult to unequivocally define a single, fixed boundary between e.g. the Pungue and Urema landscapes;
  o The vegetation consists of a mix of mostly open plant communities ranging from pure grasslands to sparse palm veld and open Acacia xanthophloea and Faidherbia albida woodlands.

• Rift Valley Colluvial Fan Landscape
  o This landscape characterises the eastern flank of the Rift Valley;
  o It has been formed by the transport of erosion products of the Cheringoma Plateau down into the Rift Valley (Plate 5);
  o The vegetation consists of a mix of open to closed woodland communities.

• Rift Valley Lake Urema Landscape
  o This landscape consists of Lake Urema;
  o The Lake is characterized by open water, but along the margins floating mats of the alien water hyacinth Eichornia crassipes are common.

• Cheringoma Plateau Seaward Slope Landscape
  o This landscape occurs on the eastern side of the watershed along which the Condue - Muanza – Inhamatinga road is located;
- As the name implies, this landscape slopes in an easterly direction towards the Indian Ocean;
- The vegetation is dominated by closed miombo woodlands on the uplands with sparse woodlands and grassy dambo’s in the bottomlands.

  - **Cheringoma Plateau Calcareous Sandstone Riftward Slopes Landscape**
    - This landscape occurs on the western side of the Inhamatinga watershed as the reciprocal landscape to the previous one. It slopes in a westerly direction to the Rift Valley;
    - The vegetation is dominated by closed miombo communities with grassy dambo’s.

  - **Cheringoma Plateau Argillaceous Sandstone Riftward Slopes Landscape**
    - This landscape occupies the south-western sector of the Cheringoma Region;
    - The argillaceous sandstones are patchily eroded resulting in patches of open *Combretum* woodlands in a matrix of *Brachystegia* closed woodlands (Plate 5).

  - **Cheringoma Plateau Limestone Gorge Landscape.**
    - This landscape is embedded in the Cheringoma Plateau Calcareous Sandstone Riftward Slopes Landscape;
    - The vegetation consists of dry woodlands with *Androstachys johnstonii* on the lip of the gorges and mesic riverine forests in the gorges.
Plate 5: Linkages between the Cheringoma Plateau Argillaceous Sandstone Riftward Slopes Landscape (A) and the Rift Valley Colluvial Fan Landscape (B) (note deposition fans at the confluence with the Urema River).

3.5. Plant communities

It is not possible at this stage to accurately map all of the plant communities that make up the different landscapes. This is because of limitations in the available data and available time resources. However, a number of the plant communities are key to either the functioning of the ecosystem or as resources to the wildlife. Others reflect important impacts on the landscape (eg machamba’s).
In terms of key resources, the dambo’s, the *Cynodon-Digitaria* short grasslands, and the saline grasslands and woodlands are vital for the wildlife (see also section 5.). The pan communities are key as sources of water and of grazing as water levels recede.

A total of 21 of these individual communities are described and visually depicted in the full report (see Plates 6 and 7 as examples). Structural terminology follows Edwards (1983). Several of these communities are found across landscapes and even across regions (Table 4). Several more communities occur than those listed here. They can however not easily be individually mapped either because they occur as very small units or because they are intergraded into larger units. Thickets on termitaria e.g. occur as small discrete patches that cannot be mapped at the scale of the GNP. However, this community represents a key resource to browsers. Termites and termite mounds play a very important functional role in this ecosystem. On the other hand, mixed *Acacia-Combretum* woodlands can be either represented as a very large complex of a loosely defined ‘super community’ (as is done here in this report) or it can be split into several communities that are more narrowly defined.

Table 4: Plant communities identified in the different landscapes and regions of the Gorongosa National Park. Plant communities may occur across different landscapes. Communities in the Mountain Region are mostly according to Muller *et al.* (2008).

