Vegetation of the Tembe Elephant Park, Maputaland, South Africa

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A hierarchical classification, vegetation map, description and ecological interpretation of the plant communities of the Tembe Elephant Park and surrounding areas are presented. The study area falls within the Maputaland Centre of Endemism, which is part of the Maputaland-Pondoland Region, a centre of plant diversity rich in endemic plants and animals. Sixty-four sample plots were distributed in a stratified manner throughout the study area. A TWINSPLAN classification, refined by Braun-Blanquet procedures, revealed eight distinct, mainly woodland plant communities. Much of the vegetation distribution can be ascribed to vegetation dynamics and the geomorphological evolution of the region. Dynamics of water in the landscape either directly or indirectly, through its role in moisture levels and soil formation, plays a role in the determination of plant communities at the higher levels. The proposed classification and general descriptions can be used for nature reserve management, land-use planning and further research. Ordinations based on floristic data give an indication of floristic and associated habitat and environmental relationships. Soil character and moisture differences are usually slight, hence the sand-based communities do not have distinct boundaries, except for Sand Forest. Indications are that in the case of Sand Forest the distinct boundary zone of nearly bare soil may well be the result of allelopathy. Eighty-four Maputaland Centre plant endemics/near-endemics were recorded for the study area, with Sand Forest being the most prolific habitat for such taxa, many which appear to be neoendemics. Because of its hypothesised origin (especially lack of specific historic events) and vegetation dynamics, the inclusion of Sand Forest in conservation areas is no guarantee of the future persistence of this rare vegetation type.

Introduction

Maputaland, a region of great scenic beauty and rich biodiversity, shows considerable ecotourism potential. Several conservation areas have been proclaimed in the region, including the Greater St Lucia Wetland Park (a World Heritage site), Tembe Elephant Park, Maputo Elephant Reserve, Ndumo Game Reserve, Mkuzi Game Reserve and Kosi Bay Coastal Forest Reserve. Recently, Mozambique granted a concession comprising approximately 230 000ha for ecotourism development in southern Mozambique. Currently initiatives for establishing a trans-frontier conservation area (‘peace park’) between northern KwaZulu-Natal and southern Mozambique are underway, effectively linking Tembe Elephant Park with some of the Mozambican parks and conservation areas.

An area comprising southern Mozambique and the northern part of KwaZulu-Natal is recognised as a Centre of Plant Endemism, namely the Maputaland Centre [MC] (Van Wyk 1994, 1996). High levels of endemism are spread across virtually the whole taxonomic spectrum, involving both plants and animals. The Maputaland region is also of exceptional biogeographical interest because of the sharp biogeographical transformation of both plants and animals in the region (Poynton 1961, Bruton and Cooper 1980). Maputaland is at the southern end of the tropics in Africa and many organisms reach the southernmost limit of their range here.

Tembe Elephant Park [TEP] was proclaimed in 1983. It lies within the core area of the MC and contains many rare plant and animal species. Noteworthy is the presence in the park of a rare forest type, locally referred to as Sand Forest and in Mozambique as Lichuari Forest. Sand Forest is very distinctive, with a unique combination of plant and animal species. As far as is known, this vegetation type is more or less restricted to ancient coastal dunes in northern KwaZulu-Natal and the extreme southern portion of Mozambique (Maputaland). Good examples of Sand Forest can be seen in the Greater St Lucia Wetland Park, Ndumo and Mkuzi Game Reserves, and particularly the TEP. Sand Forest harbours many rare and unusual plant and animal species, including several MC endemics. Because of its restricted occurrence and unusual species complement, Sand Forest
is one of the most important plant communities in the MC.

The vegetation of Maputaland is very diverse, with at least fifteen broad vegetation types described for the KwaZulu-Natal portion of the region (Moll 1977, 1980); one of these is Sand Forest. However, with the exception of the pioneering work of Myre (1964, 1971) on the vegetation of southern Mozambique, very little detailed work has been done on the phytosociology of the region's sand-associated vegetation types. Myre's vegetation classification concentrated on the grasslands, with only superficial descriptions being given for woodland and associated communities. Detailed vegetation descriptions have, however, been published for Ndumo Game Reserve (De Moor et al. 1977) and Mkuzi Game Reserve (Goodman 1990), but these areas are not chiefly on sand. Klingelhoef (1987) did some work on the vegetation of TEP, but this was a broad scale study related to elephant in the area. Data on floristic diversity and detailed habitat relations are still lacking for TEP and neighbouring areas.

Management of conservation areas in Maputaland requires more knowledge of the phytodiversity and biological intricacies of the region. In this paper we aim to provide ecological and floristic data for the Sand Forest and associated woodland habitat of a part of Maputaland by identifying, characterising, interpreting and mapping the major vegetation units and their variations that occur in the TEP and surrounding areas. An assessment of the floristic richness and level of endemism in the study area is also supplied.

Study area

Tembe Elephant Park is situated in northern KwaZulu-Natal (Figure 1). The park is 30 013ha in extent and its northern limit is the international boundary between South Africa and Mozambique. The central part of Maputaland is mainly an extensive level plain of sandy soils, covered by open and closed woodland with patches of short and tall Sand Bushveld, Sand Forest, the Muzi Swamp, Palmveld and Grassland. Wild and Barbosa (1967) mapped the vegetation of this region as Dry Semi-deciduous (lowland-subtropical) Forest as well as Woodland and Savanna Woodland (southeastern sublitoral) with extra-tropical species. Granger (1996) referred to a large portion of these areas as Subhumid Lowveld Bushveld.

The area now known as TEP was, until recently, still relatively undeveloped, with very little human influence. No major fences occurred south, east or west, with only the international border fence to the north. The international border fence was not an obstacle for game and movement, even for elephants. Very few people lived in this area because of the scarcity and seasonality of surface water; most lived along the Muzi Swamp. Soils in the region are generally too nutrient-poor for cultivation, except along the Muzi Swamp. In the past, the density of people along the Muzi Swamp was nevertheless low, as sections of the swamp can be dry for some months of the year. The more permanent waters of the northern sections of the Muzi Swamp are saline (salinity gradients of 0.5–5%) and therefore not suitable for irrigation (Klingelhoef 1987).

Topography

TEP lies in the southernmost portion of the broad Mozambican Coastal Plain. This flattish, undulating area of sand ridges is bordered by the Lebombo Mountains to the west and by the Indian Ocean to the east. Locally, in TEP linear north-south trending dunes interspersed with depressions are found. If soil clay content is high, there may form perennial pans. The highest dunes (Nhlela and Beacon Ridges) in the study area, reach a height of 129m a.s.l. and the lowest lying areas (e.g. Muzi Swamp) are at approximately 50m a.s.l. These two dune ridges are the highest areas on the Mozambican Coastal Plain.

Climate

Rainfall and temperature data for weather stations relevant to the study area are given in Table 1. Shangwana, the station representing the study area, is amongst others, compared to stations at Ndumo and Makatini (both drier areas) as well as the one at Kosi Bay (wetter coastal area). Maputaland lies within a transitional zone between the tropics to the north and sub-tropical coastal conditions to the south, with hot summers and cool to warm winters. The climate of the region can be described as warm to hot, humid and sub-tropical (Schultze 1982). Average humidity is relatively high, even in the drier inland parts of the region. Winters are drier than summers, although rain is received throughout the year. During the dry season, morning mist is not uncommon, but during the day from April to July, percentage relative humidity is comparatively low (Table 2).

Geology

TEP is underlain by Mesozoic and Cainozoic (<64Ma) geological units that can be traced southwards and northwards along the Mozambican Coastal Plain. The basal lithological unit are marine siltstone of the St Lucia Formation; these Late Cretaceous deposits are not exposed in the study area. Unconformably overlying these rocks are the basal units of the Maputaland Group (Cainozoic), namely the Uloa and Umkelwane Formations (Neogene), which underlie the dune sand deposits currently defining the surface relief in this area (Botha 1997, Maud and Botha 2000). The shallow marine, littoral and coastal dune deposits of the Mapuland Group represent a succession of regressive events following marine transgressions. High dune cordons, which can be traced for long distances along the inland margin of the coastal zone, mark stillstands during the Mio-Pliocene marine regression that deposited the Uloa/Umkelwane Formation sediments. The oldest ridges are probably Early Pleistocene (3 million – 30 000 years old) (Davis 1976, Hobday 1976, Maud and Botha 2000) whereas the youngest are probably Late Pleistocene (30 000 – 10 000 years old). These are some of the youngest formations in southern Africa.

The calcareous conglomerate and sandstone comprising the Uloa Formation is an important aquifer overlying the impervious Cretaceous siltstones; it lies at depths of more
Figure 1: Map showing the location of the Tembe Elephant Park and its broad vegetation types. Numbers in brackets refer to the specific plant communities (see text) combined under that mapping unit.
weathering profiles are red and dominant in the western areas. Soils horizon development. Typically, the soils comprise a thin, have formed adjacent to the Muzi Swamp and thick peat deposits have accumulated in the permanent swamps.

areas dominated by a high water table. These files formed in younger redistributed sands during the Pleistocene and Holocene, occur in degraded dune fields or areas dominated by a high water table. Calcrite deposits have formed adjacent to the Muzi Swamp and thick peat deposits have accumulated in the permanent swamps.

