CHAPTER 3

STUDY AREA

LOCATION AND TOPOGRAPHY

The Lake Victoria region

Uganda (Figure 3.1 & 3.2) is a relatively small, landlocked country straddling the equator in East Africa. The country lies between N 04°07 and S 01°30 latitude and E 29°33 and E 35°20 longitude. It shares borders with Sudan in the north, Kenya in the east, Tanzania and Rwanda in the south and the Democratic Republic of the Congo in the west (Harcourt 1992) (Figure 3.1).

The largest part of Uganda is situated on the east-central African plateau at an altitude of between 900 to 1 500 m (Figure 3.2). Towards the north the plateau slopes downwards, forming gently rolling plains interrupted by occasional mountains and hills. In the south the topography consists of flat-topped hills and broad, frequently swampy valleys (Figure 3.2). The rift valley with its associated mountains and lakes runs through the west of the country (Figure 3.2). In this area the Ruwenzori rises to its highest peak at 5 119 m (Figure 3.2). In the east, three high volcanic mountains dominate: Mt Elgon (4 321 m), Mt Kadam (3 068 m), and Mt Moroto (3 083 m) (Harcourt 1992) (Figure 3.2).

The total area of Uganda is 235 880 km^2. One-sixth of this total area is made up of lakes, the biggest of which is Lake Victoria (Harcourt 1992) (Figure 3.1 & 3.2).

Lake Victoria

Lake Victoria lies in an equatorial basin between the escarpments of the eastern and western Rift Valleys of East Africa. It covers an area of 68 800 km^2 and extends 300 km from north to south and 280 km from east to west (Kendall 1969). The lake has a volume of 2 700 km^3. It is rather shallow, with a mean depth of 40 m and a maximum depth of 79 m (Lamb 1966, Kendall 1969) (Figure 3.1 & 3.2).

Figure 3.1: Africa indicating position of Uganda; Uganda – land area, lakes & neighbouring countries and location of study area in Lake Victoria, Uganda.

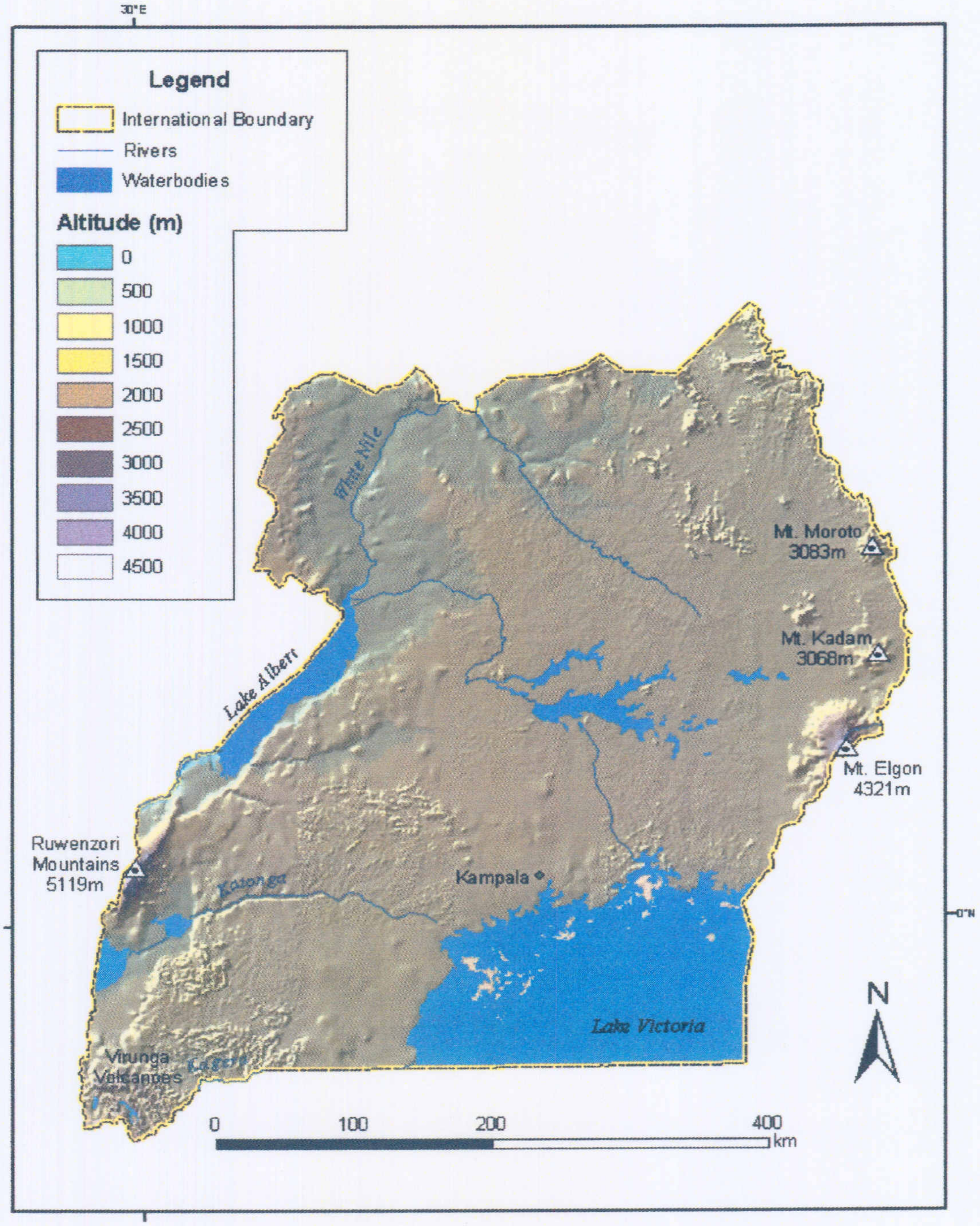

Figure 3.2: Uganda topography.

The Lake Victoria basin covers an area of 263 000 km^2 of which the lake occupies about one-fourth. The drainage of the lake is via the Nile River in the north, where it leaves the lake at Jinja (Kendall 1969). The shoreline of the lake, especially in the north and south, is very irregular and appears partially drowned. Straighter shorelines can be found in the southwest, southeast and northeast as a result of fault zones, resistant rocks or emergences (Kendall 1969). East and west of the lake its basin rises to over 1 000 m, forming highlands bordering the respective Rift Valleys, while locally in the north and south the watershed of the basin only rises to 25 m above lake level (Kendall 1969).

Volcanic emanations have covered part of the basin's periphery leading to regional uplift and Rift Valley formation (Kendall 1969). Thus, volcanics now constitute most of the lake's eastern watershed. In the northeast Mt Elgon volcano forms the corner of drainage, while in the west, with a less extensive igneous activity, only the Virunga vulcanos intrude on the basin (Kendall 1969) (Figure 3.2).

According to Kendall (1969) Lake Victoria's mean surface level prior to 1961 was 1 134 m above sea level. Even though the level has risen since then, all further references will be made to a presumed mean lake level of 1 134 m (Kendall 1969), a value which is also given by White (1983).

History

Lake Victoria originated in the middle or late Pleistocene (700 000 to 20 000 years B.P. - Tulloch 1993, Wahrig-Burfeind 1991) as a tectonically induced backwater through ponding of westwards flowing rivers (Kendall 1969). The lake was preceded by a west-to-east drainage system to which it now lies athwart, the earliest Lake Victoria was already very large and extended a considerable way to the west of its present position (Kendall 1969).

The backstopping of water was caused by uplifting of the land to the west of the present Lake Victoria basin. This uplifting began in the Miocene (> 700 000 years B.P. - Tulloch 1993, Wahrig-Burfeind 1991) and continued into the Pleistocene. Initially this uplifting was relatively slow and still allowed the westwards flowing rivers in the basin to maintain their direction of flow. The rate of uplifting increased and eventually caused river reversal and back-ponding in the middle to late Pleistocene. Through drowning of the two mature river systems of the *Kagera* in the west and the *Katonga* in the northwest Lake Victoria was originally formed (Kendall 1969). The remaining water is contributed by a number of smaller tributaries and through precipitation following evaporation from the Indian Ocean (Kendall 1969) (Figure 3.2).

Palaeogeology

Lake Victoria had three horizontally raised beaches during the last 12 000 years at 3, 12, and 18 m above the 1961 mean lake level. From 14 500 B.P. until about 12 000 B.P. the lake did not have an outlet. It also possessed a higher concentration in chemicals, especially carbon compounds, than today (Kendall 1969, Butzer *et al.* 1972).

During the period from 12 000 until 10 000 B.P. Lake Victoria had an outlet, coinciding with a rise in lake water level starting at around 12 000 B.P. (Kendall 1969, Butzer *et al.* 1972). Around 10 000 years ago the lake level dropped once again to about 12 m below the present level and the lake was closed once more (Kendall 1969, Butzer *et al.* 1972). After this period the lake level rose again and from about 9 500 B.P. Lake Victoria has had a constant drainage northward, forming the source of the White Nile (Kendall 1969, Butzer *et al.* 1972). From 9 500 until 6 500 B.P. the lake level was particularly high and it has been decreasing for the last 7 000 to 6 000 years reaching a particularly low level between 3 000 to 2 000 years ago (Kendall 1969, Butzer *et al.* 1972).

This fluctuation in mean lake level is typical for a number of East African lakes, such as Lake Turkana (Lake Rudolf), Lake Nakuru and Lake Naivasha (Lamb 1966, Butzer *et al.* 1972).

Lake level

The changes in lake levels were mainly induced by changes in climate, with a change in the precipitation/evaporation ratio being mainly responsible for subsequent changes in the mean lake level (Lamb 1966, Kendall 1969). Comparing modern rainfall conditions and water volume in the Victoria basin, Kendall (1969) concludes that from > 14 500 to 12 5000 years ago the climate must have been more arid than today to support a closed basin. Periods of higher rainfall are associated with higher lake levels (Kendall 1969).

Kendall (1969) calculates that at present Lake Victoria has a net water gain of 21 x 10^{12} litres per year. Tributaries deliver about 15 x 10^{12} to 16 x 10^{12} litres per year while the remaining volume is made up by rainfall (Kendall 1969). Kendall (1969) estimates that 90% of the lake's water income is lost again through evaporation (Kendall 1969). Lamb (1966) states an amount of 85%, with only the remaining 15% being lost by discharge through the Nile outlet.

Lamb (1966) argues that fluctuations in lake levels have been reported since measurements started. He concludes that such fluctuations should be expected to continue in the future with similar spacing as observed so far. Thus, high lake levels with peaks of up to half a metre above the ten year mean can be expected for two or three years in each decade (Lamb 1966).

Study sites

Ngamba Island is situated in the Ugandan part of Lake Victoria about 23 km southeast of Entebbe at S 00°06 and E 32°39 and an altitude of 1 160 m above sea level (Figure 3.1 & 6.1). It covers an area of 0.46 km^2 with a perimeter of 3 375.05 m (Meiklejohn pers. comm.[1]). Apart from a small area in the northern part of the island Ngamba Island is completely covered by moist evergreen secondary rain forest (Langdale-Brown *et al.* 1964) (Figure 6.1). The two control plots of the woody vegetation survey were situated in the north eastern part of neighbouring Nsadzi Island at S 00°05 and E 32°37 and a similar altitude as Ngamba Island (Figure 6.68).

CLIMATE

"The East African record ... presents a consistent picture of climatic change" (Kendall 1969).

Climate of tropical rain forests

The climate of the tropical rain forest is characterized by a high and very even temperature and heavy rainfall which is spread over the greater part of the year (Richards 1966). Throughout the rain forest belt these main features of the climate remain more or less similar. Even if considerable variations do occur, especially in the seasonal distribution of rainfall and temperature (Richards 1966).

Since the tropics are no natural climate boundaries, no simple latitudinal boundaries for the rain forest distribution can be given. Rather, in a climatologically sense, the tropical zone is

[1] Meiklejohn, I.K. 2001. Department of Geography, University of Pretoria, Pretoria, R.S.A.

defined by the isotherm of 20 °C mean annual temperature, which ultimately depends on the uneven distribution of land and sea (Richards 1966).

In general terms it may be said, that the northern and southern climatic boundaries of the tropical rain forest formation type are mainly determined by precipitation, while its altitudinal boundaries are mainly determined by temperature (Richards 1939, 1966).