<table>
<thead>
<tr>
<th>REGION &amp; Landscape</th>
<th>Plant communities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GORONGOSA MOUNTAIN REGION</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Grassland / Secondary Grassland with Scattered Trees</td>
</tr>
<tr>
<td>Gorongosa Lower Montane Grassland &amp;</td>
<td>2. Secondary Woodland &amp; Forest</td>
</tr>
<tr>
<td>Woodland</td>
<td>3. <em>Brachystegia tamarindoides</em> Woodland</td>
</tr>
<tr>
<td>Gorongosa Montane Forest</td>
<td>4. <em>Brachystegia spiciformis</em> Woodland</td>
</tr>
<tr>
<td>Gorongosa Montane Grassland &amp; Sub-</td>
<td>5. Tall Miombo Riverine Forest</td>
</tr>
<tr>
<td>montane Forest</td>
<td></td>
</tr>
<tr>
<td>Gorongosa Montane Grassland &amp; Shrub-forest</td>
<td>1. <em>Syzygium guineense</em> subsp <em>afromontanum</em> Montane Forest</td>
</tr>
<tr>
<td></td>
<td>2. Mixed sub-Montane Forest</td>
</tr>
<tr>
<td></td>
<td>3. Medium Altitude Forest</td>
</tr>
<tr>
<td><strong>MIDLANDS REGION</strong></td>
<td></td>
</tr>
<tr>
<td>Midland Moist Miombo</td>
<td>1. Short Open to Closed Pan Grassland</td>
</tr>
<tr>
<td>Midland Dry Miombo &amp; Mixed Woodland</td>
<td>2. Tall <em>Setaria</em> Floodplain Grassland</td>
</tr>
<tr>
<td></td>
<td>3. <em>Combretum</em> Short Open Woodland in Miombo</td>
</tr>
<tr>
<td></td>
<td>4. Tall Miombo Riverine Forest</td>
</tr>
<tr>
<td></td>
<td>5. Tall Closed Miombo - <em>Acacia nigrescens</em> Woodland</td>
</tr>
<tr>
<td></td>
<td>6. Short Hill-top Miombo with <em>Sterculia quinqueloba</em></td>
</tr>
<tr>
<td></td>
<td>7. <em>Acacia-Combretum-Milletia</em> Short Open Woodland</td>
</tr>
</tbody>
</table>

Landscapes of Gorongosa National Park  
Condensed version July 2008
<table>
<thead>
<tr>
<th>Location</th>
<th>Landscapes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RIFT VALLEY REGION</strong></td>
<td></td>
</tr>
<tr>
<td>Rift Valley Colluvial Fan</td>
<td>1. Short Open to Closed Pan Grassland 2. Short to Tall Dry Forest &amp; Thicket</td>
</tr>
<tr>
<td>Rift Valley Lake Urema</td>
<td>1. Tall Echinochloa-Vetiveria Floodplain Grassland 2. Submerged &amp; Floating Leaved Aquatic Communities</td>
</tr>
<tr>
<td><strong>CHERINGOMA REGION</strong></td>
<td></td>
</tr>
<tr>
<td>Cheringoma Seaward Slope</td>
<td>1. Low Dambo Grassland 2. Combretum Short Open Woodland in Miombo 3. Tall Miombo Riverine Forest 4. Tall Closed Humid Miombo Woodland</td>
</tr>
<tr>
<td>Cheringoma Calcareous Sandstone Riftward Slope</td>
<td>1. Low Dambo Grassland 2. Combretum Short Open Woodland in Miombo 3. Tall Miombo Riverine Forest 4. Tall Closed Miombo - Acacia nigrescens Woodland 5. Tall Closed Humid Miombo Woodland</td>
</tr>
<tr>
<td>Cheringoma Argillaceous Sandstone Riftward Slope</td>
<td>1. Low dambo Grassland 2. Combretum Short Open Woodland in Mombo 3. Tall Miombo Riverine Forest 4. Tall Closed Humid Miombo Woodland</td>
</tr>
<tr>
<td>Cheringoma Limestone Gorge</td>
<td>1. Tall to High Limestone Gorge Forest 2. Tall Miombo Riverine Forest</td>
</tr>
</tbody>
</table>
Plate 6: *Cynodon dactylon – Digitaria swazilandensis* Low Grassland – extent: 1,900ha (* indicates position of ground plot or control point)

**Landscape**: Rift Valley Alluvial Fan

**Topographical position**: Floodplain

**Woody structure**: Virtually no woody species present.

**Grass & field layer**: Low closed grassland.

**Woody species**: alien *Mimosa pigra*

**Grass species**: *Cynodon dactylon*, *Digitaria swazilandensis*

**Other species**: *Sesbania* sp. (woody forb)

**Notes**: extent of the *Cynodon* grasslands around Lake Umeme mapped by Lisa Rebelo
(International Water Management Institute)

**Top photo**: Short *Cynodon* grassland with sable antelope in background. Recent fires in foreground.

**Middle photo**: Short grassland with longer grass in background.

**Bottom photo**: Close-up of *Cynodon*. Note strongly stoloniferous nature of the grass layer.

**Suitability for grazers**: Very good

**Suitability for browsers**: Very low

**Carrying capacity**: 1-2 ha/LSU
Plate 7: Open to Closed, Tall Hyphaene and Borassus Palm Veld

Landscape: Rift Valley Alluvial Fan (mostly), Rift Valley Riverine & Floodplain

Topographical position: Footslope, drainage line (eg Pungue inundation lines)

Woody structure: Open to closed, short to tall woodland

Grass & field layer: Short to tall closed grassland.