Table 1: Mean annual and absolute maximum and minimum temperature for six weather stations of the region (based on local weather stations and Weather Bureau records)

| Station      | Period (yrs) | Mean | Annual temperature (°C) |
|--------------|--------------|------|-------------------------|
|              |              |      | Average max (absolute, year) | Average min (absolute, year) | Average relative humidity (%) (min, max) |
| Kosi Bay     | 42           | 944  | 34.9                     | 5.7                          | 51                               |
| Sihangwana   | 32           | 707  | (44.2, 1976)             | (0.1, 1975)                  | 32 (50)                          |
| Ndumo        | 71           | 614  | 35.4                     | 7.3                          | 60                               |
| Makatini     | 18           | 633  | (45, 1975)               | (4, 1975)                    | 43 (100)                         |
| Pongola      | 13           | 638  | 22                       | 12                           | 68                               |
| Richards Bay | 13           | 1,127| (43.4, 1964)             | (2.5, 1954)                  | 44 (97)                          |

Table 2: Mean annual and absolute maximum and minimum temperature for six weather stations of the region (based on local weather stations and Weather Bureau records)

| Station      | Period (yrs) | Mean | Average annual rainfall (mm) |
|--------------|--------------|------|------------------------------|
|              |              |      | Absolute max. (year) | Absolute min. (year) |
| Kosi Bay     | 42           | 944  | 1,552 (1985)               | 505 (1959)              |
| Sihangwana   | 32           | 707  | 2,105 (1975)               | 245 (1960)              |
| Ndumo        | 71           | 614  | 1,160 (1938)               | 276 (1931)              |
| Makatini     | 18           | 633  | 1,144 (1984)               | 433 (1986)              |
| Pongola      | 13           | 630  | 871 (1955)                 | 488 (1953)              |
| Richards Bay | 13           | 1,127| 1,807 (1971)               | 558 (1982)              |

than 30m beneath the surface dunr sands. The topography in the study area is defined by high, linear, north-south oriented dune cordons with poorly preserved parabolic dunes superimposed on the surface. Sand comprising these dunes represents the Plio-Pleistocene weathering products of the underlying Uloa/Umkwelane Formation rocks with localised aeolian as well as sheetwash and reworking of sand off high-lying areas.

The colour and textural characteristics of surface geological units in the study area are dominated by post-depositional, pedogenic weathering of the sands. Distribution of the sands, which represents a broad soil chronosequence, is characteristic of the entire coastal plain. The oldest Plio-Pleistocene weathering profiles are red and dominant in the western areas or in localised places where old sands rise above the surrounding deposits. Lesser-developed, yellowish and grey profiles formed in younger redistributed sands during the Pleistocene and Holocene, occur in degraded dune fields or areas dominated by a high water table. Calcrite deposits have formed adjacent to the Muzi Swamp and thick peat deposits have accumulated in the permanent swamps.

Soils

Surface geological units are dominated by pedogenic features and the soils formed in the fine-grained dune sands are typically red, yellowish or grey, apedal soils with incipient horizon development. Typically, the soils comprise a thin, organic-enriched A-horizon underlain by sandy subsoil with illuvial lines forming sparse ferruginous mottles or clay-enriched mottles and lamellae at depths of 3-4m below the surface. Higher clay content in the red profiles is attributed to more intense weathering of labile minerals over a long period. Broad soil patterns mapped in the study area have differentiated the high dunes comprising red/yellow, high base status soils from the surrounding lower relief areas where regic sands are dominant.

The high Nhlela and Beacon Ridges probably represent the weathered remnants of the oldest dune systems in the study area. Well-drained profiles characterised by very deep, red or yellowish, high base status soils with <5% clay are common on these high topographical features as well as sheetwash and reworking of sand off high-lying areas.

The low gradient areas with long slope lengths comprise degraded, low dunes that are characterised by sandy profiles with yellowish brown or light grey subsoil horizons. These profiles are moderately well-drained, although high water tables within low-lying interdune depressions result in bleached, grey soil profiles. These yellowish/Clayevly or grey Fernwood Form soils (Soils Classification Working Group 1991) show a sharp reduction of organic carbon to levels of less than 0.5% within 30cm of the surface. Most subsoils
classify as regosols (FAO–UNESCO 1974) or entisols (Soil Survey Staff 1996).

Lateral ground water migration towards interdune depressions or the Muzi Swamp base level has resulted in formation of clay-rich, slightly saline or calcareous duplex soils in low-lying sites. Where the dune sands border on the Muzi Swamp, narrow areas of sodic Escourt Form soils (Soil Classification Working Group 1981) with prismatic subsoil structure are common. These natric soils can be classified broadly as planosols (FAO–UNESCO 1974).

Permanent swamps in the Muzi system are characterised by gleyning with peat formation and development of organic-rich histosols (FAO–UNESCO 1974, Soil Survey Staff 1996) or soils of the Champagne Form (Soil Classification Working Group 1991).

**Hydrology**

Water table and ground water movements play an important role in relation to vegetation patterns in most parts of Maputaland, including the TEP, as the area is covered by deep sand. From borehole data, water table depths are on average approximately 35m, but depths of 60m below surface have been recorded. In some places, water table depths can exceed 90m (borehole of 90m without reaching water). An elevated water table is present in a few places such as the seasonal pans that occur on the duplex soils. Ground water is almost exclusively replenished by rainwater. After rains, quick fluctuations in local water levels can be experienced for a period. From work done by Kruger (1986) in the neighbouring areas to Sileza Nature Reserve, which have very similar soils as TEP, it is estimated that vertical seepage rates are in the order of 0.1m/day. Water movements through the sands are at an average transmissivity of 20m²/day and co-efficient of storativity of $1 \times 10^{-3}$. Permeabilities are highly variable, because the Pleistocene sediments underlying the coversands show extreme east-west lateral variability (Hattingh 1998). In general, the swamps and marshes are surface expressions of the groundwater table, with little or no evidence of perched groundwater horizons occurring in the area. The only permanent water in the TEP (most years) is the Muzi Swamp, in the east of the reserve. The flow direction of the Muzi Swamp in this area is north, into Mozambique. The only other sources of surface water in the reserve, are the seasonal pans that occur on the duplex soils. These pans are usually dry during the winter period from April to September.

**Methods**

Sixty-four sample plots (10 x 10m; in accordance with the plot size used by Matthews et al. 1999) were distributed in a stratified random manner throughout the study area. As far as possible, the plots were equally distributed in the different physiographical-physiognomically homogeneous units, distinguished on the basis of physical environment, physiognomy, dominant plant species composition and abundance. Sampling was carried out from January to May 1996. Scientific names of taxa follow Arnold and De Wet (1993). Terminology to describe vegetation structure follow Edwards (1983). The following information was recorded for each sample plot: 1, total floristic composition and cover-abundance value for each plant species, according to the Braun-Blanquet cover-abundance scale as described by Mueller-Dombois and Ellenberg (1974); 2, water table depth at the time of sampling, using a 2m soil auger; 3, soil type/form (FAO–UNESCO 1974, Soil Classification Working Group 1991) and basic colour; 4, amount of organic material ranked as distinct or indistinct and its depth of occurrence; 5, topographical position based on terrain types (Land Type Survey Staff 1986), namely (1) crest, (2) scarp, (3) midslope, (4) footslope and (5) valley bottom or floodplain; 6, geology, according to 1:250 000 geological survey maps and relevant literature (Geological Survey 1986, South African Committee for Stratigraphy 1980, Botha 1997) and locally at a larger scale, based on personal observations in the field; 7, land type according to 1:250 000 land type map (Land Type Survey Staff 1986); 8, a 50 point herbaceous species survey using the step-point method (Mentis 1981).

Largely unpublished soil analysis data were used in the description of the soils. These were based on soil samples taken from what was considered a representative example of the different plant community types as distinguished in this study. Not all sub-communities were sampled due to the cost involved in detailed soil analyses. Chemical analysis (pH, macro and micro nutrients) of the soil was done at the surface and at 1m, 2m, 3m and 4m depths. The pooled results of these different level samples were used in the discussions that follow.

Two-way indicator species analysis (TWINSPAN) was applied to the basic floristic data set to derive a first approximation of the possible plant communities (Hill 1979a). Refinement of this classification was done by the application of Braun-Blanquet procedures (Behr and Bredenkamp 1988, Bredenkamp et al. 1989).

Major vegetation and associated habitat gradients, as well as the floristic relationships among the plant communities were explained by subjecting the floristic data set to Detrended Correspondence Analysis (DECORANA) (Hill 1979b). Maputaland Centre [MC] endemic and near-endemic plant taxa mentioned in the text are based mainly on the work of Van Wyk (1996). The term 'endemic' is used to refer to a taxon limited in its range to a restricted geographical area, or a particular substrate. When a taxon is predominantly confined to a particular area or substrate, but is also marginally present elsewhere (sometimes in the form of distant satellite populations), it is called a 'near-endemic' (Matthews et al. 1993).