Rainfall

Uganda shows two different rainfall patterns. In the north of the country the rainfall is monomodal with one rainy season from April to October and a long and severe dry season for the rest of the year (Langdale-Brown *et al.* 1964, Hamilton 1974). The southern part of the country shows a bimodal rainfall pattern with a major rainy season from March to May and a minor rainy season from October to November (Langdale-Brown *et al.* 1964, Hamilton 1974). The two rainy seasons are separated by dry seasons up to three months in duration. However, the dry seasons are interrupted by occasional thunderstorms (Langdale-Brown *et al.* 1964).

Langdale-Brown *et al.* (1964) furthermore state a high variability in the quantity of precipitation throughout Uganda, with < 381 mm (15 inches) of rainfall in Karamoja, > 2 032 mm (80 inches) of rainfall in the Sese Islands and as much as 2 540 (100 inches) or more on the Ruwenzori Mountains.

The dividing line between the northern and southern rainfall profile can be roughly drawn from the northern end of Lake Albert in the west to Mbale in the east. It corresponds approximately with the northern limit of tropical rain forest as distinguishable from woodland at medium altitudes (Langdale-Brown *et al.* 1964, Hamilton 1974).

The mean annual rainfall for the years 1943 to 1959 was 1 549 mm (61 inches) for Entebbe and 1 245 mm (49 inches) for Jinja (Langdale-Brown *et al.* 1964). The mean annual rainfall at Entebbe ranged from 1 501 mm for the years 1901 to 1930, 1 605 mm (or 107% of the 01/30 mean) for the years 1956 to 1960, and 1 877 mm (or 125% of the 01/30 mean) for the years 1961 to 1964 (Lamb 1966).

Ngamba Island is located between Entebbe and Jinja and for the period between 1920 to 1980 the mean annual rainfall for Ngamba Island (at datum: S 00°06 / E 32°39) was 1 457 mm (Centre for Resource and Environmental Studies 1996, Erasmus, pers. com. [2]). Trends in rainfall patterns can be attributed to regularly occurring changes in large-scale atmospheric circulation which exert their effects over wide areas throughout the earth (Lamb 1966). However such drastic climatic changes as in 1960 are probably rare. Lamb (1966) compares this change in its magnitude and suddenness to the (in most cases opposite) climatic changes which took place around the 1890.

Figure 3.3 shows the monthly rainfall pattern during the study period. One peak appears in June and another one in October. The latter coincides with the peak of the second annual rainy season in the southern part of Uganda (Langdale-Brown *et al.* 1964). The total precipitation amounts to 528 mm during the six month study period.

Figure 3.4 shows the mean monthly rainfall pattern for the years 1920 to 1980 for the location S 00°06 / E 32°39, i.e. Ngamba Island. The bimodal rainfall pattern is clearly visible in Figure 3.4, with a major rainy season in March-April-May, and a minor one in October-November-December. This does not exactly coincide with Langdale-Brown *et al.'s* (1964) classification of the two annual rainy seasons in March-April and October-November.

[2] Erasmus, B. 2002. Conservation Planning Unit, Dept. of Zoology and Entomology, University of Pretoria, R.S.A.

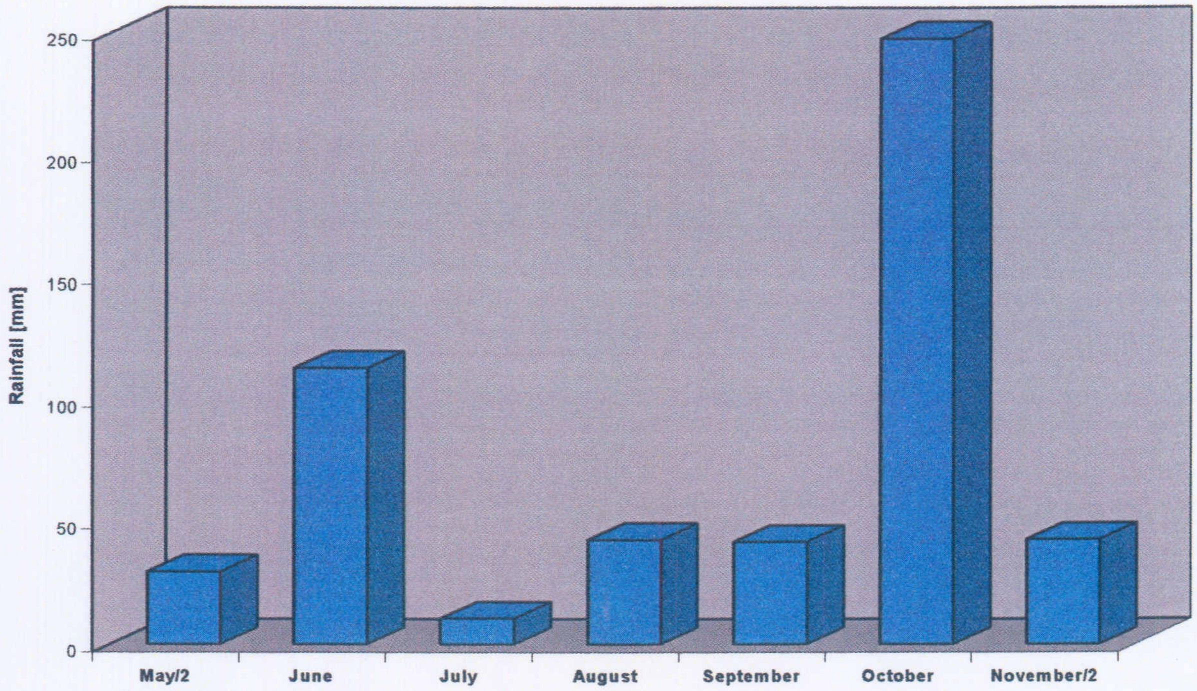

Figure 3.3: Monthly rainfall during study period – mid-May to mid-November 2000 for Ngamba Island.

Key: Rainfall

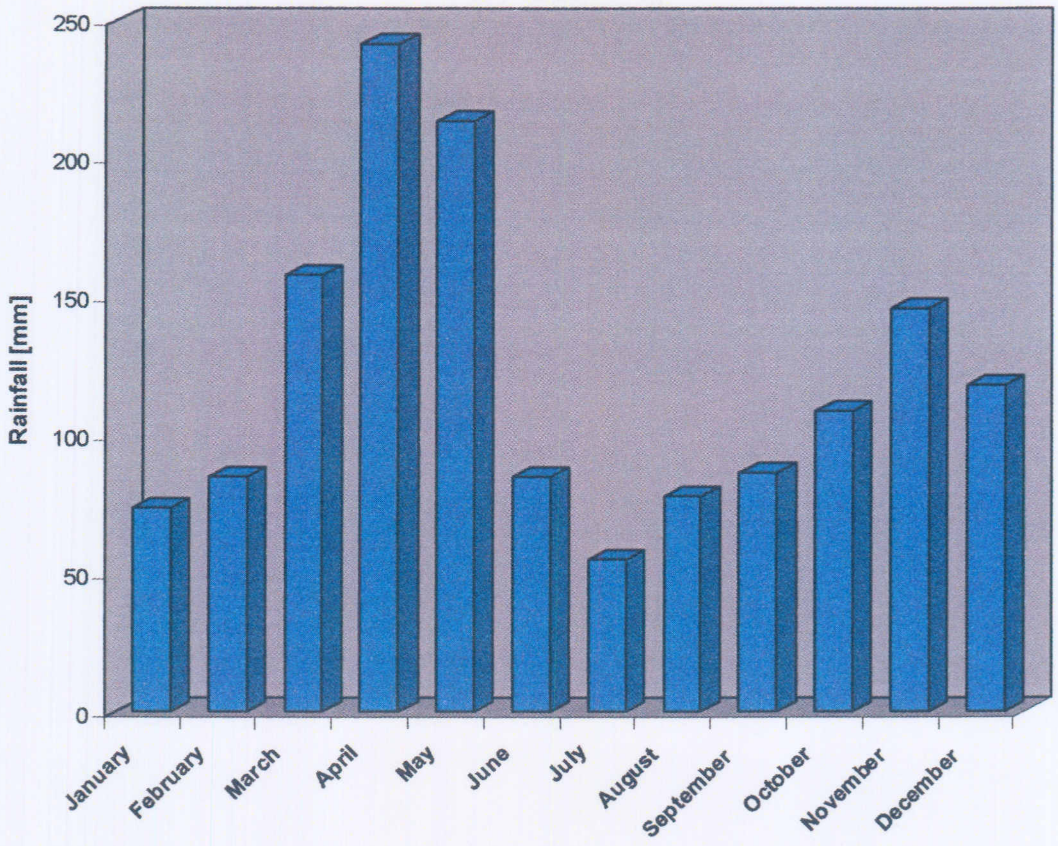

Figure 3.4: Monthly rainfall at S 00°06 / E 32°39 – mean from 1920 to 1980 (Centre for Resource and Environmental Studies 1996).

Key: Rainfall

Temperature

Ngamba Island is located between Entebbe and Jinja and Langdale-Brown *et al.* (1964) list the following values for the year 1961:

Table 3.1: *Temperatures for Entebbe and Jinja meteorological stations for the year 1961*

Temperature [°C (°F)]	Meteorological station	
	Entebbe	Jinja
Mean annual maximum temperature [°C(°F)]	23.1 (73.5)	24.4 (76.0)
Mean annual minimum temperature [°C(°F)]	15.2 (59.3)	14.7 (58.4)
Mean annual temperature [°C(°F)]	19.1 (66.4)	19.6 (67.2)
Highest maximum temperature [°C(°F)]	26.7 (80.1)	30.1 (87.0)
Lowest minimum temperature [°C(°F)]	11.9 (53.5)	10.8 (51.5)

For the years from 1920 to 1980 the temperature values are as follows (Centre for Resource and Environmental Studies 1996, Erasmus pers. comm.[2])

Table 3.2: *Temperatures for Ngamba Island (S 00°06 / E 32°39) for the years 1920 to 1980*

Ngamba Island (Datum: S 000°06 / E 32°39)	
Mean yearly maximum temperature [°C]	26.1
Mean yearly minimum temperature [°C]	16.0
(mean yearly max. + mean yearly min.) / 2 [°C]	21.1
Mean maximum temperature [°C]	27.2
Mean minimum temperature [°C]	15.0

Figure 3.5 shows the mean monthly temperature and standard deviation (STD) on Ngamba Island during the study period from the middle of May until the middle of November 2000. During these months the mean temperature was always around 25°C with a maximum standard deviation of ± 3°C (Figure 3.5), indicating a "high and very even temperature" (Richards 1966) which is characteristic for tropical rain forest habitats.

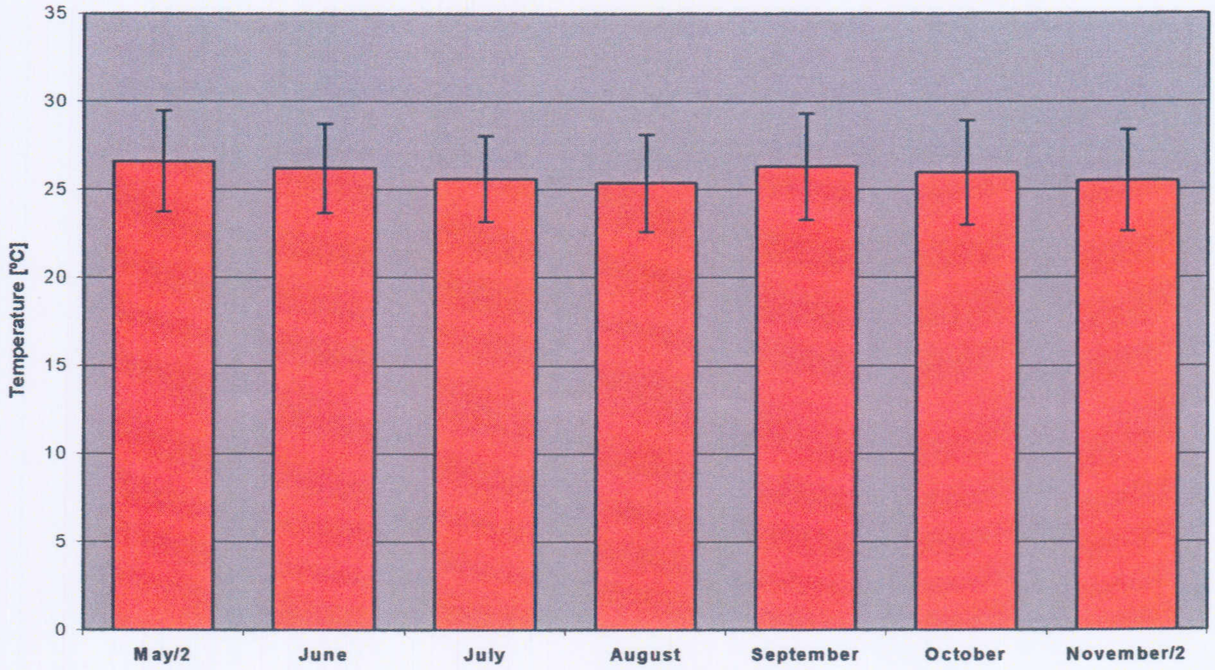

Figure 3.5: Mean monthly temperature during study period – mid-May to mid-November 2000 [Mean °C ± STD] for Ngamba Island.