Woody species: Hyphaene petersiana, Borassus aethiopium, Philenoptera violacea, Combretum adenogonium, Acacia sieberana

Grass species: Setaria incrassata, Panicum maximum, Valtiera nigritana, Hyparthenia sp.

Other species: Phoenix reclinata clumps (only observed 10km due North of Lake Urema)

Top photo: Hyphaene palmveld interspersed with Acacia xanthophloea community. Bottom: Palmveld at edge of floodplain grassland.

Suitability for grazers: Medium to good  
Suitability for browsers: Low to medium  
Carrying capacity: 4 – 8 ha/LSU
3.6. Alien plants

The diversity and spread of alien invasive species is relatively limited considering the size and mesic character of the terrestrial systems of the GNP. However, a number of waterweeds are prominent. The most important species are as follows:

- **Mimosa pigra** (mimosa):
  - This species is classified as one of the 100 ‘world’s worst invasive species’.
  - In Gorongosa it is already well-established on the floodplain, in pans and along waterways such as the Urema River;
  - It has the potential to rapidly spread and to have a significant detrimental impact in terms of displacing indigenous vegetation, lowering wildlife carrying capacity, and impeding wildlife viewing;
  - The status of this species and its management needs in Gorongosa have been comprehensively documented by Beilfuss (2007).

- **Eichornia crassipes** (water hyacinth):
  - This species is well established and widespread on Lake Urema and in the Urema River.

- **Pistia stratiotes** (water lettuce):
  - This species is well established and widespread on Lake Urema and in the Urema River as well as in the smaller pans of the Rift Valley.

- **Lantana camara** (lantana):
  - This species was observed at two localities along the main entrance road (no GPS readings were taken) and at Boa Maria.

- **Ricinus communis** (castor-oil plant)
  - This species was found in clearings for machamba’s in the montane forest on Gorongosa Mountain and at the edge of machamba’s in the Midlands Moist Miombo Landscape;
  - It was also observed in ‘naturally’ disturbed areas on the banks of rivers in the limestone gorges and the Midlands Dry Miombo & Mixed Woodland Landscape;

- **Psidium guajava** (guava):
  - The guava was observed amongst the ruins at Boa Maria;
  - This species is expected to have a very high invasive potential on the lower and middle slopes of Gorongosa Mountain.

- **Cassia** (Senna) sp.
  - This species occurs as an escape from the ornamental trees planted in the Chitengo rest camp. They occur in a concentric pattern around Chitengo. They are also spreading along the northern bank of the Pungue River south of Chitengo.
  - This species has the potential to invade the *Pilostricta thonningii* – *Borassus aethiopium* Closed Woodland /Dry Forest.
  - This species has been planted near homesteads in the Midlands Moist Miombo Landscape. It does appear to be relatively stable and may only be a weak invader in that environment.

- **Caesalpinia decapetala** (Mauritius thorn):
o This very aggressive climber in riverine forest was reported by Dr David Goyder on the Cheringoma Plateau c. 20 km SW of Inhaminga.

- **Catharanthus roseus** (periwinkle):
  o This small garden weed was spotted at Boa Maria.

- **Opuntia sp.** (prickly pear):
  o This invasive succulent was observed at the main entrance gate.

The Gorongosa environment is very conducive for the spread of the above species as well as for the establishment and spread of a number of other very invasive species. Management must be aware of this. Immediate action and thorough follow-up are essential if one wants to avoid massive control costs in future.

## 4. IMPLICATIONS FOR WILDLIFE

### 4.1. Introduction

It is well documented that decades ago the Gorongosa National Park used to support very high densities of a wide range of wildlife. Following the massive reduction in animal numbers as a result of the civil war, a substantial recovery has been experienced for some species. Other species such as zebra and blue wildebeest however have been reduced to extremely low numbers that are unlikely to recover to any significant extent without introductions from outside.