**Results**

**Classification**

Eight major plant communities were identified (Table 3). These are mapped for TEP in Figure 1. Since the whole study area contains regic sand, no major geological feature plays a role in differentiating the plant communities. These major communities relate to the presence of clay and varying degrees of soil moisture in the regic sands. Soil character and moisture differences are usually slight, hence the sand-based communities do not have distinct boundaries.
Table 3: Phytosociological table of the vegetation of the Tembe Elephant Park and surrounding areas (species with an occurrence of 1 have been omitted throughout). Community 8 (reed beds of Muza Swamp) is not included.

| COMMUNITY NUMBER | 1 | 1 | 1 | 1 | 1 | 1 |
|------------------|---|---|---|---|---|---|
| SPECIES GROUP A  |   |   |   |   |   |   |
| Species          |   |   |   |   |   |   |
| SPECIES GROUP B  |   |   |   |   |   |   |
| Species          |   |   |   |   |   |   |
| SPECIES GROUP C  |   |   |   |   |   |   |
| Species          |   |   |   |   |   |   |
| SPECIES GROUP D  |   |   |   |   |   |   |
| Species          |   |   |   |   |   |   |
| SPECIES GROUP E  |   |   |   |   |   |   |
| Species          |   |   |   |   |   |   |

**Legend:**
- **R** = present but not dominant
- **+** = present
- **-** = absent
- **x** = not applicable

**Notes:**
- Community 8 (reed beds of Muza Swamp) is not included.
- Species with an occurrence of 1 have been omitted throughout.

**References:**
- Matthews, Van Wyk, Van Rooyen and Botha.
Table 3 cont.

| COMMUNITY NUMBER | SPECIES GROUP 1 | SPECIES GROUP 2 | SPECIES GROUP 3 | SPECIES GROUP 4 | SPECIES GROUP 5 | SPECIES GROUP 6 | SPECIES GROUP 7 | SPECIES GROUP 8 |
|------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| SPECIES GROUP 1  |               |               |               |               |               |               |               |               |
| SPECIES GROUP 2  |               |               |               |               |               |               |               |               |
| SPECIES GROUP 3  |               |               |               |               |               |               |               |               |
| SPECIES GROUP 4  |               |               |               |               |               |               |               |               |
| SPECIES GROUP 5  |               |               |               |               |               |               |               |               |
| SPECIES GROUP 6  |               |               |               |               |               |               |               |               |
| SPECIES GROUP 7  |               |               |               |               |               |               |               |               |
| SPECIES GROUP 8  |               |               |               |               |               |               |               |               |
Table 3 cont.

| COMMUNITY NUMBER | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|------------------|---|---|---|---|---|---|---|
| SPECIES GROUP M | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Andropogon solanarius | Taphirene terpines sac-longipes | Lygeum angustifolium | Cyperus esculentus | C. obtusiflorus | Eragrostis curvula | P. pyramidalis | Sporobolus subulatus |
| SPECIES GROUP N | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Dactylis glomerata | Lippia javanica | Dodonaea viscosa | Sporobolus pyramidalis | E. curvula | E. curvula | E. curvula | E. curvula |
| SPECIES GROUP O | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Pennisetum americanum | Pennisetum clandestinum | Indigofera angustifolia | Chloris gayana | Chloris gayana | Chloris gayana | Chloris gayana | Chloris gayana |
| SPECIES GROUP P | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Commene cerae | Commene cerae | Commene cerae | Commene cerae | Commene cerae | Commene cerae | Commene cerae | Commene cerae |
| SPECIES GROUP Q | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Xanthochimon hispidum | Xanthochimon hispidum | Xanthochimon hispidum | Xanthochimon hispidum | Xanthochimon hispidum | Xanthochimon hispidum | Xanthochimon hispidum | Xanthochimon hispidum |
| SPECIES GROUP R | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Acacia tortilis | Acacia tortilis | Acacia tortilis | Acacia tortilis | Acacia tortilis | Acacia tortilis | Acacia tortilis | Acacia tortilis |
| SPECIES GROUP S | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Netolza autumnalis | Netolza autumnalis | Netolza autumnalis | Netolza autumnalis | Netolza autumnalis | Netolza autumnalis | Netolza autumnalis | Netolza autumnalis |
| SPECIES GROUP T | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Imperata cylindrica | Imperata cylindrica | Imperata cylindrica | Imperata cylindrica | Imperata cylindrica | Imperata cylindrica | Imperata cylindrica | Imperata cylindrica |
| SPECIES GROUP U | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Eryngium heterophyllum | Eryngium heterophyllum | Eryngium heterophyllum | Eryngium heterophyllum | Eryngium heterophyllum | Eryngium heterophyllum | Eryngium heterophyllum | Eryngium heterophyllum |
| SPECIES GROUP V | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Agrostis tenuis | Agrostis tenuis | Agrostis tenuis | Agrostis tenuis | Agrostis tenuis | Agrostis tenuis | Agrostis tenuis | Agrostis tenuis |

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Matthews, Van Wyk, Van Rooyen and Botha
(except Sand Forest) but grade into each other, although each community is quite distinct in the field. It is proposed that much of the vegetation distribution can be attributed to the vegetation dynamics (succession) and historic evolution of the geomorphology of the region. The number of plant species per plot (species richness) ranges from a minimum of 11 to a maximum of 55, with an average of 34.

The hierarchical classification of the vegetation reinforces the correlation between habitat and plant communities (Figures 2 and 3). The distribution among various plant communities of Me endemic/near-endemic plant taxa, is listed in each community is quite distinct in the field. A major community which is mostly associated with dunes (crests, slopes but also in some interdune depressions), on the orange-brown arenosols and dystric regosols. Soils are sand with very little clay and low pH values (pH 5.6). Results of a separate soil analysis showed Sand Forest soils to be more acidic than those of the other region sand communities.

This plant community is characterised by species group C (Table 3). Diagnostic consistent species include the tree Pteleopsis myrtifolia, the understory shrubs Drypetes arguta, Croton pseudopulchellus and the liana Uvaria lucida subsp. virens. Prominent species (>50% constancy) include the trees Hymenocardia ulmoides, Dialium schlechteri, Cleistanthus schlechteri, Brachylaena huillensis, Manilkara discolor, the understory shrubs Todaliopsis bremekampii, Salacia leptactina, Drypetes natalensis, Monodora junodii, Leptactinia delagoensis subsp. delagoensis, Vitex amboniensis and the liana Secarnone delagoensis. In places Newtonia hildebrandii can be quite prominent but is not always consistent. The understory shrub Synaptolepis kirkii, the grass Panicum deustum and the liana Monanthotaxis caffra have a high constancy in this commu-
Species group E links the forest community with the thickest communities, indicating a floristic relationship. These more shade-tolerant species are common to such closed habitats; none are trees, most being herbaceous shrubs and creepers. On average 35 species were recorded per sample plot. Forty-two MC endemic/near-endemic species were recorded of which 27 are restricted to these forests, thus making this one of the richest communities for MC endemic/near-endemic plant species (Table 4).

Structurally, this plant community is a forest, in some instances having a low canopy of approximately 5m and in other places extending up to approximately 15m. The species composition is typical of what has been called Licuati or Sand Forest (Myre 1964, Moll and White 1978, Ward 1981, Matthews et al. 1999), with species present such as Dialium schliechieri, Pleoepsis myrtifolia, Pteroxyylon obliquum, Croton pseudopulchellus and Newtonia hildebrandlii. Protruding crowns of some of the larger tree species in Sand Forest are covered by many epiphytes, such as Microcoelia exilis and various lichens including Usnea spp.

This major community is subdivided into two sub-communities based on structure and floristic composition.

### 1.1 Cola greenwayi-Balanites maughamii tall Sand Forest

A sub-community which is mostly associated with dunes (crests, slopes, but also in some interdune depressions), on the orange brown arenosols and dystric regosols. Soils are sand with very little clay and acidic (pH 5.6).

This sub-community is characterised by species group A (Table 3). Diagnostic consistent species include the tall tree Balanites maughamii and understory shrub Cola greenwayi. Prominent species (>50% constancy) include the trees Pteroxyylon obliquum, Haplocoelium galiense, Wrightia natalensis, the understory shrubs Suregada zanzibariensis, Strychnos henningsii, the creepers Acacia kraussiana, Strophanthus luteolus and the grass Panicum laticomum. On average, 35 species were recorded per sample plot. Thirty-one MC endemic/near-endemic species were recorded, of which five are restricted to this community (Table 4).

### 1.2 Psydrax fragrantissima-Hyperacanthus microphyllus short Sand Forest

A sub-community which is mostly associated with dunes (crests, slopes, but also in some interdune depressions), on the orange brown arenosols and dystric regosols. Soils are sand with very little clay and acidic (pH 5.6). Reasons for the floristic differences between this community and the previous one are not clear, but may well be due to vegetation dynamics.

This sub-community is characterised by species group B (Table 3). Diagnostic consistent species include the shrubs Psydrax fragrantissima and Hyperacanthus microphyllus. Prominent species (>50% constancy) include the short trees Cassipourea mossambicensis, Combretum mkuzena, Zanthoxylum leprieurii, the shrubs Tricalylia junodii, Grewia microthyrsra, Phyllanthus sp. nov., Oxyanthus latifolius, Tarenna littoralis and the sedge Cyperus albostriatus. On average, 35 species were recorded per sample plot. Thirty-four MC endemic/near-endemic species were recorded of which six are restricted to this community (Table 4).

### 2. Spirostachys africana-Berchemia zeyheri closed woodland on duplex soils (clays)

A major community which is found on the clay-rich duplex soils normally associated with bottomlands of dunes as well as the borders of the Muzi Swamp. Perennial pans are to be found interspersed throughout these clay areas. Many of these pans have developed from mud wallows use by game species, especially elephant. This community is found on the grey-brown planosols.