Key: Temperature

Figure 3.6 shows the mean monthly temperature at 08:00, 14:00 and 18:00 as well as the mean of the minimum and maximum temperatures during the six month study period. Again, the temperatures are relatively even throughout the months and the mean maximum (14:00) and minimum (08:00) temperatures do not differ with more than a maximum of 6.5°C.

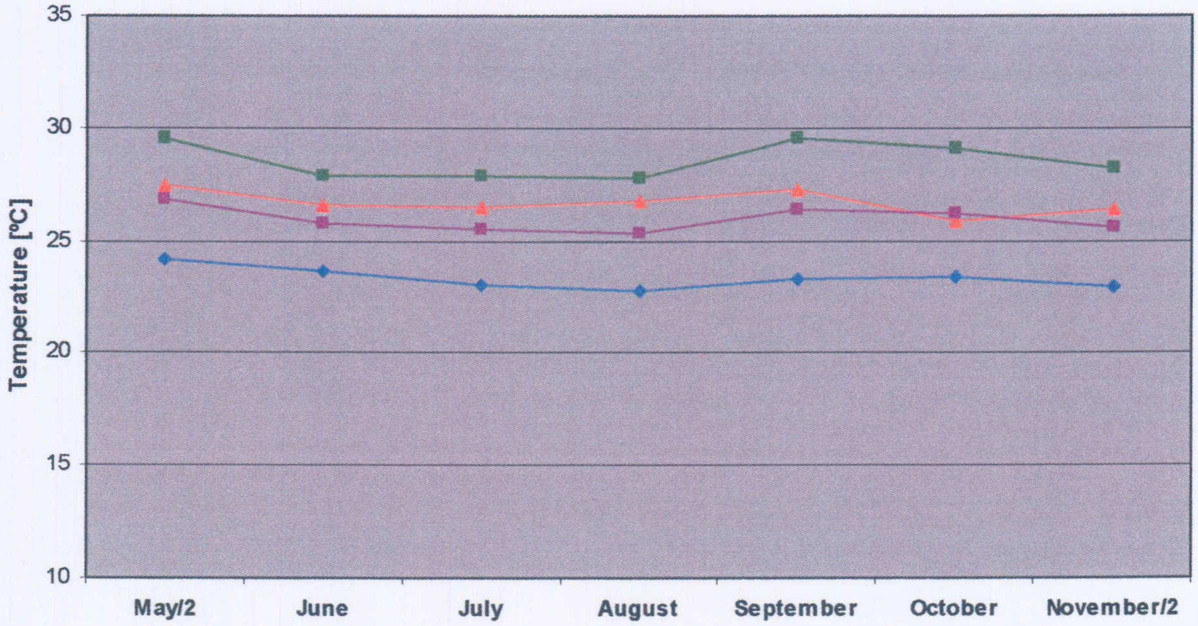

Figure 3.6: Monthly temperatures during study period: 08:00, 14:00, 18:00 & mean for Ngamba Island.

Key:

08:00
14:00
18:00
Mean

Figure 3.7 shows the mean temperature for the years 1920 to 1980 for the location S 00°06 and E 32°39, i.e. Ngamba Island. Like the rainfall data from 1920 to 1980 these data have been extracted for S 00°06 / E 32°39 from a CD containing digitized coordinates for the whole of Africa. The underlying Digital Elevation Model (DEM) has a standard error of between about 20 to 150 m, depending on the roughness of terrain. Overlaid on the DEM are monthly and annual mean values of rainfall and daily minimum and maximum temperatures for the years 1920 to 1980. These climate data have been subjected to comprehensive error detection and corrective procedures based on ANUDEM and ANUSPLIN. The standard error for the temperature values is about 0.5°C. The standard error of the rainfall values is between 5 - 15%.

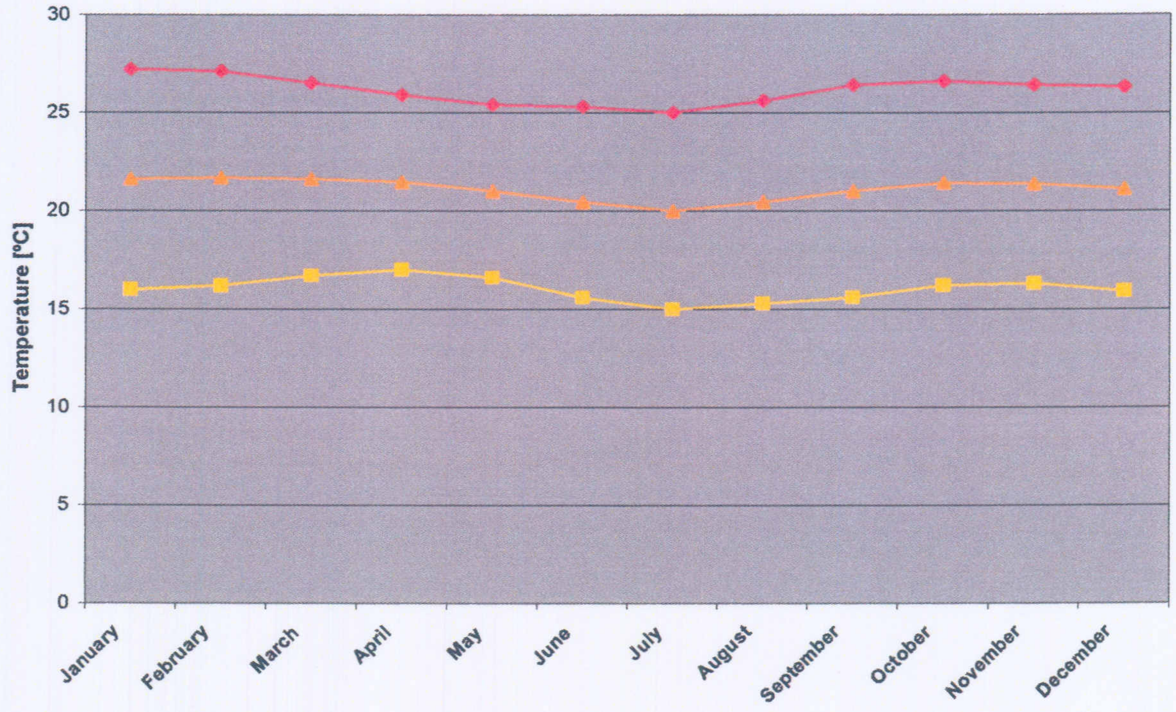

Figure 3.7: Monthly minimum, maximum & mean temperatures at S 00°06 / E 32°39 – mean of 1920 to 1980 (Centre for Resource and Environmental Studies 1996).

Key:

Maximum

Minimum

Mean

Even though, the mean temperature for these 61 years is about 5°C lower than for the mean during the study period, the general pattern, though slightly shifted in time, is still the same for both periods. The 5°C difference might at least partly be caused by the fact that the 08:00 temperature was taken as representative of the minimum temperature and not the real minimum (e.g. from a thermograph) which might be underlying the 1920 to 1980 data.

There is a slight decline in mean temperature from May until August, a slight increase of mean temperature from August to October leading into a second slight temperature decline towards November for the study period. The overall temperature pattern for 1920 to 1980 is slightly shifted in time with the lowest temperature occurring in July, followed by a slight increase in temperature until October/November and leading into a slight temperature decrease towards December. While the mean temperature during the study period never falls below 25°C, the lowest mean temperature for the years of 1920 to 1980 is 20°C in the month of July.

Relative humidity

For relative humidity Langdale-Brown *et al.* (1964) give the following values for 1961 (source: East African Meteorological Department):

Entebbe:	Mean of monthly means (06:00 am):	85%	lowest mean: 72%
	Mean of monthly means (12:00 noon):	67%	lowest mean: 55%
Jinja:	Mean of monthly means (06:00 am):	85%	lowest mean: 68%
	Mean of monthly means (12:00 noon):	61%	lowest mean: 41%.

Figure 3.8 shows the mean monthly relative humidity and standard deviation (STD) on Ngamba Island during the study period from the middle of May until the middle of November 2000. During these months the mean monthly relative humidity was always between 57 and 64 % with a relatively small maximum standard deviation of about ± 6 %.

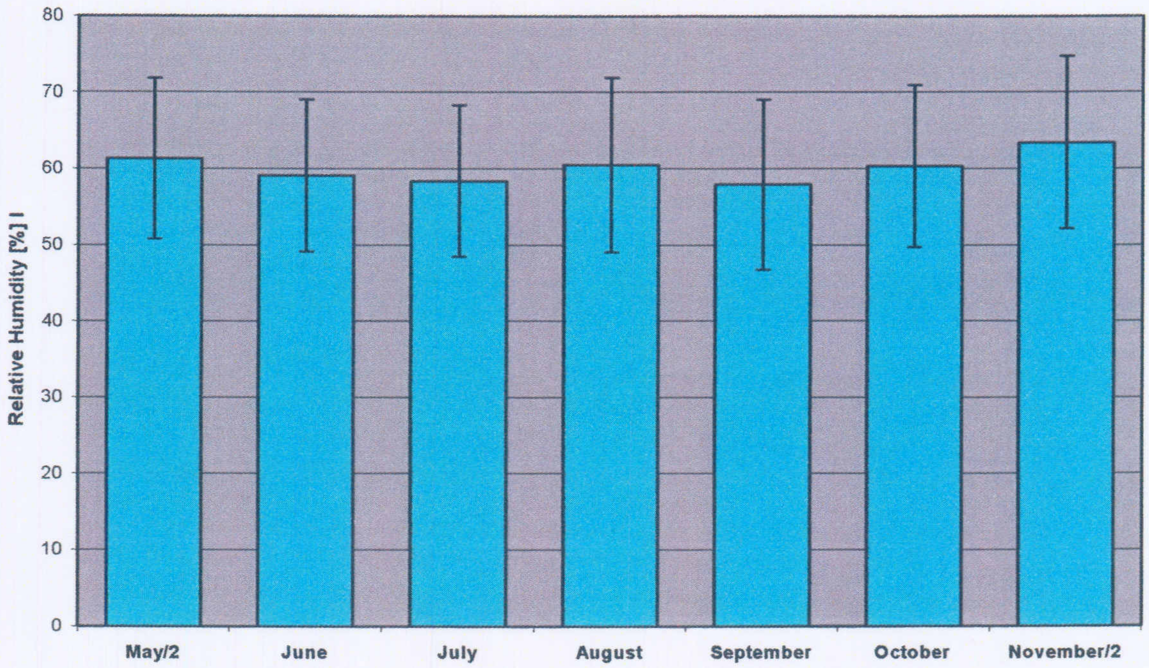

Figure 3.8: Mean monthly relative humidity during study period - mid-May to mid-November 2000 [Mean % ± STD] for Ngamba Island.