A re-introduction strategy has therefore been devised aimed at rapidly boosting numbers (Anderson *et al*. 2006). The question is ‘to what numbers’? Anderson *et al*. (2006) appropriately stated the following: ‘There is a temptation to regard the wildlife species composition and numbers at the time of his (namely Tinley) study as being the natural situation, the restoration of which must be the aim of the rehabilitation project. Tinley noted that both roan and tsessebe had disappeared from the area and that earlier in the 20th century that zebra were then considered to be the most numerous species. It is therefore accepted that as has occurred in other areas that the species composition and numbers in Gorongosa area have undergone fluctuations and that these will likely continue in the future.’

The large reduction in grazing and browsing pressure for at least three decades is expected to have resulted in some significant changes. In particular, the grazing succession whereby the impact of one species on the grass sward makes it more easily accessible to another species, has largely been lost because of the dramatic reduction in grazing pressure. Can this grazing succession be re-established?

Furthermore, natural and/or man-made changes may or may not have affected the flooding regime of the floodplain and thus its productivity and seasonal availability of forage. The spread of alien species such as *Mimosa pigra* may negatively impact on carrying capacity.

An important question for management is thus whether the current carrying capacity and habitat suitability are adequate in terms of the generally accepted end state (although this end state has not been explicitly defined). If the current situation is not adequate, what should be done from a management perspective? If management-induced changes are not feasible or would be too costly, should a different end objective be defined?
4.2. Habitat suitability

The different parts of Gorongosa have a very different suitability for different species. This is as a consequence of the different structure of the vegetation and nutrient content as determined by the underlying soils and by the moisture- and fire-regime.

The results of the subjective rating of the 139 ground plots, for their suitability for grazers and browsers on a scale of 1 to 5, are listed in Table 5 and 6. There is a very distinct pattern in terms of the relative suitability of certain plant communities for grazers. Densely wooded communities, particularly in the miombo of the Midlands and the Cheringoma Plateau Region have a very low to low value. Communities in the Rift Valley, especially grasslands, rate as good to very good. Not surprisingly, the inverse pattern applies for browsers. The grassland communities are not very suitable. It is only the Acacia Sparse to Open Woodland with Saline Grassland and the Faidherbia albida Open to Closed, Tall Woodland that offer habitat that is of equal value to the grazers and browsers.

Table 5: Relative suitability on a scale of 1 to 5 of the sampled communities in Gorongosa for grazers (communities are listed in increasing order of suitability).

<table>
<thead>
<tr>
<th>Community</th>
<th>Habitat suitability for grazers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very low</strong></td>
<td>Low</td>
</tr>
<tr>
<td>Dichrostachys cinerea Tall/High Closed Shrubland</td>
<td>1.0</td>
</tr>
<tr>
<td>Short to Tall Dry Forest &amp; Thicket</td>
<td>1.6</td>
</tr>
<tr>
<td>Miombo undifferentiated</td>
<td>2.0</td>
</tr>
<tr>
<td>Tall Closed Humid Miombo Woodland</td>
<td>2.0</td>
</tr>
<tr>
<td>Tall Miombo Riverine Forest</td>
<td>2.0</td>
</tr>
<tr>
<td>Miombo – hill</td>
<td>2.3</td>
</tr>
<tr>
<td>Low dambo Grassland</td>
<td>2.5</td>
</tr>
<tr>
<td>Combretum Short Open Woodland in Miombo</td>
<td>2.6</td>
</tr>
<tr>
<td>Piliostigma thonningii – Borassus aethiopium Closed Woodland/Dry Forest</td>
<td>2.6</td>
</tr>
<tr>
<td>Dalbergia melanoxylon Low Closed Woodland</td>
<td>3.0</td>
</tr>
<tr>
<td>Tall Closed Miombo – Acacia nigrescens woodland</td>
<td>3.0</td>
</tr>
<tr>
<td>Termitaria</td>
<td>3.0</td>
</tr>
<tr>
<td>Acacia-Combretum-Milletia Short Open Woodland</td>
<td>3.5</td>
</tr>
<tr>
<td>Colophospermum mopane Closed Tall Woodland</td>
<td>3.5</td>
</tr>
<tr>
<td>Phragmites Reedbed</td>
<td>3.5</td>
</tr>
<tr>
<td>Hyphaene / Borassus / Phoenix Open to Closed, Tall Palm Veld</td>
<td>3.6</td>
</tr>
<tr>
<td>Acacia – Combretum Open to Close, Short to Tall Woodland</td>
<td>3.6</td>
</tr>
<tr>
<td>Tall Setaria Floodplain Grassland</td>
<td>3.8</td>
</tr>
<tr>
<td>Acacia xanthophloea Open to Closed, Tall Woodland</td>
<td>4.0</td>
</tr>
<tr>
<td>Pan</td>
<td>4.2</td>
</tr>
<tr>
<td>Tall Echinochloa – Vetiveria Floodplain Grassland</td>
<td>4.2</td>
</tr>
<tr>
<td>Acacia Sparse to Open Woodland with Saline Grassland</td>
<td>4.3</td>
</tr>
<tr>
<td>Cynodon dactylon – Digitaria swazilandensis Short Grassland</td>
<td>4.9</td>
</tr>
<tr>
<td>Faidherbia albida Open to Closed, Tall Woodland</td>
<td>5.0</td>
</tr>
</tbody>
</table>
Table 6: Relative suitability on a scale of 1 to 5 of the sampled communities in Gorongosa for browsers (communities are listed in increasing order of suitability).