This plant community is characterised by species group D.
Table 4: Maputaland Centre endemic or near-endemic plant species (according to Van Wyk 1996), and the plant communities with which they are associated

| Endemic/near-endemic taxon | Family | Plant community number |
|----------------------------|--------|------------------------|
|                            |        | 1 | 1.1 | 1.2 | 2 | 3.1 | 3.2 | 4 | 5 | 6 | 7 |
| Acacia kraussiana          | Mimosaceae | XX |     |     |   |     |     |   |   |   |   |
| Acridocarpus natalitius var. linearifolius | Malpighiaceae | x |     |     |   |     |     |   |   |   |   |
| Albizia delagoensis        | Menispermaceae | x |     |     | x |     |     |   |   |   |   |
| Aloe marlothii subsp. orientalis | Asphodelaceae | x |     |     | x |     |     |   |   |   |   |
| Aloe parvibracteata        | Asphodelaceae | x |     |     | x |     |     |   |   |   |   |
| Acanthanthos monteiroi    | Rubiacae  | x |     |     | x |     |     |   |   |   |   |
| Aneilema arenicola         | Com困难inae | x |     |     | x |     |     |   |   |   |   |
| Aspidoglossum delagoense   | Asclepiadaceae | x |     |     | x |     |     |   |   |   |   |
| Barleria priornitis subsp. delagoensis | Acanthaceae | x |     |     | x |     |     |   |   |   |   |
| Bosanea lamprophylla       | Orchidaceae | x |     |     | x |     |     |   |   |   |   |
| Brachychloa fragilis       | Poaceae   | x |     |     | x |     |     |   |   |   |   |
| Brachychloa schiemanniana | Poaceae   | x |     |     | x |     |     |   |   |   |   |
| Cariussetum setilorum subsp. setilorum | Rubiacae | x |     |     | x |     |     |   |   |   |   |
| Cassipourea mossambicensis | Rubiacae  | x |     |     | x |     |     |   |   |   |   |
| Cleome boretieis           | Combretaceae | x |     |     | x |     |     |   |   |   |   |
| Coffeee racemosa           | Combretaceae | x |     |     | x |     |     |   |   |   |   |
| Combretum celastroides subsp. orientale | Combretaceae | x |     |     | x |     |     |   |   |   |   |
| Combretum mikrouzeae       | Combretaceae | x |     |     | x |     |     |   |   |   |   |
| Corchorus junodi           | Tiliaceae  | x |     |     | x |     |     |   |   |   |   |
| Crassula maputensis        | Crassulaceae | x |     |     | x |     |     |   |   |   |   |
| Crinum acaule              | Amaryllidaceae | x |     |     | x |     |     |   |   |   |   |
| Grosszafruculosa           | Fabaceae   | x |     |     | x |     |     |   |   |   |   |
| Crotalaria monteiroi var. monteiroi | Fabaceae | x |     |     | x |     |     |   |   |   |   |
| Croton steenkampianus      | Fabaceae   | x |     |     | x |     |     |   |   |   |   |
| Dialium schleschier         | Caesalpiniaceae | x |     |     | x |     |     |   |   |   |   |
| Diospyros inhacensis       | Ebenaceae  | x |     |     | x |     |     |   |   |   |   |
| Doyialis longiperna        | Flacourtiaceae | x |     |     | x |     |     |   |   |   |   |
| Encephalartos forox        | Zamiaceae  | x |     |     | x |     |     |   |   |   |   |
| Ergrotris maggi var. maggi | Poaceae   | x |     |     | x |     |     |   |   |   |   |
| Erythrophleum lasianthum   | Euphorbiaceae | x |     |     | x |     |     |   |   |   |   |
| Erythroxylum delagoense    | Euphorbiaceae | x |     |     | x |     |     |   |   |   |   |
| Eugenia mossambicensis     | Myrtaceae  | x |     |     | x |     |     |   |   |   |   |
| Galpinia transvaalica      | Lythraceae | x |     |     | x |     |     |   |   |   |   |
| Gardenia cornuta           | Rubiacae  | x |     |     | x |     |     |   |   |   |   |
| Grevia microphylla         | Tiliaceae  | x |     |     | x |     |     |   |   |   |   |
| Haplocoelum gallense       | Sapindaceae | x |     |     | x |     |     |   |   |   |   |
| Helichrysum adencarpum subsp. armophilum | Asteraceae | x |     |     | x |     |     |   |   |   |   |
| Helichrysum silvaticum     | Asteraceae | x |     |     | x |     |     |   |   |   |   |
| Hippocraea delagoensis     | Celastraceae | x |     |     | x |     |     |   |   |   |   |
| Hyperacanthus microphyllus | Rubiacae  | x |     |     | x |     |     |   |   |   |   |
| Indigofera delagoensis     | Fabaceae   | x |     |     | x |     |     |   |   |   |   |
| Indigofera inhambanensis   | Fabaceae   | x |     |     | x |     |     |   |   |   |   |
| Indigofera podophylla      | Fabaceae   | x |     |     | x |     |     |   |   |   |   |
| Kalanchoe neglecta         | Crassulaceae | x |     |     | x |     |     |   |   |   |   |
| Lagynias lasiantha         | Rubiacae  | x |     |     | x |     |     |   |   |   |   |
| Lepidium sulbense          | Brassicaceae | x |     |     | x |     |     |   |   |   |   |
| Maerua nervosa             | Capparaceae | x |     |     | x |     |     |   |   |   |   |
| Maytenus markwardii        | Celastraceae | x |     |     | x |     |     |   |   |   |   |
| Memecylon souae            | Melastomataceae | x |     |     | x |     |     |   |   |   |   |
| Ochna barboae              | Ochnaceae  | x |     |     | x |     |     |   |   |   |   |
| Oxyanthus latifolius       | Rubiacae  | x |     |     | x |     |     |   |   |   |   |
| Oxygynum robustum          | Polygonaceae | x |     |     | x |     |     |   |   |   |   |
| Ozorea engleri             | Anacardiaceae | x |     |     | x |     |     |   |   |   |   |
| Parini casperis subsp. incohata | Rubiacae | x |     |     | x |     |     |   |   |   |   |
| Pavetta catophylla         | Rubiacae  | x |     |     | x |     |     |   |   |   |   |
| Pavetta gerstnerii         | Rubiacae  | x |     |     | x |     |     |   |   |   |   |
| Pavetta sp. nov.           | Geraniaceae | x |     |     | x |     |     |   |   |   |   |
| Pelargonium tongaense       | Euphorbiaceae | x |     |     | x |     |     |   |   |   |   |
Table 4 cont.

| Endemic/near-endemic taxon                  | Family                  | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 |
|--------------------------------------------|-------------------------|---|---|---|---|---|---|---|---|---|
| Plectroniella armata                       | Rubiaceae               |   |   |   |   |   |   |   |   |   |
| Psydrax fragrantissima                     | Rubiaceae               |   |   |   |   |   |   |   |   |   |
| Psydrax locuples                           | Rubiaceae               | x |   |   |   |   |   |   |   |   |
| Pyrostria hystrix                          | Rubiaceae               |   | x |   |   |   |   |   |   |   |
| *Rhus kwazuluana*                          | Anacardiaceae           |   |   |   |   |   |   |   |   | x |
| *Salacia kraussii*                         | Rubiaceae               |   |   |   |   |   |   |   |   |   |
| *Sanseveria coccinia*                      | Liliaceae               |   | x |   |   |   |   |   |   |   |
| *Schotia capitata*                         | Fabaceae                |   |   |   |   |   |   |   |   | x |
| *Schisochiton apiculatus*                  | Acanthaceae             |   |   |   |   |   |   |   |   |   |
| *Secamone delagoensis*                     | Asclepiadaceae          |   |   |   |   |   |   |   |   | x |
| *Striga junodii*                           | Strophanthaceae         |   |   |   |   |   |   |   |   |   |
| *Striphanthus gerrardii*                   | Apocynaceae             | x | x | x | x |   |   |   |   |   |
| *Striphanthus luteolus*                    | Apocynaceae             | x | x |   | x |   |   |   |   |   |
| *Tarenna junodii*                          | Rubiaceae               |   |   | x |   | x |   |   |   |   |
| *Theespia acutiloba*                       | Rubiaceae               |   |   |   |   |   |   |   |   | x |
| *Todalliaopsis bremekampii*                | Malvaceae               |   |   |   |   |   |   |   |   | x |
| *Tricalysia delagoensis*                   | Rubiaceae               |   |   | x |   | x |   |   |   |   |
| *Tricalysia junodii var. junodii*          | Rubiaceae               | x | x | x | x |   |   |   |   |   |
| *Tricalysia mossambicensis*                | Rubiaceae               |   |   |   |   |   |   |   |   | x |
| *Vahlia capensis subsp. vulgaris var. latifolia* | Vahliaiceae            |   |   |   |   |   |   |   |   |   |
| *Vernonia centaureoides*                   | Asteraceae              | x | x | x |   | x |   |   |   |   |
| *Warburgia salutaris*                      | Apocynaceae             | x | x | x | x | x | x |   |   |   |
| *Wrightia natalensis*                      | Apocynaceae             | x | x |   |   |   |   |   |   |   |

Restricted to sub-community

Restricted to community

Sub-community total

**TOTAL**

84 Species (11% of flora of study area)  41 Families

XXX = Abundant
XX = Average
X = Rare

Species in bold have been recorded from TEP, although not recorded in sample plots.

Bold blocks represent species restricted to a particular plant community.