Key: Relative humidity

Figure 3.9 shows the mean monthly relative humidity at 08:00, 14:00 and 18:00 as well as the mean of the minimum and maximum values during the six month study period. The range of values between the maximum (08:00) and minimum (14:00) mean values of relative humidity increases during the second half of the study period. The relative humidity at 08:00 and 14:00 behave rather similar and their values decrease and increase parallel to each other during the whole study period (Figure 3.9). While the relative humidity at 18:00 is very similar to that of 14:00 during the first half of the study period, its values behave inversely to the former from the middle of the study period (August 2000) onwards (Figure 3.9).

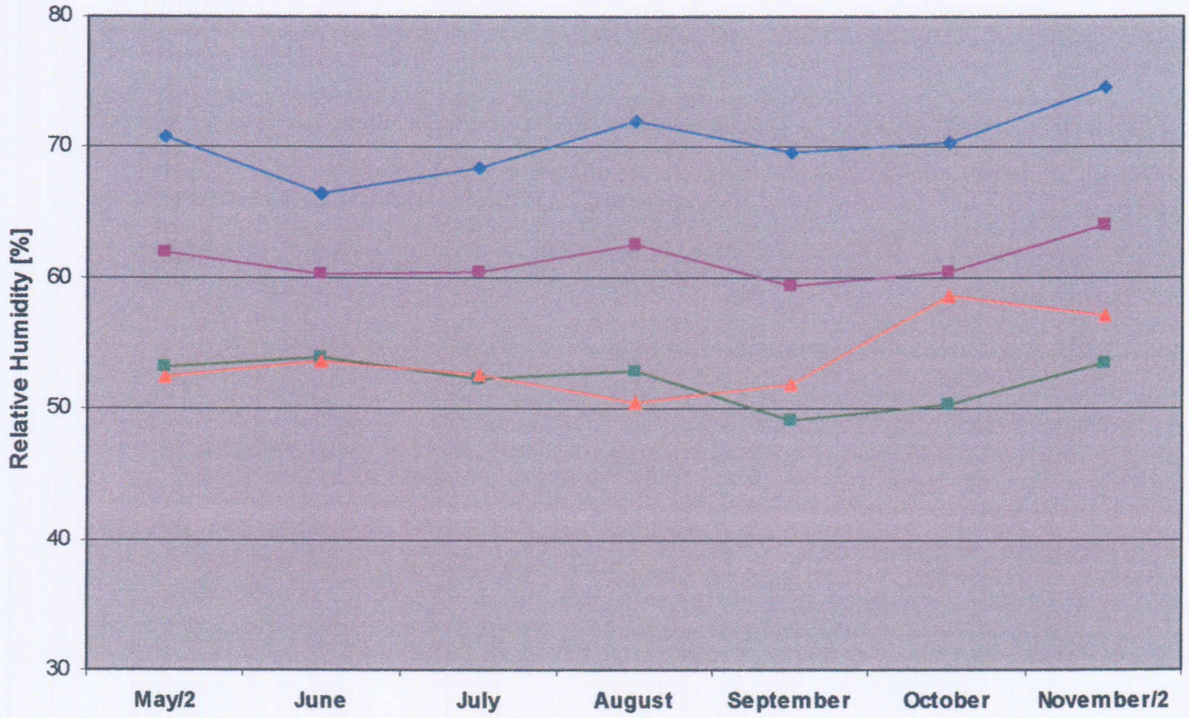

Figure 3.9: Monthly relative humidity (%) during study period 08:00, 14:00, 18:00 & mean for Ngamba Island.

Key:

- 08:00
- 14:00
- 18:00
- Mean

The values for relative humidity at Entebbe from 1990 to 2000 are given in Figures 3.10 & 3.11 (Deutscher Wetterdienst 2001) and can be summarized as follows:

Entebbe Meteorological Station (N 01°00 / E 32°50):

Mean of monthly means (06:00 am):	87%	lowest mean: 84%
Mean of monthly means (12:00 noon):	72%	lowest mean: 65%

Figure 3.10 shows the mean monthly relative humidity at Entebbe meteorological station from 1990 to 2000. The mean relative humidity during the months of the study period (from mid-May until mid-November) ranges from 78 to 83 % and is hence on average about 20% higher during the years 1990 to 2000 compared with the values of the study period in the year 2000 on Ngamba Island (Figures 3.8 & 3.10). This might be due to a more arid climate on Ngamba Island compared to Entebbe meteorological station and / or to the fact, that minima and maxima where determined at slightly different times of day for the two locations. With a maximum of ± 16 % the standard deviation for the Entebbe data also shows a larger range than that for Ngamba Island (Figure 3.8 & 3.10).

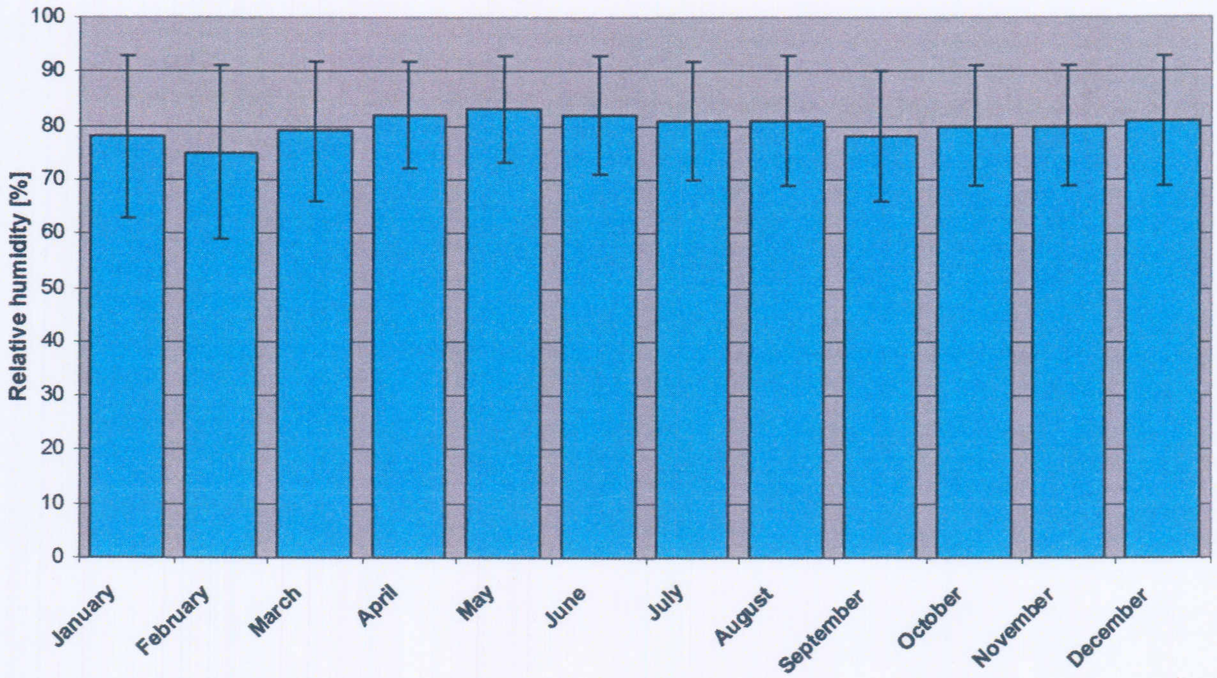

Figure 3.10: Mean monthly relative humidity [Mean % ± STD] at Entebbe Meteorological Station (N 01°00 / E 32°50) from 1990 - 2000 (n = 3 895) (Deutscher Wetterdienst 2001).

Key: Relative humidity

Figure 3.11 shows the monthly minimum, maximum and mean relative humidity for Entebbe meteorological station for the years 1990 to 2000. Here again the values for maximum (06:00) and minimum (12:00) are on average about 20 % higher than those values measured at maximum (8:00) and minimum (14:00) during the study period on Ngamba Island (Figure 3.9 & 3.11). As stated above this is most likely due to the different time of day at which the measurements were taken at the two different locations.

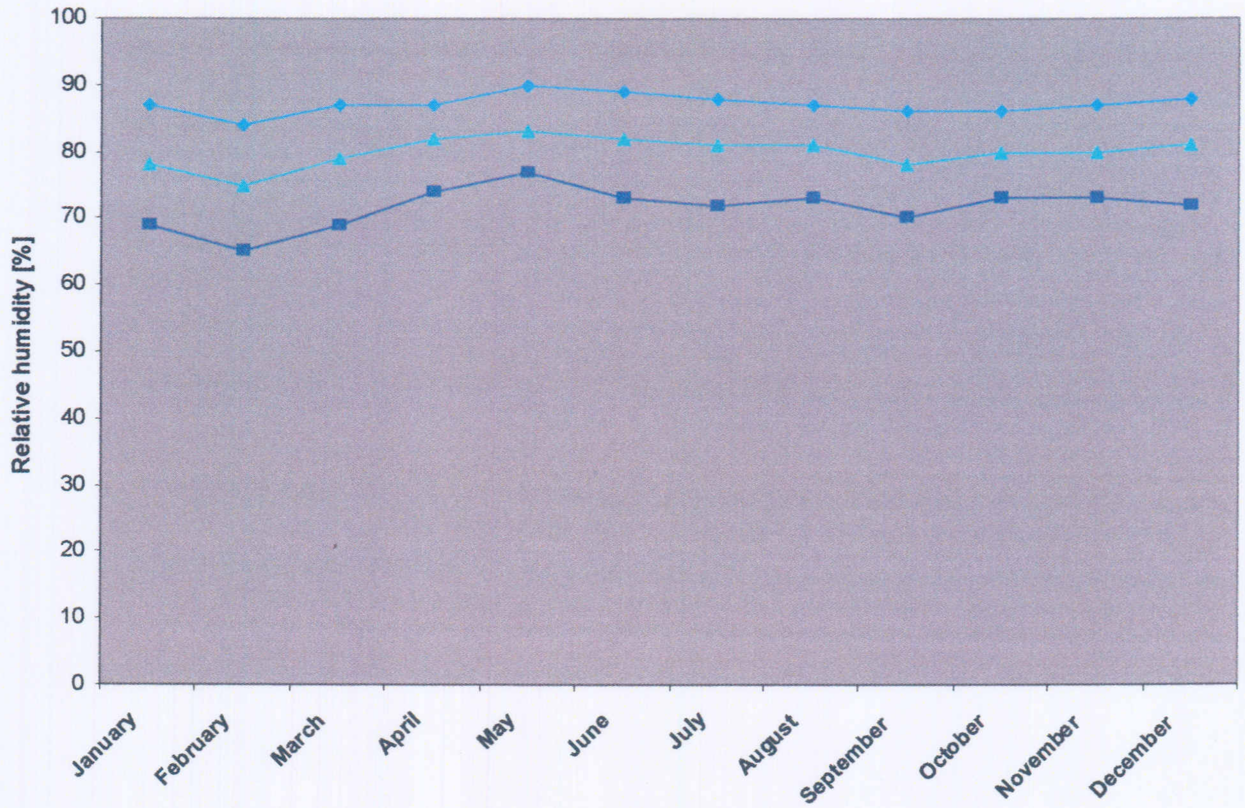

Figure 3.11: Monthly minimum, maximum & mean relative humidity [%] at Entebbe Meteorological Station (N 01°00 / E 32°50) from 1990 to 2000 (n = 3 895) (Deutscher Wetterdienst 2001).

Key:
- 06:00
- 12:00
- Mean

Wind

The winds of Eastern Africa mainly come from an easterly direction supported by monsoons coming in from the northern hemisphere (Kendall 1969). However Newell (1960 in Kendall 1969) found conclusive evidence for a predominantly south to south easterly direction of the winds over Lake Victoria. This finding of a net southerly component is supported by the likewise directed, wind-generated currents of the lake through most of the year, and by the drift of thunderstorm tracks, the orientation of wave cut cliffs and long shore bars (Kendall 1969). Further evidence is given by precipitation patterns at different weather stations along the shores of Lake Victoria: upwind stations, such as Mwanza in the south (1 000 mm per year), receive considerably less precipitation than downwind stations, such as Entebbe in the north (1 500 mm per year) (Kendall 1969, Hamilton 1974).

Langdale-Brown *et al.* (1964) attribute the main seasonal rainfalls in Uganda to southeast monsoons coming from the Indian Ocean. For the dry season the authors state prevailing northeast winds occasionally interrupted by moist westerly winds which are responsible for additional "instability" rainfalls (Langdale-Brown *et al.* 1964). A summary of wind direction frequency from Entebbe Meteorological Station for the years from 1990 to 2000 shows a predominance of southerly winds, although northerly winds are nearly as frequent (Figure 3.12) (Deutscher Wetterdienst 2001).