<table>
<thead>
<tr>
<th>Community</th>
<th>Habitat suitability for browsers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very low</td>
</tr>
<tr>
<td><strong>Cynodon dactylon – Digitaria swazilandensis Short Grassland</strong></td>
<td>1.0</td>
</tr>
<tr>
<td>Low dambo Grassland</td>
<td>1.0</td>
</tr>
<tr>
<td>Miombo undifferentiated</td>
<td>1.0</td>
</tr>
<tr>
<td>Pan</td>
<td>1.0</td>
</tr>
<tr>
<td>Reedbed</td>
<td>1.0</td>
</tr>
<tr>
<td>Tall Closed Humid Miombo Woodland</td>
<td>1.0</td>
</tr>
<tr>
<td>Tall <em>Echinocloa – Vetiveria</em> Floodplain Grassland</td>
<td>1.1</td>
</tr>
<tr>
<td>Tall <em>Setaria</em> Floodplain Grassland</td>
<td>1.3</td>
</tr>
<tr>
<td>Miombo hill</td>
<td></td>
</tr>
<tr>
<td><em>Hyphaene / Borassus / Phoenix</em> Open to Closed, Tall Palm Veld</td>
<td></td>
</tr>
<tr>
<td><em>Acacia–Combretum-Milletia</em> Short Open Woodland</td>
<td></td>
</tr>
<tr>
<td><em>Colophospermum mopane</em> Closed Tall Woodland</td>
<td></td>
</tr>
<tr>
<td>Riverine forest Rift</td>
<td></td>
</tr>
<tr>
<td><em>Combretum</em> Short Open Woodland in Miombo</td>
<td></td>
</tr>
<tr>
<td><em>Pilostigma thonningii</em> – <em>Borassus aethiopium</em> Closed Woodland/Dry Forest</td>
<td></td>
</tr>
<tr>
<td>Short to Tall Dry Forest &amp; Thicket</td>
<td></td>
</tr>
<tr>
<td><em>Acacia xanthophloea</em> Open to Closed, Tall Woodland</td>
<td></td>
</tr>
<tr>
<td>Tall Closed Miombo – <em>Acacia nigrescens</em> woodland</td>
<td></td>
</tr>
<tr>
<td>Tall Miombo Riverine Forest</td>
<td></td>
</tr>
<tr>
<td><em>Acacia – Combretum</em> Open to Close, Short to Tall Woodland</td>
<td></td>
</tr>
<tr>
<td><em>Dichrostachys cinerea</em> Tall/High Closed Shrubland</td>
<td></td>
</tr>
<tr>
<td><em>Faidherbia albida</em> Open to Closed, Tall Woodland</td>
<td></td>
</tr>
<tr>
<td><em>Acacia</em> Sparse to Open Woodland with Saline Grassland</td>
<td></td>
</tr>
<tr>
<td><em>Dalbergia melanoxylon</em> Low Closed Woodland</td>
<td></td>
</tr>
<tr>
<td>Termitaria</td>
<td></td>
</tr>
</tbody>
</table>

As the exact size of the different communities is not known, one cannot derive a relative suitability across the Park. Nevertheless, it is clear that the greater part of the Rift Valley consists of communities with high suitability values for grazers (*Acacia – Combretum*, Palmveld and the different grassland communities). Even in the miombo, the Tall Closed Miombo – *Acacia nigrescens* woodland that adjoins the Rift Valley offers relatively good grazing. This latter community probably represented some of the summer dispersal range for wildlife as documented by Tinley (1977).