(TEP 3); diagnostic consistent species include the trees *Spirostachys africana*, *Berchemia zeyheri* and *Cassine aethiopica*. Prominent species (>50% constancy) include the trees *Ziziphus mucronata*, *Sideroxylon inermee*, *Euphorbia ingens*, *Acacia senegal*, *Pappea capensis*, *Schotia brachypetala*, the shrubs *Euclea divinorum*, *Dovyalis longispina*, *Schotia capitata*, *Carissa bispinosa*, *Pavetta cataphylla*, the forbs *Justicia protracta*, *Protasparagus suaveolens*, the creepers *Senecio viminalis*, *Capparis brasii* and *Capparis tomentosa*. The understory shrubs *Rhus guenizzi*, *Coddia rudis* and the forbs *Protasparagus natalensis* have a high constancy in this community and are character species of species group G; *Coddia rudis* having its highest cover values in this community. This community has many species associated with the more sandy areas. This can be ascribed to the duplex nature of this community's soil. It would be expected that sand-associate species should be found in the more sandy areas on the clay. These species would occur in the form of shrubs and forbs as reflected in the species groups G and H, but very few tree species are represented. Other taxa showing a strong affinity to this community are *Euclea natalensis*, *Grewia califra* and *Catunaregam spinosa* subsp. *spinosa* (species group H, Table 3). This reaffirms the association with sandy soils thicklet vegetation although all of these species are shrubs and not trees; *Euclea natalensis* can be over 2m in height. On average, 45 species were recorded per sample plot, the richest of all the plant communities in the TEP. Twenty endemic/near-endemic MO species were recorded, of which ten are restricted to this community (Table 4).

In structure this plant community varies from areas of dense vegetation to thicklets associated with termitaria, which are on clay (duplex soils). Species composition of these thicklets on termitaria is similar to that found in other areas in South Africa, such as Roodeplaat Dam Nature Reserve, and are sometimes referred to as bush clumps (Van Rooyen 1984).

3. *Strychnos madagascariensis-Combretum molle* woodland of deep sandy areas

A community which is found on dune crests, slopes, and interdune depressions, on the grey dystric regosols. This community is the most dominant and widespread community in the study area.
This plant community is characterised by species group L (Table 3). Diagnostic consistent species include the tall short shrub *Styrchnos madagascariensis*, and the trees *Combretum molle* and *Acacia burkei*. Prominent species (>50% constancy) include the tree *Sclerocarya birrea*, the shrubs *Styrchnos spinosa*, *Dichrostachys cinerea* and the creeper *Rhoicissus revollii*. On average, 39 species were recorded per sample plot. Thirty-seven ME endemic/near-endemic species were recorded, of which thirteen are restricted to this community, making this the second richest community in the TEP for ME endemic/near-endemic species (Table 4).

This community is the dominant vegetation type of TEP, thus the diagnostic species represent the general species for this area and as such would not be very consistent. Structurally this plant community is a woodland of varying density, from closed to open. Canopy height varies from approximately 5m, extending up to 10m in places. This major community is what Granger (1996) called Subhumid Lowveld Bushveld, although his species composition described for this area and as such would not be very consistent.

This major community is subdivided into two sub-communities based on vegetation density, structure and floristic composition.

### 3.1 *Acacia burkei-Euclea nataliensis* closed woodland and thicket

A sub-community which is found on dune crests, slopes and interdune depressions, on the grey dystric regosols. Soils are acidic (pH 5.5) sands with very little clay, although sometimes may have very narrow bands of clay present. This is one of the most widespread sub-communities in the study area.

This sub-community has no diagnostic species. It is characterised by the absence of species group K and the presence of species group H. Although species group H is also associated with thicket on clay, those species are linked to the presence of narrow clay bands (Table 3). Prominent species (>50% constancy) include the shrubs *Euclea natalensis*, *Grewia caffra*, *Catunaregam spinosa* and *Bridelia cathartica* (species group H). Another species showing a strong affinity to this community is the tree *Acacia burkei*, which has its highest constancy in this community (species group L). On average 41 species per plot were recorded, this community having the second highest number of species among the studied plant communities. Twenty-eight ME endemic/near-endemic species were recorded, of which one was restricted to this community (Table 4).

This plant community can be distinguished based on density, which in most cases varies from continuous to sub-continuous crown gaps, with a canopy from 6m to approximately 12m high.

This sub-community is subdivided into two variations, one being a generally dense plant community and the other an ecotonal form which is less dense and having affinities with the more open woodlands.

#### 3.1.1 *Zanthoxylum capense-Clausena anisata* closed woodland and thicket on sand

A community which is found on dune crests, slopes and interdune depressions throughout the TEP, on the grey brown dystric regosols, which sometimes may have very narrow clay bands present.

This plant community is characterised by species group F (Table 3). Diagnostic consistent species include the tree *Zanthoxylum capense* and the shrub *Clausena anisata*. Prominent species (>50% constancy) include the trees *Vepris lanceolata* and the forb *Achyranthes aspera*. Other species showing a strong affinity to this community are the shrubs *Phylanthus reticulatus*, *Grewia caffra* and the tree *Acacia burkei* (species group L). The shrubs are from species groups G and H, showing an association with thicket vegetation. *Acacia burkei* has its highest constancy in this
community. On average 42 species per plot were recorded, making this the second richest plant community.

3.1.2 Panicum maximum-Acacia burkei ecotonal closed woodland

A community which is found on dune crests, slopes and interdune depressions throughout TEP, on the grey brown dystric regosols, which may sometimes have very narrow clay bands present.

This plant community is characterised by the absence of species groups F and G (Table 3) and the presence of H and L. This community has no diagnostic or prominent species as it is an ecotonal community associated with less dense areas with essentially no clay in the soil. Species showing a strong affinity to this community are the shrub/tree Combretum molle and the grass Panicum maximum. The tree Acacia burkei attains its highest cover-abundance in this community. Other species showing an affinity to this community is the tree Terminalia sericea and the grass Digitaria eriantha, both belonging to species group O (species associated with open to sparse vegetation). All the above species belong to more generally distributed species groups and species more strongly associated with less dense vegetation. On average 35 species were recorded per sample plot.

3.2 Salacia kraussii-Themeda triandra open woodland on sand

A community which is found on dune crests, slopes and interdune depressions throughout TEP, on the grey brown dystric regosols. This is also one of the more widespread communities of the study area.

This plant community is characterised by the presence of species group K (Table 3). Diagnostic consistent species include the geoxyl-suffrutex Salacia kraussii, the grasses Themeda triandra, Pogonarthria squarrosa and Eustachys paspaloides. Not all these species have high constancy. The tree Terminalia sericea attains its highest cover values in this community and is also the most consistent species (100% present) (species group O, Table 3). Species group O is associated with open to sparse vegetation cover. Prominent species (>50% constancy) include the shrubs Vangueria infausta, Brachylaena discolor and the grass Cymbopogon validus. Another species that shows a strong affinity to this community is Strychnos madagascariensis, which has its highest cover-abundance values in this community. On average 37 species per sample plot were recorded. Twenty-two MC endemic/near-endemic species were recorded, of which six are restricted to this community (Table 4).

This community can be distinguished based on density, which in most cases varies from open to sparse woodland, with few tall trees from approximately 8m to 10m.

3.2.1 Andropogon gayanus-Albizia versicolor open woodland on sand

A sub-community which is found on dune crests, slopes, and interdune depressions throughout TEP, on the orange grey dystric regosols. Soils are acidic (pH 5.34) and sandy with very little clay. This is also one of the more widespread sub-communities of the study area.

This plant community is characterised by the presence of species group I (Table 3). Diagnostic consistent species include the grass Andropogon gayanus and the tree Albizia versicolor. Prominent species (>50% constancy) include the shrubs Sapium integerimum, Garinia livingstoniae and the forb Hostundia opposita. Another species that shows a strong affinity to this community is Strychnos madagasariensis, which has its highest abundance values in this sub-community. The grass Panicum maximum also attains very high abundances in this sub-community. Other species are the trees Combretum molle, Terminalia sericea, the geoxyl-suffrutex Eugenia mossambicensis and the grasses Digitaria eriantha, Dicteropogon amplexent, and Perotis patans. The last two species come from species group N, this group representing grassland areas associated with Sand Forest edges. On average 37 species per sample plot were recorded.

This community has few tall trees from approximately 8m to 10m.

3.2.2 Helichrysum kraussii-Dichapetalum cymosum sparse woodland

A sub-community which is found mainly on the flat areas between dunes, but also occurring to a lesser degree on dune slopes and crests throughout TEP, on the grey brown dystric regosols. Soils are slightly acidic (pH 5.8) sand with very little clay, the lowest percentage clay of all soils examined.

This plant community is characterised by the presence of species group J (Table 3). Diagnostic consistent species include the woody forb Helichrysum kraussii and the geoxyl suffrutices Dichapetalum cymosum. Prominent species (>50% constancy) include the shrub Dalbergia obovata, the grasses Trichoneura grandiglumis, Panicum kala­harenses and the geoxyl-suffrutices Perinari capensis subsp. inohata. Another species showing a strong affinity to this community is Terminalia sericea, which attains its highest abundance in this sub-community. Other species are the shrub Strychnos madagascariensis, the geoxyl-suffrutices Salacia kraussii, Eugenia mossambicensis, the grasses Pogonarthria squarrosa, Themeda triandra, Dichapetalum amplexent, Perotis patans, Aristida stipitata subsp. spicata, Digitaria eriantha, the forb Corchorus junodii and the woody creeper Rhoicissus revolii. Three of the last-mentioned species come from species group O, this group representing grassland areas associated with Sand Forest edges, a clear link between woodland and these areas. On average 37 species per sample plot were recorded.