In essence, all three observations agree on the fact that the major component of the winds over Lake Victoria is a strong southerly current.

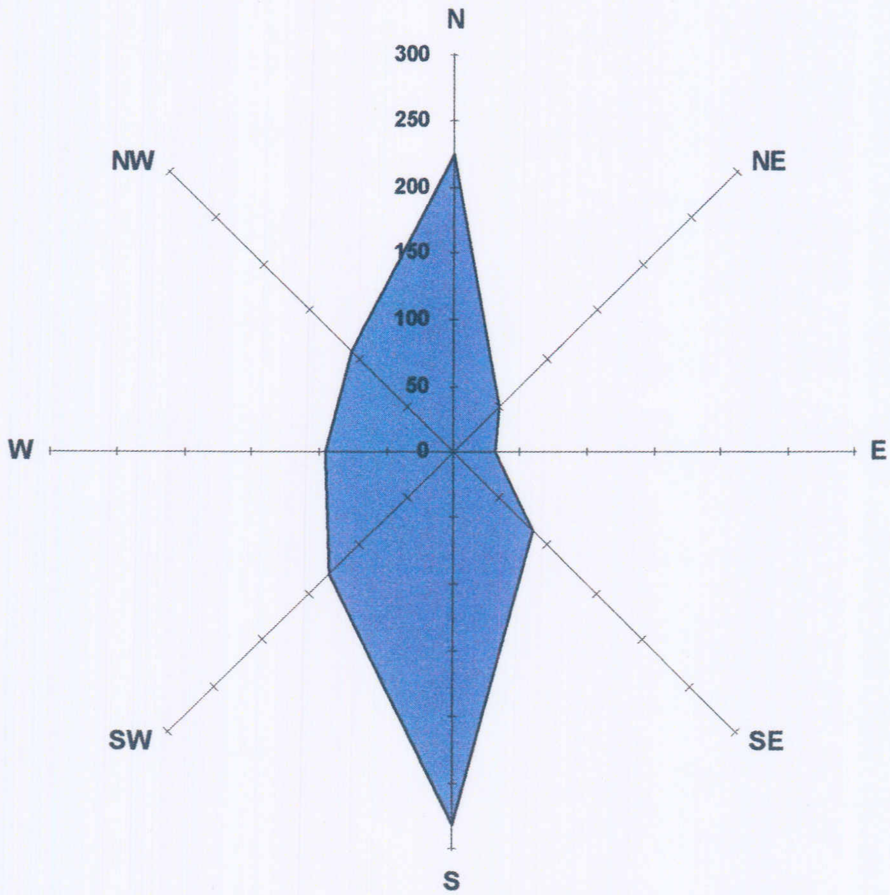

Figure 3.12: Wind rose showing the mean wind direction frequencies per 1000 recordings (n = 9 974) at Entebbe Meteorological Station for the years 1990 – 2000 (Deutscher Wetterdienst 2001).

Key: Wind direction frequency

Wind velocity

Fons (1940) determined that the wind velocity is greatly decreased at the top of the crowns of the trees in a forest, and that it remains nearly constant in the canopy zone. This effect is mainly caused by the branches and foliage of the trees which (1) reduce wind velocity, and (2) render the distribution of wind velocity nearly uniform (Fons 1940). Several zones with different climatic conditions exist from the ground surface to the space above the crowns.

Figure 3.13 – 3.16 show the wind directions and wind velocities for Entebbe Meteorological Station for the years 1900 – 2000 (Deutscher Wetterdienst 2001). The majority of winds are feeble and comes from a southern and northern direction (Figure 3.13). Moderate to strong winds mainly come from a southern direction but are far less common (Figure 3.14). Strong to high winds occur rarely and are as frequent from the north as from the south (Figure 3.15); while heavy storms occur about twice a year and come mainly from the north (Figure 3.16).

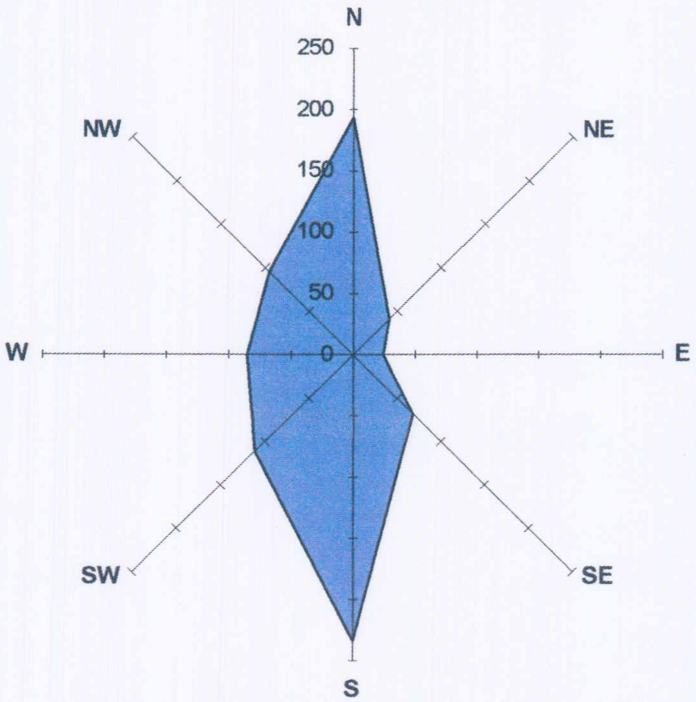

Figure 3.13: Wind rose showing the mean wind direction frequencies (n = 8 599) per year for feeble winds (0 – 10 knots = 0 – 19 km/h) at Entebbe Meteorological Station for the years 1990 – 2000 (Deutscher Wetterdienst 2001).

Key: Wind direction frequency

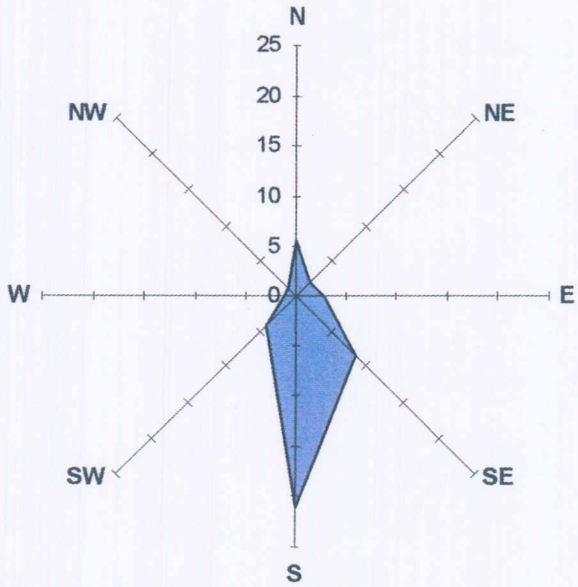

Figure 3.14: Wind rose showing the mean wind direction frequencies (n = 503) per year for moderate to strong winds (11 – 40 knots = 20 – 74 km/h) at Entebbe Meteorological Station for the years 1990 – 2000 (Deutscher Wetterdienst 2001).

Key: Wind direction frequency

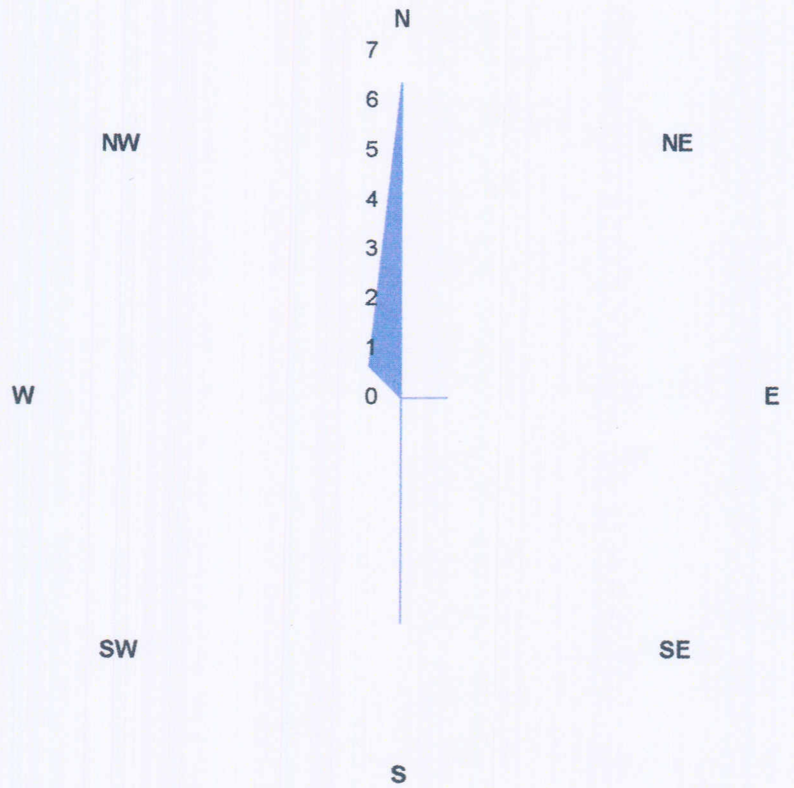

Figure 3.15: Wind rose showing the mean wind direction frequencies (n = 14) per ten-year period for strong to high winds (41 – 63 knots = 75 – 117 km/h) at Entebbe Meteorological Station for the years 1990 – 2000 (Deutscher Wetterdienst 2001).

Key: Wind direction frequency

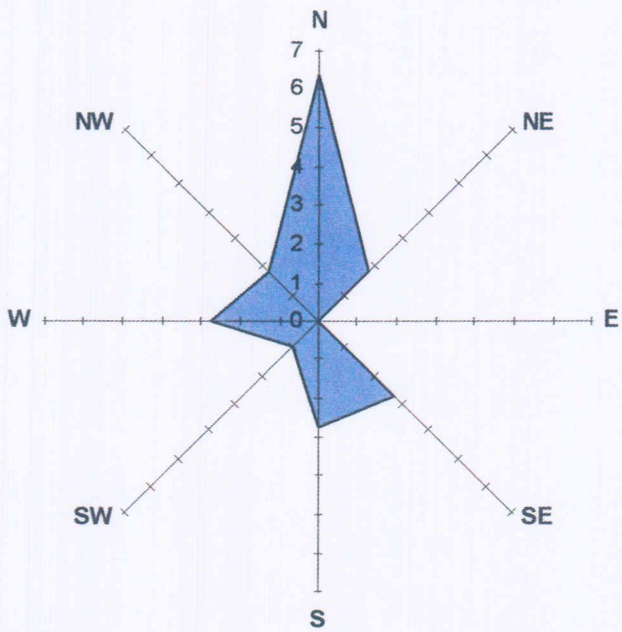

Figure 3.16: Wind rose showing the mean wind direction frequencies (n = 21) per ten-year period for heavy storms (> 64 knots = > 118 km/h) at Entebbe Meteorological Station for the years 1990 – 2000 (Deutscher Wetterdienst 2001).

Key: Wind direction frequency

Geology & soil

The soils of tropical rain forests share certain characteristics (Eggeling 1947, Richards 1966):

colour:	bright red or yellow
texture:	generally loamy or clayey, but often sandy in the superficial layers
humus:	low in humus content and mostly confined to the upper horizons
clay:	relatively rich in aluminium and poor in silica
nutrients:	generally deficient in plant nutrients
pH:	usually deficient in bases and thus almost invariably acid.

Most forest soils of the damp tropics are lateritic, even if true laterite, i.e. the end product of laterization, "a mixture of aluminium and iron oxides with very little else", normally is never reached under rain forest conditions (Richards 1966). A lateritic soil according to Richards (1966) is a soil of which the silica/aluminium ratio is less than 2.0 in the clay fraction. *Laterite* in the sense of Richards (1966) should be comparable to the *ferralitic soils* or *ferralsoils* mentioned by Langdale-Brown *et al.* (1964). The red colour which is common in tropical soils, thus the term "tropical red earths", that are formed under conditions of unimpeded drainage is due to the abundance of iron oxides. The exact shade of the colour depends on the degree of hydration of the iron oxides (Richards 1966). Richards (1966) assumes that lateritic soils may be the most widespread soil type of the rain forest region, even if not all tropical soils are lateritic. This tropical red earth as a result of lateritic weathering is best seen on fragmental volcanic rocks (Richards 1966), such as those that are found on the islands in Lake Victoria.