Gorongosa offers much less suitable habitat for browsers. It is only some of the less extensive communities that rate highly for browsers. The current situation mirrors the historic pattern. The ratio of bulk grazers, concentrate grazers, mixed feeders and
browsers was approximately 65%:10%:24%:1% in 1972 when wildlife populations were still very high.

A graphical representation of habitat suitability is presented in Fig. 7 by allocating an estimate across the different landscapes. This coarse approach confirms the patterns discussed earlier.

No assessment was made of the habitat suitability for individual animal species. The overall impression is that at present the Park remains suitable for the full range of species that were historically present. The lack of grazing succession however has probably led to a relative lowering of the overall extent of short grass habitat. Although short grass habitat is still present, the lower extent could place a limit on species such as wildebeest. Is not only the structure and quality of the grazing that is important. The ability to avoid lion predation by using short open areas is important for this species.

![Fig. 7: Relative suitability of the different landscapes for grazers and browsers.](image)

### 4.3. Carrying capacity

The concept of ‘carrying capacity’ is a nebulous one with many definitions, and it is difficult to determine in heterogeneous environments experiencing variable environmental and resource conditions (Peel et al. 1999). It should therefore not be considered as a static figure but must reflect climatic conditions and influence of management practices followed.

Within the context of the GNP, ‘ecological carrying capacity’ is loosely defined as the population size of a species in an area as determined by the capacity of that area to support the individuals in that population and enable them to reproduce (adapted from Caughley 1979 and Grossman 1984). This assessment of carrying capacity looks at ecological carrying capacity.
Traditionally, carrying capacity has been expressed as the number of hectares required to support an Animal Unit (ha/AU). This has several shortcomings including the fact that the unit decreases in magnitude as animal numbers increase. The term is also not linearly related to the number of animals on an area of land. The Animal Unit also ignores dietary differences. The use of kg km\(^2\) is preferred from a methodological viewpoint. Both units are however being used in this technical document as the former is familiar to most ecologists and as it allows easy comparison with other documents and opinions.

During the field survey of the 139 sample plots a visual estimate of carrying capacity was made. These estimates were used to group the different communities into ‘bands’ of increasing carrying capacity (Table 7). This field survey represents only a snapshot in time in a limited number of localities. Such a subjective estimate is influenced by the season and phenology of the vegetation. In summer, it is likely that a more positive assessment will be made.

How does the above compare to other estimates based on general equations and how does this compare to other case studies?

Coe et al. (1977) established that a high degree of correlation exists in natural systems between the herbivore biomass and annual rainfall. This allows for predicting animal biomass from simple long-term rainfall figures. The relationship between rainfall and carrying capacity starts deteriorating above a rainfall of 800 to 900 mm, particularly in nutrient-poor environments. Carrying capacity can actually drop in very wet areas due to excessive leaching of nutrients from the soil and the ensuing production of a low quality sward. This would certainly apply to the miombo on the Cheringoma plateau. Fritz & Duncan (1994) further refined the rainfall-related carrying capacity approach by taking into account the underlying low, medium or high fertility substrates.

Only limited recommendations on stocking rates and carrying capacity are available for Moçambique and further research is required (Maposse et al. 2003). A predictive model for livestock carrying capacity has been developed for Moçambique (Timberlake & Reddy 1986). Their study lists a carrying capacity of 2.3 ha/AU for grassy bottomlands on heavy soils in Chokwe with a annual rainfall of 656 mm. Tinley (1977) mentions carrying capacity estimates by Myre & Antão (1972) of 15 ha per AU for miombo, 6 – 8 ha per AU for Urochloa savanna grasslands (similar to Combretum – Acacia veld of the present study) and 3 – 4 ha per AU for flooded alluvial grasslands.
Table 7: Carrying capacity for wildlife of the sampled communities in Gorongosa (visual, subjective estimate only).