This community is similar to what is called 'woody grassland' (Matthews et al. 1999) — a type of grassland characterised by an abundance of species with the geoxyl-suffrutex growth form.
4. Andropogon schirensis-Tephrosia longipes subsp. longipes grassland associated with Sand Forest

A community which is found directly neighbouring on the Sand Forest patches, throughout TEP, on the grey brown dystric regosols. Soils are slightly acidic (pH 5.47) sand with very little clay. These soils have been shown to possibly retain some allelopathic properties that are present in the Sand Forest community (unpublished results).

This plant community is characterised by the presence of species group M (Table 3). Diagnostic consistent species include the grass Andropogon schirensis and the forb Tephrosia longipes subsp. longipes. Prominent species (>50% constancy) include the forbs Indigofera inhambanensis. Trachyandra cf. salti, the grasses Bewisia biflora, Urelytrum agrophyoides and the sedge Cyperus obtusiflorus. Another species showing a strong affinity to this community is the grass Perotis patens that is very consistent (100%) and attains its highest cover-abundance value in this community. Perotis patens is a characteristic pioneer species. Strychnos madagascariensis also has an affinity to this community, but takes the form of a stunted-shrub. Other species are the grasses Diheteropogon amplexentens, Aristida stipitata subsp. spicata, and Digitaria eriantha. The first two mentioned species come from species group N, which includes species common to open woodland, showing that this community has a close association with the open woodland areas. On average 23 species per sample plot were recorded. Ten MC endemic/near-endemic species were recorded, of which two are restricted to this community (Table 4).

This community is open grassland with little or no trees and shrubs, and is always found directly bordering on the Sand Forest community. These characteristic grasslands do not extend very far from Sand Forest edges and exhibit a gradient; further from the Sand Forest patches these grasslands gradually acquire an open woodland character.

5. Nidorella auriculata-Justicia flava hygrophilous grassland on clay-rich soils

A community which is often found next to pans and marshy areas as well as clay-based thickets, throughout TEP, on the grey brown to brown orange planosols. This community has soils with the highest percentage clay in the study area.

This plant community is characterised by the presence of species group S (Table 3). Diagnostic consistent species include the forbs Nidorella auriculata, Justicia flava and Kyllinga erecta. Prominent species (>50% constancy) include the grasses Panicum maximum, Aristida congesta and the forb Commelina c. erecta. On average 25 species per sample plot were recorded. One MC endemic species has been recorded in this community, to which it is also restricted (Table 4).

This community can be associated with 'wet areas' as water collects in these clayey areas after rain, resulting in temporary pans. Therefore, much moister soils occur here than are found on the sands where the water drains away. The Muzi Swamp on the other hand is also clay-based but is fed mostly by outside ground water sources.

Based on floristics, this community is subdivided into two sub-communities.

5.1 Waltheria indica-Sporobolus pyramidalis grassland on clay between thicket and pan marsh edges

A sub-community which is often found next to or surrounding pans and marshy areas as well as clay-based thickets, throughout TEP, on the grey brown planosols. These soils have a high percentage of clay.

This sub-community is characterised by the presence of species group Q (Table 3). Diagnostic consistent species include the forbs Waltheria indica and the grass Sporobolus pyramidalis. Prominent species (>50% constancy) include the grass Eragrostis ciliaris, the forbs Monochaema debile and an Indigofera sp. On average 29 species per sample plot were recorded.

5.2 Acacia borleae-Kohautia virgata shrubland on clay soils often associated with calcrete

A sub-community which is found next to marshy areas as well as the clay-based thickets associated with the Muzi Swamp, on the orange grey brown planosols. These soils are alkaline (pH 9) with a high percentage of clay.

This sub-community is characterised by the presence of species group R (Table 3). Diagnostic consistent species include the shrub Acacia borleae and the forb Kohautia virgata. Prominent species (>50% constancy) include the grass Eragrostis heteromera that attains its highest cover-abundance values in this sub-community. Eragrostis heteromera associated with species group U, which represents the common species of the Muzi Swamp. On average 23 species per sample plot were recorded.

6. Imperata cylindrica-Eragrostis lapulosa grassland on sandy clay soils associated with Muzi Swamp and other marsh/pan areas

A community which is found neighbouring the Muzi Swamp as well as marshy areas associated with sand, on the dark brown grey humic gleysols to planosols. This plant community is characterised by the presence of species group T (Table 3). Diagnostic consistent species include the grasses Imperata cylindrica, Eragrostis lapulosa and Dactylolctenium gerninatum. Prominent species (>50% constancy) include the shrub Acacia nilotica, the grass Panicum genutflexum and the forb Nidorella anomala. Other species showing a strong affinity to this community are the grass Eragrostis heteromera (species group U) and the sedge Cyperus natalensis. Cyperus natalensis comes from species group W, linking this community with the clay-based communities. On average 21 species per sample plot were recorded. Seven MC endemic/near-endemic species were recorded of which six are restricted to this community (Table 4).

7. Oxalis cf. semiloba-Nymphaea nouchali aquatic vegetation of standing water in marshes and pans

A community which is found associated with the many
perennial and permanent pans and marshes occurring in the clay-based areas (duplex soils), throughout TEP. This community is found in the water of inundated planosol soils.

This plant community is characterised by the presence of species group V (Table 3). Diagnostic consistent species include the forb *Oxalis cf. semiloba* and the hydrophyte *Nymphea nouchali*. Prominent species (>50% constancy) include the sedges *Cyperus distans*, the grasses *Digitaria didactyla* and *Echinochloa pyramidalis*. Another species showing a strong affinity to this community is the sedge *Cyperus natans*. On average 13 species per sample plot were recorded, the lowest of all samples. No MC endemic species were recorded for this community.

8. *Phragmites australis* reed beds of the Muzi Swamp

One particular community that was sampled but not included in Table 3 is the reed beds of the extensive Muzi Swamp, which crosses the eastern side of the reserve and extends northwards to Maputo Bay in Mozambique. This is a well-described community that is widespread and associated with water bodies throughout South Africa and the world. Here along the entire length of the Muzi Swamp, dense stands of *Phragmites australis* occur, although in some places these are mixed with *Typha capensis*. Some of these are utilised by the local community for harvesting of reeds. The Muzi Swamp is the only source of permanent water in TEP, even in the driest years. This community is rather similar to the Phragmito-Magnocaricetea (Kikla in Kikla and Novak 1941) described for Europe (Mucina 1997). However, its precise relationship to this class of swamp vegetation is uncertain and requires further study.

Discussion

Ordination

Distribution of the sample plots (relevés) along the X and Y1 axis as well as X and Y2 axis of ordination is given in the form of scatter diagrams (Figures 4 and 5). The scatter diagrams illustrate a moisture gradient along the horizontal axis, with the wetter habitats to the right and the drier habitats to the left. Arenosols and regosols communities base themselves on the left of the diagram, while planosols and histosols communities base themselves on the right. On the X and Y1 axis, a distinct discontinuity exists between the communities of the Sand Forest (A), woodlands (B), Muzi Swamp grassland and the perennial pans (H). Grassland communities associated with clays (G) do not show a discontinuity, but do form a strong group restricted to a specific area of the scatter diagram.

There is no discontinuity in the distribution of the sample plots representing the woodland and associated communities on the X and Y1 axes. However, on the X and Y2 axis a clear separation with discontinuities can be seen within the woodland communities, namely, closed woodland associated with duplex soils and grassland associated with Sand Forest. The rest of the woodland communities show no discontinuities but each community group recognised in the proposed classification is more or less restricted to a specific area of the scatter diagram, thus supporting their treatment as closely related sub-communities. They also show a gradient of density from top to bottom, with the more open communities at the top and the thickets at the bottom.

This pattern of one woodland community merging with another woodland community can clearly be seen in the field. On the other hand, communities such as Sand Forest are quite distinct with sharp boundaries.

Plant community relationship

Eight ecologically-interpretable plant communities have been distinguished, described and mapped. This information can be used in reserve and area management, land-use planning, and extrapolation to other parts of Maputaland, as well as in further ecological studies. Results of the ordination not only confirm the classification, but also give an indication of floristic and associated habitat gradients. Dynamics of water in the landscape clearly control the structure of the community at the first physiognomic level. This is a common phenomenon in savanna areas (Solbrig 1993).

All the proposed communities are distinguishable in the field based on structure, growth form, general species composition and character species — this is despite the gradual environmental gradients that cause communities to merge into one another, particularly so in the case of the woodlands. The different woodland sub-communities often can be difficult to distinguish based on floristics alone, but structure and density help to distinguish between them.

Except for the broad-scale classification of the coastal grasslands of southern Mozambique (Myre 1964, 1971) and the detailed classification of coastal and inland communities elsewhere in Maputaland (Lubbe 1996, Matthews et al. 1999), the present study is a further attempt at a more detailed, larger scale phytosociological classification of some of the Maputaland coastal plain communities. A correlation between the plant communities of the present study and the various syntaxa described by Myre (1964, 1971) and other workers has been attempted. Myre (1964) did not formally describe any of the closed woodland or forest and related communities, but rather concentrated on the grassland and related communities. He did, however, give a basic species composition list for what he called Licuati Forest. The composition of this Licuati Forest in southern Mozambique corresponds closely with what is called Sand Forest in South Africa. Included in this species list are also some species associated with thicket vegetation on sand and clay, e.g. *Spirostachys africana* and *Euphorbia ingens*. This is also the case for the Sand Forest type described for Sileza Nature Reserve, namely the *Artabotrys monteiroae-Dialium schlechteri* forest, the coastal form of Sand Forest (Matthews et al. 1999). The last mentioned variation compares well with typical Sand Forest, although it also contains a few species which are associated with what is referred to as thicket or closed woodland in the present study (e.g. *Commiphora neglecta*). Such species are, however, very few in the case of the *Artabotrys monteiroae-Dialium schlechteri* forest. Lubbe (1996) found a degree of similarity with Sileza 'Sand Forest' with what he described as *Tricalysia delagoensis-Dalium schlechteri* inland forest.
However, the latter inland forest type contains many coastal dune forest species and is obviously more closely associated with coastal dune forest whilst containing a few Sand Forest elements. The open to sparse woodlands described in this study do have similarities with the Themeda-Salacietum. M. Myre (1964) woody grasslands of Myre (1964) and Matthews et al. (1999). The typical woodland communities, as described in the present study, are limited in distribution and in variety in Sileza Nature Reserve (Matthews et al. 1999).