The soils of the Lake Victoria basin are described by Kendall (1969) as being an abundance of silicate rocks and well-leached laterite soils (also: Thomas 1941). While Langdale-Brown *et al.* (1964) classify the soils of the Sese Islands as ferralitic soils (= ferralsols) on undifferentiated rock with a dominant red colour.

The soils of Ngamba Island show the typical acidity, (compare Results, Chapter 6) prevalent in a tropical rain forest habitat where soils are usually deficient in bases and thus almost invariably acid (Richards 1966) as well as generally deficient in plant nutrients (Richards 1966). They belong to the soil type named *ferrallitic soils* or ferralsols by Langdale–Brown *et al.* (1964) or *lateritic soils* by Richards (1966) with a dominant red colour and found on volcanic or undifferentiated rock in the tropics.

VEGETATION

Vegetation of tropical rain forests

"Evergreen, hygrophilous in character, at least 30 m high, but usually much taller, rich in thick-stemmed lianas and in woody as well as herbaceous epiphytes" (Schimper 1903 in Richards 1966).

Primary tropical rain forest

This evergreen forest or primary tropical rain forest is, in ecological terms, according to Richards (1966), the climax vegetation of the equatorial climate. The author lists the following growth forms of primary tropical forest (Richards 1966):

A. Autotrophic plants (with chlorophyll)

1. Mechanically independent plants

    (a) Trees and 'shrubs' } arranged in a number of strata

    (b) Herbs }

2. Mechanically dependent plants

    (a) Climbers

    (b) Stranglers

    (c) Epiphytes (including semi-parasitic epiphytes)

B. Heterotrophic plants (without chlorophyll)

1. Saprophytes

2. Parasites

Secondary tropical rain forest

Richards (1966) defines a *typical secondary rain forest* as "the earlier seral stages found on areas which have been cultivated or exploited for timber, but not subsequently grazed or burnt."

Richards (1966) lists the following general characteristics of secondary rain forest:

1. It is lower and consists of trees of smaller average dimensions than those of primary forest.
2. Occasionally, trees of much larger dimensions than the average are found scattered through secondary forest, being 'leftovers' from the destruction of the original primary rain forest.
3. Young secondary forest is often remarkably regular and uniform in shape, but shows an abundance of small climbers and young saplings that gives it a dense and tangled appearance different to primary forest.
4. At a later stage in the succession an extremely irregular structure is characteristic.
5. Over time pioneer tree species become senescent and are often unable to regenerate under the new ecological conditions they have created. Thus, many trees in a large area may simultaneously become liable to wind throw or death from some other cause, leaving large gaps in the forest cover.
6. Slower-growing trees dominate the next phase of succession.
7. Lianas are typically abundant in secondary rain forest.
8. The different successional stages of secondary rain forest usually show a characteristic species composition, almost all secondary forest trees are light-demanding and intolerant of shade, but grow well in any opening or clearing of sufficient size.
9. Many secondary rain forest trees are unable to regenerate in their own shade and thus a community dominated by them necessarily lasts for only a single generation.
10. Secondary rain forest trees possess efficient means of seed dispersal as well as rapid growth.

Secondary succession in tropical Africa goes through three distinctive stages the first of which is marked by the invasion of herbaceous plants with rapid growth and a short life span. The second stage is followed by the invasion of perennial and 'suffrutescent' herbs in which herbaceous and woody climbing plants are abundant. Additionally, saplings are regenerating from seeds and resprouting from stumps that have survived in the soil. The third stage is also called the 'tree stage of the succession' and can again be divided into three different phases (Richards 1966, Ewel 1980).

During the first phase of the tree stage bushes and young trees become dominant and soon a tree canopy is formed. This phase is dominated by *Musanga cecropioides*, *Trema guineensis*, *Harungana madagascariensis* and *Pycnathus angolensis*. It reaches its optimum at 10 to 20 years of age and has a total duration of between 20 to 30 years (Richards 1966). The second phase is dominated by genera like *Bosqueia*, *Conopharyngia*, *Alstonia*, *Funtumia*, *Albizia*, *Pentaclethra*, *Sterculia*, *Ricinodendron*, *Fagara*, and *Ficus*. It reaches its optimum at 20 to 30 years after the beginning of the 'tree stage' and has a duration of about 50 years (Richards 1966). The third stage marks the gradual return to dominance of species characteristic of primary rain forest. This stage first becomes dominant 60 to 100 years after the beginning of the tree stage (Richards 1966).

Vegetation of Uganda

"Modern vegetational patterns have been greatly affected by human activity" (Kendall 1969).

Langdale-Brown *et al.* (1964) give a list of "Open Water, Crops and the Main Vegetation Types" for Uganda. They attribute the following percentage areas to the different land-use types:

Cropland	11.7%
High Altitude Grassland, Heath and Moorland	0.8%
Forest and Moist Thicket	4.6%
Well Drained Savanna (including Grass Savanna)	48.3%
Dry Thicket, Bushland and Steppe	7.5%
Communities on Sites with Impeded Drainage	7.9%
Permanent Swamp	3.9%
Open water	15.3%

The natural vegetation has been modified to a large extent by cutting, cultivation, burning, grazing and similar interferences by man according to Langdale-Brown *et al.* (1964). It is now often no longer possible to see the broad distribution of natural vegetation and what prevails is a mosaic of forest and derived savanna communities in the wetter areas to the northwest of Lake Victoria and in the Western Highlands (Langdale-Brown *et al.* 1964).

Figure 3.21 shows the Ecological Zones of Uganda as established by Langdale-Brown *et al.* (1964). Figure 3.22 indicates the Land Use of Uganda as delimited by Langdale-Brown *et al.* (1964) for the late 1950s and early 1960s. The establishment of the Ecological Zones was based on this latter map and additional climatic findings (Langdale-Brown *et al.* 1964).

Figure 3.23 has been drawn according to a map by Katende *et al.* (1995) and shows the main vegetation zones as identified in 1995.

Already in 1964 Langdale-Brown *et al.* (1964) reported a substantial impact of man on the vegetation of Uganda. They established that the mountainous vegetation had suffered least, still showing large areas of natural or semi-natural montane forest, high montane grassland and afro-alpine communities (Langdale-Brown *et al.* 1964). For the rest of the country the authors stated considerable changes in the vegetation due to annual or biennial grass fires, coupled with an overloading of traditional farming systems. This resulted in the prevalence of fire climax and seral communities constituting about 80% of the vegetation (Langdale-Brown *et al.* 1964).

Langdale-Brown *et al.* (1964) give four different areas of natural forest which are restricted by the prevailing rainfall patterns and altitude:

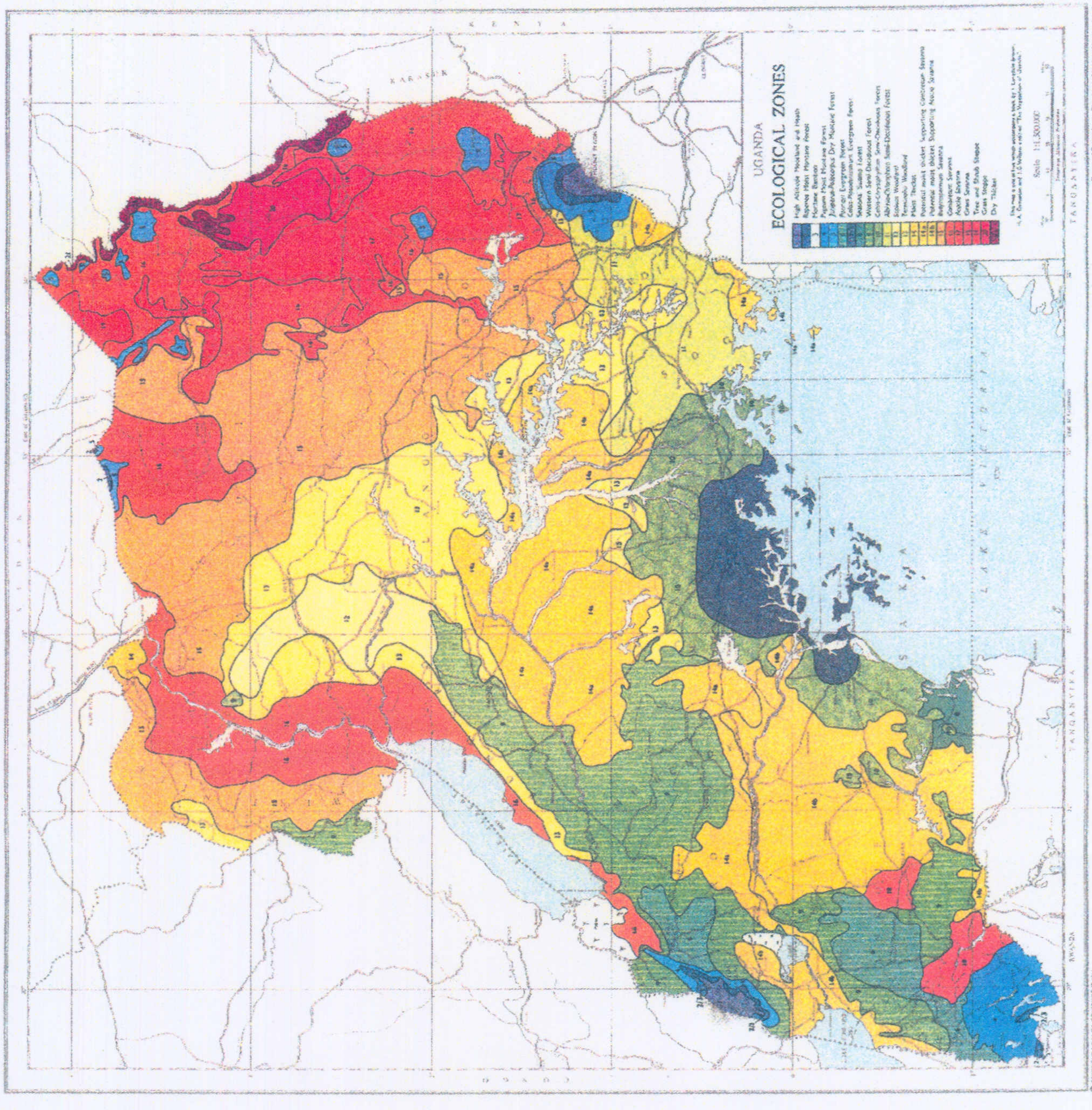

Figure 3.17: Ecological zones of Uganda (following Langdale-Brown *et al.* 1964).