<table>
<thead>
<tr>
<th>Community</th>
<th>Carrying capacity</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg km⁻²</td>
<td>ha/LSU</td>
</tr>
<tr>
<td>Tall Closed Humid Miombo Woodland</td>
<td>2,571</td>
<td>18</td>
</tr>
<tr>
<td>Short to Tall Dry Forest &amp; Thicket</td>
<td>3,158</td>
<td>14</td>
</tr>
<tr>
<td>Low dambo Grassland</td>
<td>3,333</td>
<td>14</td>
</tr>
<tr>
<td>Miombo undifferentiated</td>
<td>3,333</td>
<td>14</td>
</tr>
<tr>
<td>Miombo hill</td>
<td>3,333</td>
<td>14</td>
</tr>
<tr>
<td>Tall Miombo Riverine Forest</td>
<td>3,913</td>
<td>12</td>
</tr>
<tr>
<td><em>Pilostigma thonninii</em> – <em>Borassus aethiopium</em> Closed Woodland/Dry Forest</td>
<td>3,971</td>
<td>11</td>
</tr>
<tr>
<td><em>Combretum</em> Short Open Woodland in Miombo</td>
<td>4,500</td>
<td>10</td>
</tr>
<tr>
<td><em>Dichrostachys cinerea</em> Tall/High Closed Shrubland</td>
<td>4,500</td>
<td>10</td>
</tr>
<tr>
<td>Tall Closed Miombo – <em>Acacia nigrescens</em> woodland</td>
<td>4,909</td>
<td>9</td>
</tr>
<tr>
<td><em>Colophospermum mopane</em> Closed Tall Woodland</td>
<td>5,000</td>
<td>9</td>
</tr>
<tr>
<td><em>Acacia–Combretum–Milletia</em> Short Open Woodland</td>
<td>5,625</td>
<td>8</td>
</tr>
<tr>
<td>Termitaria</td>
<td>6,429</td>
<td>7</td>
</tr>
<tr>
<td><em>Dalbergia melanoxylon</em> Low Closed Woodland</td>
<td>6,429</td>
<td>7</td>
</tr>
<tr>
<td><em>Acacia – Combretum</em> Open to Close, Short to Tall Woodland</td>
<td>7,290</td>
<td>6</td>
</tr>
<tr>
<td><em>Acacia</em> Sparse to Open Woodland with Saline Grassland</td>
<td>7,500</td>
<td>6</td>
</tr>
<tr>
<td>Tall <em>Setaria</em> Floodplain Grassland</td>
<td>7,941</td>
<td>6</td>
</tr>
<tr>
<td><em>Hyphaene / Borassus / Phoenix</em> Open to Closed, Tall Palm Veld</td>
<td>8,504</td>
<td>5</td>
</tr>
<tr>
<td><em>Acacia xanthophloea</em> Open to Closed, Tall Woodland</td>
<td>11,124</td>
<td>4</td>
</tr>
<tr>
<td>Reedbed</td>
<td>13,333</td>
<td>3</td>
</tr>
<tr>
<td>Pan</td>
<td>13,500</td>
<td>3</td>
</tr>
<tr>
<td><em>Cynodon dactylon</em> – <em>Digitaria swazilandensis</em> Short Grassland</td>
<td>21,429</td>
<td>2</td>
</tr>
<tr>
<td><em>Faidherbia albida</em> Open to Closed, Tall Woodland</td>
<td>30,000</td>
<td>2</td>
</tr>
<tr>
<td>Tall <em>Echinochloa</em> – <em>Vetiveria</em> Floodplain Grassland</td>
<td>31,765</td>
<td>1</td>
</tr>
</tbody>
</table>

A historic stocking rate for the GNP is obtained from Tinley (1977) (Table 10.3 p181). It is however not known whether the area was at, below or above carrying capacity at the time of the air counts. Tinley (1977) does however mention the poor physical condition of the hippo. It would appear that Gorongosa was stocked at very high rates. The loss of tsessebe and roan prior to the civil war may also point to problems of competition for resources.

The results from the predictive equations, GNP counts, case studies from Parks further a field and the current study are synthesized in Table 8. The field estimates fit within the overall ‘envelope’ of carrying capacity derived from other sources. It should also be noted that recent work indicates that the ‘true’ figure for carrying capacity lies closer to the upper limit of Coe *et al.* (1976) rather than the average figure (Dr M Peel, ARC, *pers. comm.*). All of the above would indicate that the field estimates can indeed be used as a guideline for initial planning and stocking of the GNP.

A coarse visual representation of carrying capacity across the area is provided in Fig. 8 by allocating a relative estimate across all of the landscapes.
Fig. 8: Relative estimate of carrying capacity for the different landscapes (with additional detail for the *Cynodon-Digitaria* plant community).

### 4.4. Implications

It is pointless at this stage to try to refine the calculation of carrying capacity for the Park. This is not only because of the shortcomings in the mapping. Carrying capacity is not static. It depends on rainfall and is influenced by feedback from the wildlife. In this case, there is no fixed boundary between the tall *Echinochloa*, short *Cynodon* and tall *Setaria* grasslands. These communities expand and retract in reaction to the length and depth of inundation. The inundation pattern will vary from year to year and includes extreme high levels such as those experienced in early 2008.