The Muzi Swamp communities described in this study are also rather similar to the Sileza Nature Reserve’s Ischaemum fasciculatum-Eragrostis inamoena hygrophilous grasslands and specifically to the Monocymbium cerosilforme-Eragrostis lapillula grassland of areas not regularly inundated with water (pan edges). However, in TEP, which has drier conditions with much deeper water table levels, these communities are limited, and species compositions differ accordingly.

**Major determinants of plant communities**

A simple situation exists in the MC with the important determinants being the interconnected effects of water table (moisture), soil type and topography, upon which fire and vegetation dynamics have been superimposed. Casual observations and comparison with other studies (notably Myre 1964, 1971, Lubbe 1996, Matthews et al. 1999) have nevertheless shown that the plant communities (and thus associated environmental factors) of the present study extend over most of the Maputaland Coastal Plain. In the case of TEP, which lies in a drier and topographically more elevated part of the Maputaland Coastal Plain, water table level is not a leading factor, although soil moisture plays an important role. In the case of Sand Forest associated with the ancient dune cordons and driest soils, it is suggested that historic plant dynamics could be a major determinant of the present day Sand Forest patches.

Regular fires are a natural phenomenon in these areas, although today most fires are anthropogenic. As a result of humans, fires are more regular (sometimes more than once a year) and are now taking place at times of year when the vegetation would not naturally, on a regular basis, be exposed to fire. In many managed areas, current fire frequency and intensities are lower than in the past, resulting in increased woody biomass in these areas (Van Wilgen and Scholes 1997). There can be no doubt that fire is an important natural ecological factor in these communities. In the
past, it is probable that fires would have taken place annually to tri-annually, depending on biomass build up. These fires would occur during the dry season (winter to early spring), when the grasses are dormant and at that time of year when lightning frequencies are the highest.

Margins of Sand Forest are often exposed to fire, which in some cases has a low impact, but at other times can be quite destructive. Many of these 'negatively' fire-impacted Sand Forest patches and margins do not regenerate at all. This leads us to the assumption that Sand Forest is decreasing as a result of fire. However, a comparison of aerial photographs of TEP taken in 1942, 1959, 1969 and 1975 indicates that the Sand Forest patches we see today are very stable. There has been no increase in Sand Forest distribution, this being in contrast to the areas neighbouring Sand Forest which show a distinct increase in woody plants. There is indication of slight reduction of Sand Forest patches, as would have been predicted. This reduction is very slight and depending on Sand Forest dynamics in other areas and over the long term, should not be looked on negatively. However, the negative impact of large herbivores, such as elephant, which in the past were not closely associated with Sand Forest, in combination with fire, could promote Sand Forest shrinkage. Under the time scale at which Sand Forest dynamics seem to operate, these added impacts could negatively affect Sand Forest conservation within TEP.

Endemism

About 2 500 species, but probably more, of vascular plants occur in the Maputaland Centre of Endemism (Van Wyk 1996). Of these, at least 230 species or infraspecific taxa and three genera are endemic or near-endemic to the region (Van Wyk 1996). Eighty-four of these Maputaland Centre endemics/near-endemics were recorded in the study area (Table 4), but the actual number present is expected to be slightly higher due to incomplete sampling. Most endemics were associated with only two of the seven major plant communities. Forty-two taxa are associated (27 restricted) with Drypetes arguta-Uvaria lucida subsp. viresens forest (Sand Forest) and 37 (13 restricted) to the Strychnos madagas-
cariensis-Combestrum mollis woodland. Most of the *Salacia kraussii-Themeda triandra* open woodland sub-communities’ endemics have the geosylic saxifraga growth form. Hence this community shows a strong association with the *Themeda-Salacietum* woody grasslands described from the Silewza Nature Reserve and surrounding area (Matthews et al. 1999). *Themeda-Salacietum* woody grassland, which occurs closer to the coast, is another plant community noted for its high numbers of MC endemics. Another community relatively rich in endemics is the *Sporostachys africanaa-Berchemia zeyheri* closed woodland on clay, where 20 MC endemic/near-endemic species have been recorded. This is a restricted community in TEP, many of the endemics having a wider distribution outside the park on similar clay-based substrates. In the study area, by far the majority of plant endemics are confined to non-hygrophilous plant communities. The observed low species diversity and paucity of regional endemics in hygrophilous grassland communities is a common phenomenon throughout southern Africa.

The geological history of Maputaland suggests that the current ecosystems in the region may be of recent derivation. This part of the Mozambican Coastal Plain was last inundated by the ocean approximately 3–1.8 million years ago. In fact, many endemic plant taxa comply with the concept of neoendemics (young taxa). Thus, the MC comprises a unique environment in Africa in that it is geologically young with biological evolution (notably speciation) being actively driven.

Maputaland Centre endemics/near-endemics recorded in the study area, and even more so for the Centre as a whole, represent a wide spectrum of growth forms, including trees, shrubs, suffrutesces, lianas, forbs, geophytes and annual herbs (Van Wyk 1996). Maputaland Centre endemics are also well represented in Sand Forest, woodland and grassland, with Sand Forest, on a regional basis, being perhaps the single richest community in MC plant endemics. In contrast, the Pondoland Centre of Endemism, located on the Pondoland Plateau to the south of the MC, is particularly rich in woody palaeoendemics associated with forest (Van Wyk 1994). It is hypothesised that one of the reasons for this marked difference in growth form and vegetation-type partitioning of endemics between these two centres of endemism is the relatively youthful (Quaternary) age of the exposed sandy Maputaland Coastal Plain and its associated plant communities. The species and plant communities had to adapt to more arid conditions inland as a result of sea level changes and resultant decrease in rainfall and soil moisture (water table drop); the lowering of the water table from deeper sand deposits rather than diminished rainfall.

The southern Kalahari, similarly associated with sand deposits, is also a relatively youthful ecosystem. Accumulation of Kalahari sands began towards the end of the Cretaceous, approximately 65 million years ago (Partridge and Maud 1987). Today many Kalahari sand plant endemics are to be found on the mesic northern areas of these sand deposits (Angola/Zambia/Democratic Republic of Congo/Zimbabwe). In contrast, the arid southern Kalahari sands (South Africa/Namibia/Botswana) contain very few local endemics. The southern Kalahari has been subjected to two major arid events, the second beginning in the Late Pleistocene, although there have been intermitted wetter periods during this time (Malherbe 1984). The most recent arid period began approximately 10 000 years ago — consequently little time was available for speciation. The southern Kalahari also borders on ancient arid areas (e.g. Namib Desert and Karoo); thus there has been the opportunity for pre-adapted arid species establishing themselves through migration in Kalahari areas subjected to aridification. The latter invasions may have hindered in situ speciation and the development of neoendemics. On the other hand the southern portion of the Mozambican Coastal Plain (Maputaland) were at the time of its most recent exposure from the ocean apparently not bordered by any significant pre-adapted, arid, psammophilous floras. This may have resulted in the availability of many vacant niches on the sandy coastal plains subsequently occupied by newly evolved taxa derived from the available regional floras, hence the preponderance of neoendemics in the MC.

Four Maputaland Centre endemic/near-endemic bird species, namely, Neergaard’s sunbird (*Nectarinia neergaardi*), Rudd’s apalis (*Apalis ruddi*), Pinkthroated twinspot (*Hypargos marginatus*) and Woodward’s batis (*Batis fratrum*) are to be found in the study area. They are closely associated with Sand Forest (Van Rensburg 1998).

**Sand Forest (†Licuati Forest)**

Floristically, White (1983) classified the southern Africa forests as mainly belonging to two phytocoria, namely the Afromontane Archipelago-like Regional Centre of Endemism (which extends to the northeastern African uplands) and the Tongaland-Pondoland Regional Mosaic (which is largely restricted to the eastern coastal belt of southern Africa). His mapping was not at a fine enough scale to separate the ‘Sand Forest’ of northern KwaZulu-Natal and southern Mozambique from other Tongaland-Pondoland vegetation types. Mol and White (1978) considered many typical Sand Forest species (e.g. *Balanites maughanii*, *Cleistanthus schlechteri* and *Newtonia hildebrandii*) to be Zanzibar-Inhambane linking species (the Zanzibar-Inhambane Region is the coastal phytocorall mosaic extending from southern Mozambique to east Africa). This phytocorall, together with the Tongaland-Pondoland Regional Mosaic, form White’s (1983) Indian Ocean Belt. Low and Rebelo (1996), on the other hand, divide the southern African forests into three main types: Afromontane, Coastal and Sand Forest. These are then further subdivided. Van Rooyen et al. (1981) also recorded typical Sand Forest species (e.g. *Pteleopsis myrtifolia*, *Cleistanthus schlechteri*, *Hymenocardia ulmoides* and *Monodora junodi*) in the Sandveld communities (thicket) described from the Punda Milia-Pafuri-Wambiya area in the Kruger National Park.