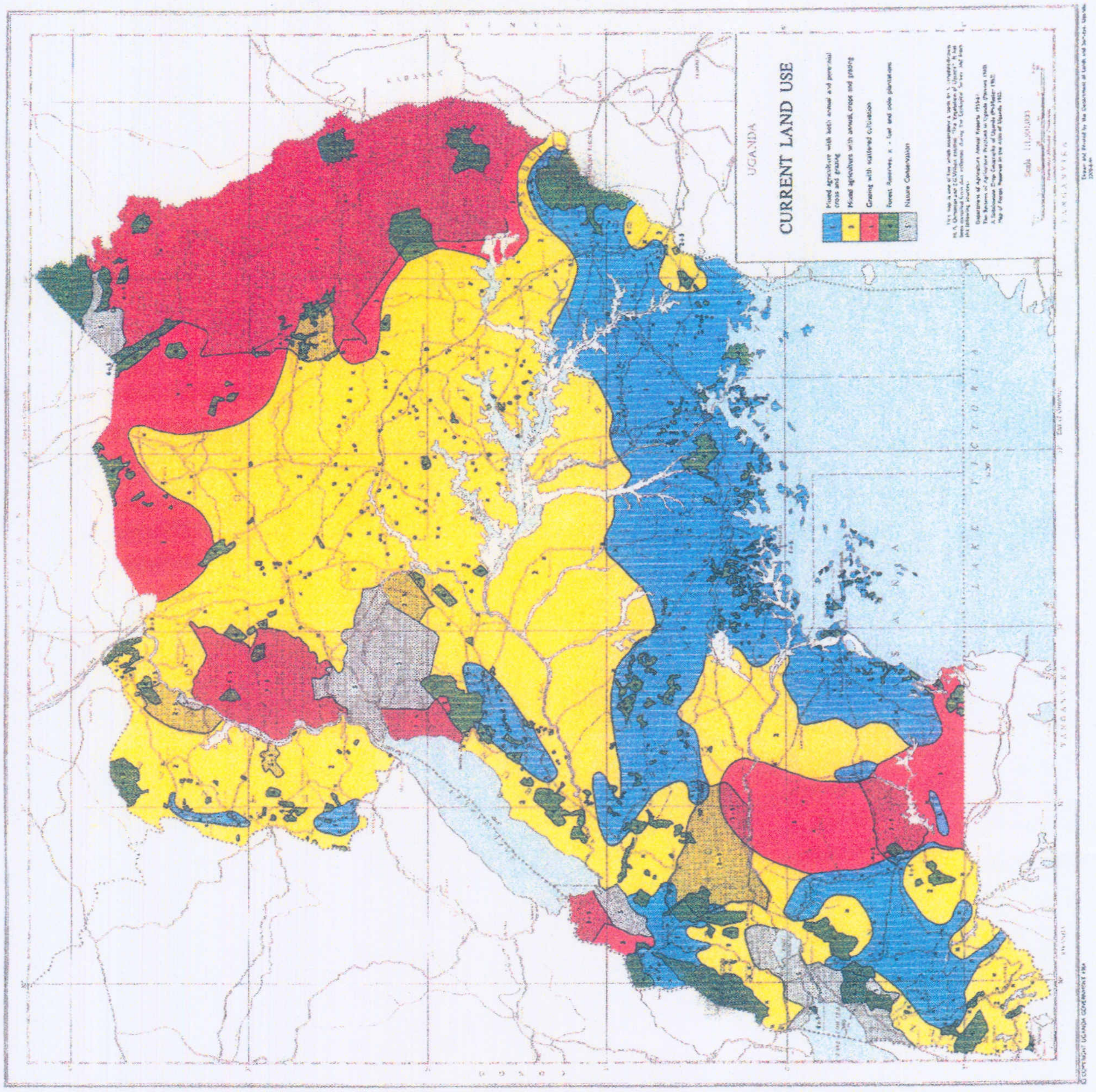

Figure 3.18: Land use of Uganda (following Langdale-Brown *et al.* 1964).

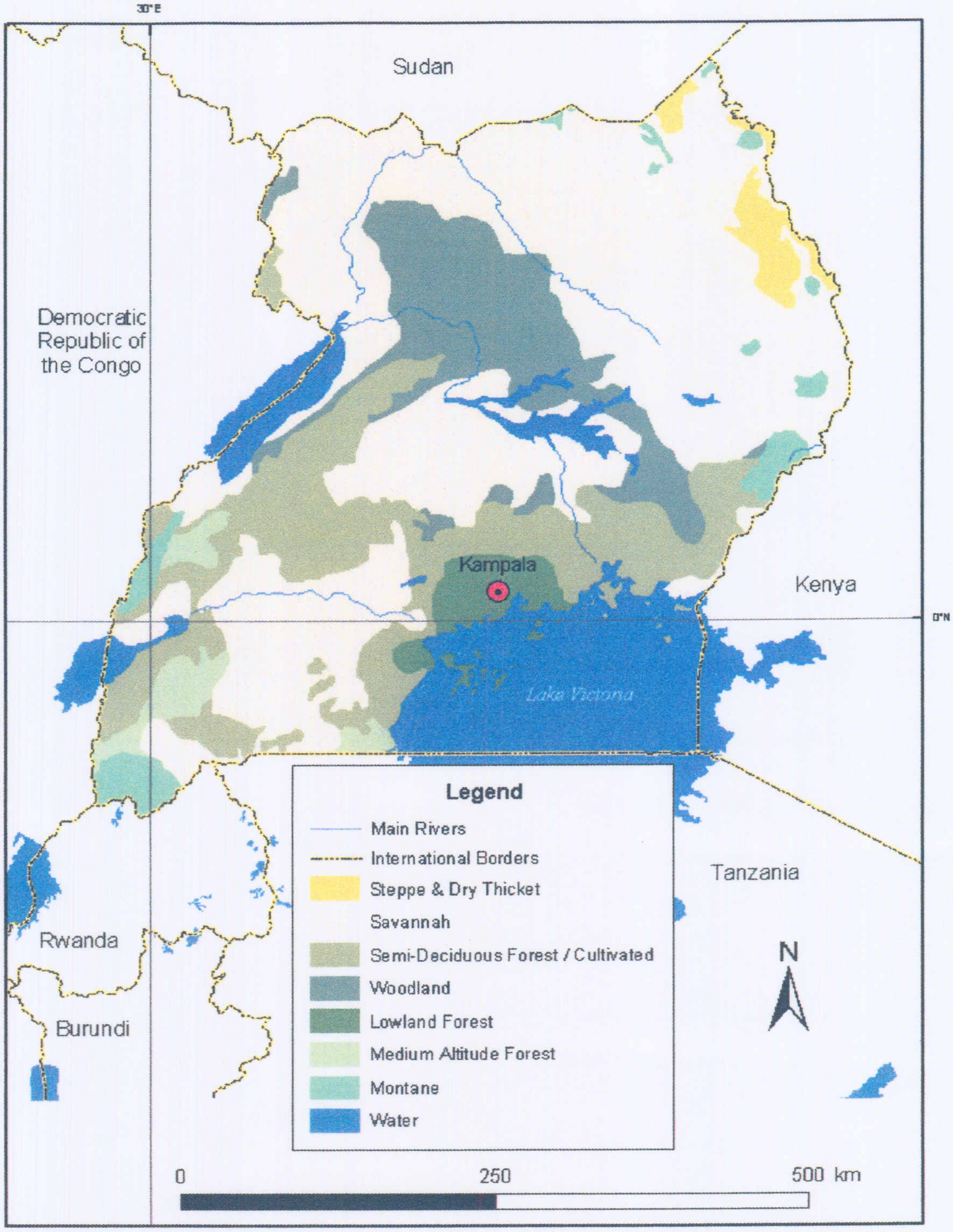

Figure 3.19: The main vegetation zones of Uganda (following Katende *et al.* 1995).

1. The high rainfall belt north-west of Lake Victoria
2. The high rainfall belt along the eastern side of the Western Rift Valley
3. A medium rainfall belt between the first two, where there are some young forests
4. The mountains over 1 524 m (5 000 feet) where orographic rainfall occurs.

Hamilton (1974) distinguishes only three different forest zones in Uganda, namely:

1. A region in the west including the shoulder of the Rift Valley and also extending in places into the Rift itself
2. The region around the northern shore of Lake Victoria
3. A number of isolated montane forests in the north and east.

Hamilton (1974) also classifies the Ugandan forests as floristically heterogeneous. Both articles determine temperature, moisture availability and human disturbances as the three most important factors that determine this varied floristic composition (Langdale-Brown *et al.* 1964, Hamilton 1974).

Until 3 000 years B.P. the vegetation in Uganda was mainly rainfall-dependent: when the climate changed from dry to wet around 12 000 B.P. lowland forest vegetation started to appear around the northern shore of Lake Victoria and replaced the prevailing grass-rich communities, around 10 000 B.P. a drier climate prevailed again and led to a reduction in forest cover, at about 9 500 B.P. the climate was humid again and the forest cover started spreading again and attained an evergreen character, while between 7 000 and 6 000 B.P. the forest became more semi-deciduous again, suggesting a shift to a drier or more seasonal climate.

After 3 000 B.P. the interpretation of climatic conditions based on pollen stratigraphy becomes less reliable since man started exercising his influence on the vegetation, mainly through deforestation (Langdale-Brown *et al.* 1964, Kendall 1969, Hamilton 1974, 1981). Present day vegetation of Uganda is still undergoing changes along rainfall gradients (Kendall 1969).

The Ugandan lowland forests are part of the Guineo-Congolian region (Hamilton 1974). The lowland forests show an increasing species poverty in plant and mammal species from west to east over the whole of Africa and also over Uganda itself. Hamilton (1974, 1976 & 1981) concludes that the lowland forest has spread fairly recently from refuge areas, namely the impenetrable Kayonza Forest, to the west of Ruwenzori and probably Sango Bay at the eastern shore of Lake Victoria, eastwards through Uganda. While forest mammals have spread into East Africa from three forest refuge areas in Upper Guinea, Cameroon-Gabon and Ruwenzori-Kivu (Kingdon 1971 in Hamilton 1974). In contrast, the avifauna is rather homogenous throughout the West and Central African lowland forests (Hamilton 1976).

Even though the spread of lowland forest was initiated through a climatic change about 12 000 years ago the direction of the spread can still be evaluated today. After a major climatic event there is usually a very long lag period until a forest ecosystem adjusts to a new equilibrium (Hamilton 1981).

For montane forest Hamilton (1976) states an opposite movement and a probable spread of species from east to west within West, Central and East Africa. He attributes these differences in spread of the two forest types mainly to differences in dispersal mechanisms and suitable climatic and edaphic conditions for the establishment of dispersed seeds (Hamilton 1976). For the recent past a more pronounced north-south movement of species of all vegetation types can be observed (Hamiltion 1976).

Langdale-Brown *et al.* (1964) make some general remarks about the forest structure in Uganda. The authors describe the Ugandan forests as rich in species and communities. The composition of these forests is mainly dependent on climatic conditions and drainage. Given a minimum depth of the soil, edaphic factors, such as nutrient content, seem to have little influence on the composition of forest stands (Langdale-Brown *et al.* 1964).

For many of the tropical tree communities it is not possible to determine the climax community, but stand tables suggest that the regeneration of trees is insufficient to maintain the present populations of mature trees (Langdale-Brown *et al.* 1964). The intermediate successional stages show the higher species richness and the least tendency for the dominance of only a few or one species, with the ground flora also differing widely between forest areas (Langdale-Brown *et al.* 1964).

The authors also observe that in the more mixed forests there is normally a smoothly decreasing number of trees in each size class from the smallest to the largest (Langdale-Brown *et al.* 1964). These forests also show an entirely arbitrary concentration of vegetation at certain levels (= strata), even if terms such as "emergents", "under storey" and "shrub layer" may still be used. This contrasts to forests with one dominant species where marked strata, occupied by mature individuals of one or a few species, can easily be distinguished (Langdale-Brown *et al.* 1964).

The authors observe a certain re-expansion of some of the Ugandan forests where there are no dense human, cattle or elephant populations. They ascribe this fact mainly to a depopulation of certain areas due to rinderpest, sleeping sickness or tribal strife (Langdale-Brown *et al.* 1964). This is especially true for the islands in the northwestern region of Lake Victoria. Following sleeping sickness epidemics between 1902 to 1906 many of the islands were depopulated and soon attained a forest cover again (Thomas 1941, Langdale-Brown *et al.* 1964). Many of these forests are distinct from the mainland forest vegetation often showing an abundance of *Uapaca guineensis*, a small to medium sized evergreen tree, which is for example ubiquitous on the Sese Islands while being hardly prevalent in the mainland forest vegetation (Langdale-Brown *et al.* 1964).

Since 1964 the population of Uganda has been expanding again and it seems more than likely that this newly formed cover of secondary rain forest has been deforested again in most of the areas on the mainland as well as on many of the Lake Victoria islands.

Vegetation on Ngamba Island

Figures 3.20 to 3.26 show photographs of the northern, eastern and southern shoreline of Ngamba Island taken from a boat, illustrating the landing area including housing facilities for chimpanzees and people, the area of herbaceous vegetation and the dense secondary rain forest cover of the remaining island.

Figure 3.20: View of the landing area, staff housing, chimpanzee enclosure and visitors platform in the northern corner of Ngamba Island.

Figure 3.21: View of the north eastern shoreline of Ngamba Island.

Figure 3.22: View of the eastern shoreline of Ngamba Island.

Figure 3.23: View of the easternmost point of Ngamba Island.

Figure 3.24: View of the south eastern corner of Ngamba Island.