It is clear from the range of estimates, that the individual plant communities are capable of supporting the same order of magnitude in stocking rate as was historically experienced in Gorongosa. Even without a precise map of the extent of the plant communities, it is obvious that for example the *Acacia-Combretum* community occurs over a very large extent. This community has a medium high
carrying capacity. The key resource communities on which the wildlife historically relied during the dry season, namely the short floodplain grasslands still occur. Their extent however has probably been reduced through a collapse of the grazing succession.

There are three main recommendations for the GNP veld and wildlife management:

- The grazing succession must be re-established. This will require the presence (and concentration) of megaherbivores such as elephant, hippo, buffalo or white rhino. Several areas were identified where the potential exists for a switch from tall (*Setaria*) grasslands to short *Cynodon* grasslands under the influence of heavier grazing.
- The dambo’s, the short *Cynodon-Digitaria* grasslands, and the saline grasslands and woodlands are vital key resources for the wildlife. The pan communities are key as sources of water and of grazing as water levels recede. Management must ensure that these key resource areas do not lose their value through bush enchroachment and the spread of the alien *Mimosa pigra*. Key resources must also be protected from human enchroachment;
- Conversely, the *Dichrostachys cinerea* Tall to High Closed Shrubland is a community that may expand if the flood regime of the Rift Valley changes towards a drier state. This community has a very low carrying capacity for grazers and its eventual spread should be limited (through active fire management, mechanical intervention etc.).

### 5. GAPS & SHORTCOMINGS

A number of shortcomings in the availability of information as well as in the approach that was followed during this study have become apparent:

<table>
<thead>
<tr>
<th>Gaps &amp; shortcomings</th>
<th>Requirement to address current gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient knowledge on flooding dynamics.</td>
<td>Quantitative assessment on the spatial and temporal pattern of inundation extent and depth.</td>
</tr>
<tr>
<td>No explicit mapping of different grassland communities</td>
<td>Mapping coupled to understanding of determining factors and dynamics (flood regimes, inundation depth and length of inundation).</td>
</tr>
<tr>
<td>True extent of cultivation has not been determined (including slash-and-burn cycle, fallow portion, fallow cycle). Any recent changes - shortening of fallow cycles ?</td>
<td>Two-pronged approach: social study on land use patterns coupled to remote sensing analysis using sequence of imagery and/or aerial photographs</td>
</tr>
<tr>
<td>Pans – insufficiently mapped</td>
<td>Automated approach with analysis of the LISS IV satellite imagery using eCognition / Spring software.</td>
</tr>
<tr>
<td>Vegetation dynamics – insufficient knowledge of temporal changes over last decades (including effect of low elephant numbers)</td>
<td>Full comparison with Tinley descriptions. Scanning and georeferencing a set of historic aerial photographs to compare with modern photographs. Revisiting of areas for which historic photographs can be sourced in order to look at change (Fig. 9).</td>
</tr>
<tr>
<td>Little quantitative information on temporal aspects of the carrying capacity for wildlife</td>
<td>Production studies / Fodder flow (that identify possible ‘bottlenecks’ in time and space).</td>
</tr>
<tr>
<td>No single integrated image of the study area</td>
<td>Acquire remote sensing over a short-time period in the same season. Single image (different ‘tiles’ to be ‘stitched’ together). Image resolution – balance resolution, costs and size (probably SPOT image).</td>
</tr>
</tbody>
</table>
6. CONCLUSION

The landscapes and plant communities of the Gorongosa National Park and its Buffer Zone are very diverse and occur in a complex and intricate pattern. Although the broad relationships between the vegetation and the environment are known, there is insufficient quantitative information to accurately model and map the different floodplain grasslands.

The habitat of the Park remains extremely suitable for grazers although the collapse of the grazing succession has led to a reduction in the extent of the short Cynodon-Dactylon grasslands which represent a key resource to the herbivores.

The carrying capacity of the Park is high and should allow stocking rates that are comparable to historic levels.
7. ACKNOWLEDGEMENTS

Staff of the Carr Foundation and personnel from the GNP provided much logistical support during fieldwork and staying over at Chitengo. Franziska Steinbruch provided much GIS data including the LISS IV satellite imagery that was used. The provision of a helicopter (ably piloted by Tosch Ross and Bertus Reyneke) enabled invaluable ground truthing and led to a better perspective on the GNP, its landscapes and its functioning. Greg Carr is gratefully acknowledged for making all of this possible.

8. REFERENCES