Sand Forest occurs under drier conditions than most other forest types, and is thus classified as tropical dry forest. Marker and Russel (1984) have stated that the presence of mixed forest in low rainfall areas of the Eastern Cape can partly be ascribed to the presence of fog and the water holding capacity of deep sand, which sustain forest growth. Sand Forest in Maputaland is also found on deep sand, periodically experiencing heavy dews and low-level mists, espe-
or mesophyllous and entire. Our moisture (Alvin 1987). Moist grassland and woodland. Relict patches of Androstachys johnsonii but were hypothesised to be due to the ability of the stands to absorb water from the winter rains. It can now be shown that only 5% of the species are definitely wind-dispersed. This also applies to the more coastal Sand Forest types. Leaf attributes are generally similar in all forests. Sand Forest is generally evergreen, non-spiny, with the leaves predominantly simple, micro- or mesophyllous and entire. Semi-deciduous trees do occur in Sand Forest, but these species are not dominant.

**Threats and conservation**

Conservation efforts in the Maputaland Centre have hitherto centred mainly on areas containing species of large game. The vegetation of nearly all existing nature reserves and game reserves in KwaZulu-Natal is dominated by various types of savanna. A notable exception is the TEP that contains well-preserved stands of MC endemic-rich Sand Forest.

Outside conservation areas, the main threats to the Sand Forest habitat are uncontrolled fires used in clearing areas for agriculture, as well as selective species utilisation for traditional medicines, construction, fuel and other purposes. Examples of species selected for are Cassipourea mossambicensis that is used for cosmetic purposes (Brenton-Styles pers. comm.) and Cleistanthus schlechteri that is used in the wood carving trade. Uncontrolled cattle grazing, random uncontrolled fires, as well as selective species utilisation also have an effect on the other woodland areas outside conservation areas.

Inclusion of Sand Forest in conservation areas is no guarantee of the future persistence of this vegetation type. The effects of large herbivores, regular fires and Sand Forest dynamics can lead to disappearance of this vegetation type. One such threat to Sand Forest within a conservation area is highlighted in TEP, the conservation area in South Africa with the greatest amount of protected Sand Forest. The two primary reasons for the proclamation of TEP were that of Sand Forest conservation and the protection of the natural elephant population of Maputaland. This has lead to a clash of interests between Sand Forest and elephant. Although these elephant prefer plant species from woodland habitats, they are increasingly utilising Sand Forest species. This is mainly due to the fact that old movement patterns have been fenced off and the elephant are now confined to a relatively small reserve. Since the old elephant movement routes were closed off in 1989, negative effects on Sand Forest and associated vegetation types in TEP have increased markedly (Matthews and Page unpublished results).

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References

Alvin KL (1987) Leaf anatomy of Androstachys johnsonii Prain, and its functional significance. Annals of Botany 59: 579–591
Arnold TH, De Wet BC (eds) (1993) Plants of southern Africa: names and distribution. Memoirs of the Botanical Survey of South Africa 62: 1–825
Bahr CM, Bredenkamp GJ (1988) A phytosociological classification of the Witwatersrand National Botanical Garden, South African Journal of Botany 54: 525–533
Botha GA (1997) The Maputaland Group: a provisional lithostratigraphy for coastal KwaZulu-Natal. In: Botha GA (ed.) Maputaland: Focus on the Quaternary Evolution of the South-East African Coastal Plain, field guide and abstracts. Council for Geoscience, Pretoria, South Africa, pp 21–26
Bredenkamp GJ, Joubert AF, Bezuidenhout H (1989) A reconnaissance survey of the vegetation of the plains in the Pofinhoof-Fochville-Parys area. South African Journal of Botany 56: 54–64
Bruton MN, Cooper KH (eds) (1980) Studies on the Ecology of Maputaland, Rhodes University and Wildlife Society of South Africa, Grahamstown and Durban, South Africa
Clausen SC (1938) Phytosociology, vegetation structure and landscapes of the Central District, Kruger National Park, South Africa. DSc Thesis, University of Pretoria, Pretoria, South Africa
Cowling RM (1993) Phytoclimatology and vegetation history in the southeastern Cape, South Africa. Journal of Biogeography 20: 393–414
Davies O (1976) The older coastal dunes in Natal and Zululand and their relation to former shorelines. Annals of the South African Museum 71: 19–32
De Moor PP, Pocock E, Neville G, Barichewy J (1977) The vegetation of Ndimu Game Reserve, Natal: a quantitative phycosociological survey. Annals of the Natal Museum 23: 239–272
Edwards D (1983) A broad-scale structural classification of vegetation for practical purposes. Bothalia 14: 705–712
FAO–Unesco (1974) Soil Map of the World. Vol. 1. Legend by R Duda et al. Unesco, Paris, France
Geological Survey (1986) Geology map 1:250 000 geological series: 2632 Kosi Bay. Government Printer, Pretoria, South Africa
Goodman PS (1990) Soil, vegetation and large herbivore relations in the Mkuzi Game Reserve, Natal. PhD Thesis, University of Natal, Pietermaritzburg, South Africa
Granger JE (1996) Subhumid Lowveld Bushveld. In: Low AB, Rebelo AG (eds) (1996) Vegetation of South Africa, Lesotho and Swaziland. Dept. Environmental Affairs & Tourism, Pretoria, South Africa
Holladay DK (1976) Quaternary sedimentation and development of the lagoonal complex, Lake St Lucia, Zululand. Annals of the South African Museum 71: 93–113
Hopkins B (1979) Forest and Savanna. An Introduction to Tropical Terrestrial Ecology with Special Reference to West Africa. 2nd edn. Heinemann, London, UK
Klinkelhoefer EW (1987) Aspects of the ecology of the elephant Loxodonta africana. Journal of the South African Institute of Plant Cultivators 18: 89–94
Klinkelhoefer EW (1987) A management plan for the Tendele Elephant Reserve in Tshing, KwaZulu. MSc Thesis, University of Pretoria, Pretoria, South Africa
Krugert GP (1986) A report on the results of a hydrogeological and geomorphological survey. In: An investigation into the feasibility and economy of rice cultivation on the Ngwamusa coastal plain, Northern Natal. Unpublished report. Industrial Development Corporation, Johannesburg
Land Use Survey Staff (1986), Land types of the map 2632 Mkuzu. Memoirs on the Agricultural Natural Resources of South Africa 6
Low AB, Rebelo AG (eds) (1996) Vegetation of South Africa, Lesotho and Swaziland. Dept. Environmental Affairs & Tourism, Pretoria, South Africa
Liddle RA (1996) Vegetation and flora of the Kosi Bay Coastal Forest Reserve in Maputaland, northern KwaZulu-Natal, South Africa. MSc thesis, University of Pretoria, Pretoria, South Africa
Maud RR, Botha GA (1993) Floristics of the Natal Indigenous Forests. In: Geidenhuyze, ECJ (ed) Biogeography of the Mixed Evergreen Forests of Southern Africa. Occasional Report 45, Ecosystems Programmes, Foundation for Research Development, Pretoria, South Africa, pp 124–144
Malherbe SJ (1984) The geology of the KwaZulu-Natal National Park. Koedoe Supplement: 33–44
Marker ME, Russel SJ (1984) The application of biogeographic techniques to forest site-factor analysis. South African Geography Journal 65: 65–78
Matthews WS, Van Wyk AE, Bredenkamp GJ (1993) Endemic flora of the North-eastern Transvaal escarpment, South Africa. Biological Conservation 63: 83–94
Matthews WS, Van Wyk AE, Van Rooyen N (1999) Vegetation of the Sileza Nature Reserve and neighbouring areas, South Africa, and its importance in conserving the woody grasslands of the Maputaland Centre of Endemism. Bothalia 29: 151–167
Maunderest, Boitha GA (2000) Decomists of the south eastern and southern coasts. In: Partridge TC, Maud RR (eds) The Cenozoic of Southern Africa. Oxford University Press, Oxford, UK, pp 19–32
Mentis MT (1981) Evaluation of the wheel-point and step-point methods of veld condition assessment. Proceedings of the Grassland Society of Southern Africa 16: 89–94
Migidley JJ (1993) Biogeographic and other perspectives on the management and conservation of forests patches. In: Edwards D (ed.) The Relevance of Island Biogeographic Theory in Commercial Forestry. Foundation for Research Development, Pretoria, South Africa, pp 67–71
Migidley JJ, Cowling RM, Seydack AHW, Van Wyk GF (1997) Forests. In: Cowling RM, Richardson DM, Pierce SM (eds) Vegetation of Southern Africa. Cambridge University Press, Cambridge, UK, pp 279–299
Moli EF (1977) The vegetation of Maputaland — a preliminary report on the plant communities and their future conservation status. Trees in South Africa 29: 31–58
Moli EF (1980) Terrestrial plant ecology. In: Bruton MN, Cooper KH (eds) Studies on the Ecology of Maputaland. Rhodes University & Wildlife Society of SA, Grahamstown & Durban, South Africa, pp 52–68
Moli EF, White F (1978) The Indian Coastal Belt. In: Wenger MJA (ed) Biogeography and Ecology of Southern Africa. Junk, The Hague, pp 575–598