Figure 3.25: View of the southern shoreline of Ngamba Island; note the much coarser water surface compared to the north eastern side.

Figure 3.26: View of the south western corner of Ngamba Island; note Nsadzi Island in the background left (arrow).

Figures 3.27 to 3.30 are taken from the visitors' platform and show the area of herbaceous vegetation where the chimpanzees assemble for the morning (11:00) and afternoon (15:00) feeding and where they can be observed by tourists. The assemblage of these pictures also shows an east to west panorama view of the transition of herbaceous vegetation in the north into secondary rain forest vegetation in the centre and south of the island.

Figure 3.27: View of the eastern corner of the grassland area on Ngamba Island from the visitors' platform; note Kimi Island in the middle and background left.

Figure 3.28: View of the transition between grassland and forested area on Ngamba Island showing part of the morning and afternoon outdoor feeding area and a chimpanzee path leading into the forest; note remnant group of forest trees and 'delayed' onset of forest.

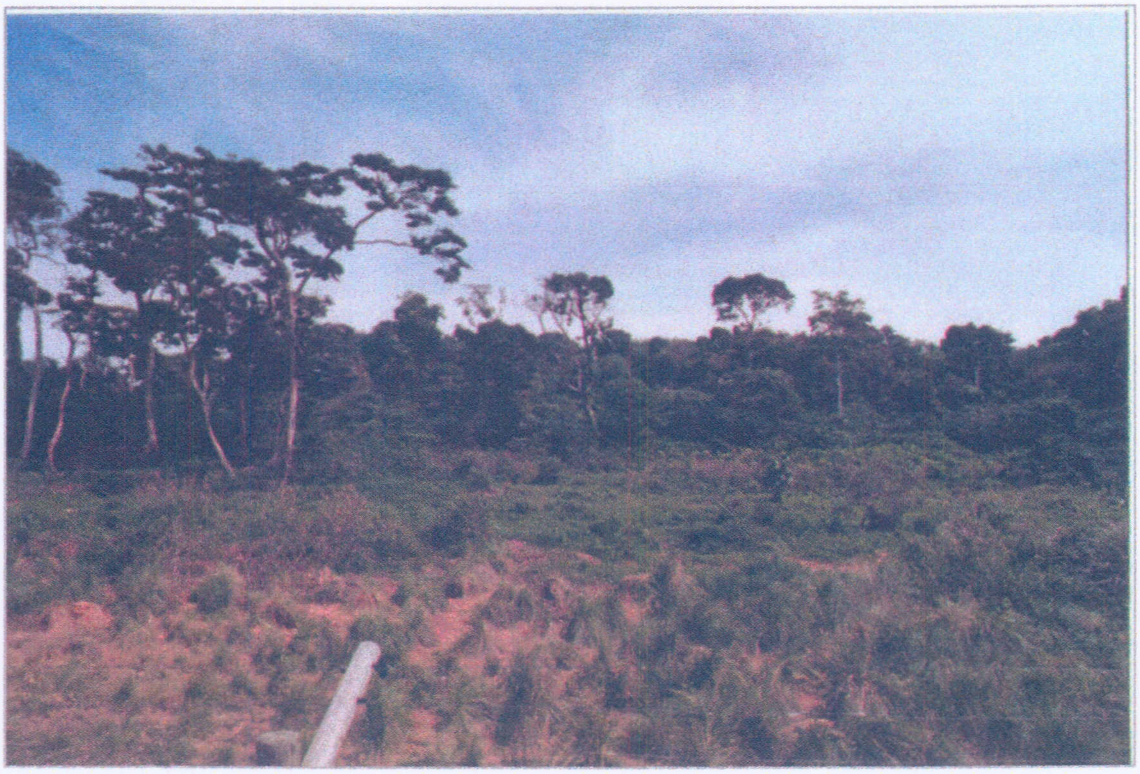

Figure 3.29: View of the central to western part of the grassland area on Ngamba Island and transition into the forested area; note single primary rainforest trees scattered throughout the secondary rain forest in the background.

Figure 3.30: View of the western corner of the grassland area on Ngamba Island.

Figures 3.31 to 3.35 show an aerial view of the secondary rain forest cover of Ngamba Island from the south westerly corner over the centre area to the easternmost outlayer of the island taken from a northerly direction. The "extremely irregular structure, typical of later successional stages of secondary rain forest vegetation" (Richards 1952), a number of upright dead trees especially in the western part of the island, "occasionally, trees of much larger dimensions than the average … usually … scattered through secondary forest, being 'leftovers' from the destruction of the original primary rain forest" (Richards 1952), and the open area in the eastern part of the island (Figure 3.34) can be distinguished.

Figure 3.31: Aerial view of the southwesterly corner of Ngamba Island taken from a northerly direction.

Figure 3.32: Aerial view of the southwest to central area of Ngamba Island taken from a northerly direction.

Figure 3.33: Aerial view of the central area of Ngamba Island taken from a northerly direction; note the calm lake surface on the northern side and the rough lake surface on the southern side of the island, indicating mainly southerly winds.

Figure 3.34: Aerial view of the eastern area of Ngamba Island showing the open area inside the forest towards the centre-left of the picture (arrow).

Figure 3.35: Aerial view of the easternmost point of Ngamba Island; note the open area in the forest in the centre-right of the picture.

Figures 3.36 to 3.40 show some impressions of the canopy cover of Ngamba Island's secondary rain forest cover taken from directly above. Smaller and larger gaps and a number of upright, dead and/or defoliated trees can be distinguished. Again, the irregularity of the vegetation and the variety of tree species contributing to the canopy cover are evident.

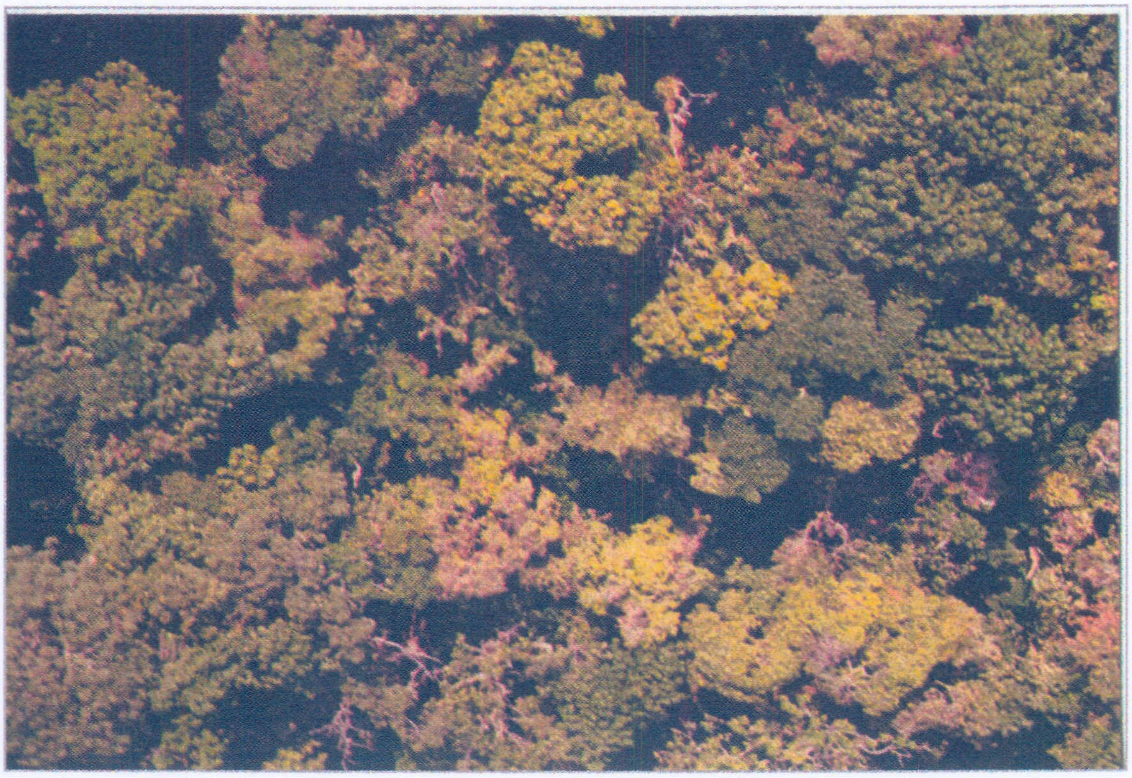

Figure 3.36: Aerial view of the closed but irregular canopy cover of the forested area on Ngamba Island.

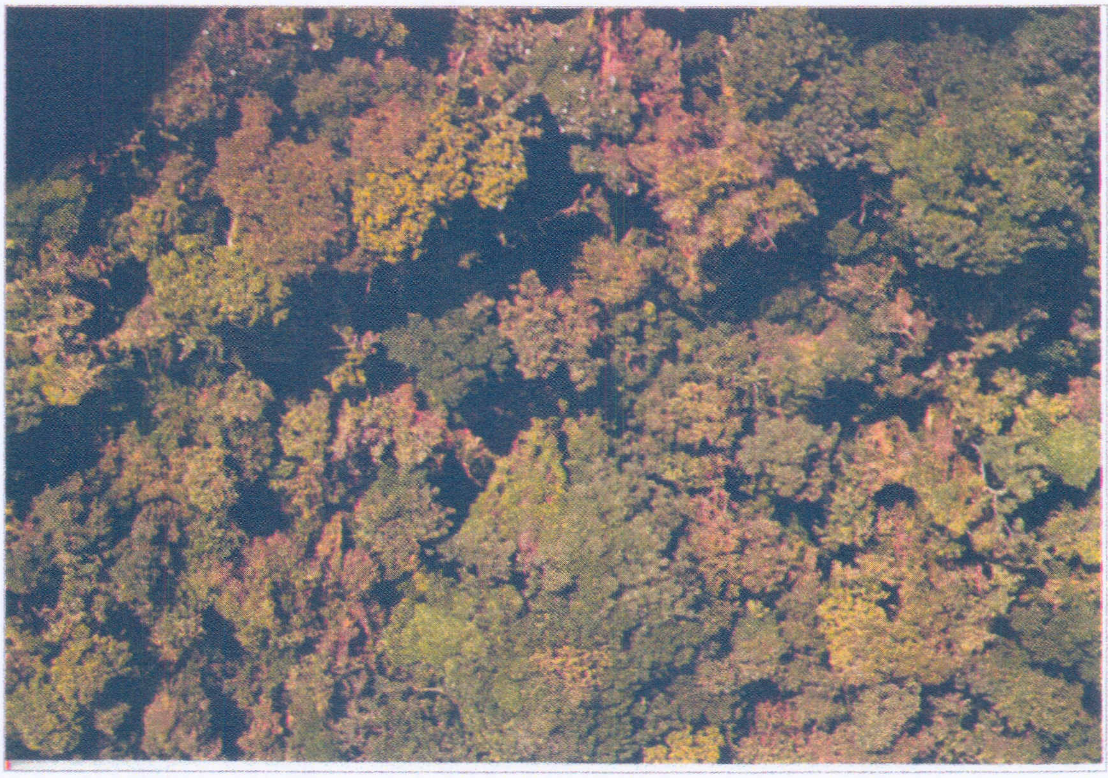

Figure 3.37: Aerial view of a more open area in the canopy cover of the forested area on Ngamba Island.

Figure 3.38: Aerial view of a more open area in the canopy cover of the forested area on Ngamba Island; note the defoliated tree in the foreground in the centre-right (arrow).

Figure 3.39: Aerial view of a partially refilled gap in the canopy cover of the forested area on Ngamba Island.

Figure 3.40: Aerial view of a further partially refilled gap in the canopy cover of the forested area on Ngamba Island; note the defoliated tree in the top centre-left of the picture.

FAUNA

The fauna of Ngamba Island consists mainly of over 200 different bird species (Annex – Table 5), a number of reptiles, e.g. the nile monitor lizard (*Varanus niloticus*), and as only natural occurring large mammal species, two hippopotami (*Hippopotamus amphibious*) (Annex – Table 5). Mainly small rodents and bats compose the small mammal fauna of the island (Annex – Table 5).

Nsadzi Island is also home for a number of bird and small rodent species. Furthermore, some livestock species are also present on this island, e.g. cattle and goats.