The afromontane forests of Transkei, southern Africa. I: The importance of phytogeography and past utilization to the study of forest patches and a description of a sampling strategy

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A brief overview of the distribution and exploitation of forests in southern Africa is presented as a basis for a sampling design and classification of forests. A sampling strategy was adopted for the quantitative study of disjunct forest patches in Transkei. The approach, which has not been used in southern Africa, is described.

'n Kort oorsig van die verspreiding en ontginning van inheemse woude in suidelike Afrika word voorgelê as basis vir die bemonstering en klassifikasie van woude. 'n Bemonstering-strategie vir die kwantitatiewe studie van geïsoleerde woude in Transkei is ontwikkel. Die strategie, wat nie tevore in suidelike Afrika gebruik is nie, word beskryf.

Keywords: Biogeography, exploitation, forest, sampling, synecology

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Introduction

This paper consists of two parts; the first part briefly reviews research and management reports pertaining specifically to phytogeography, management and community studies in southern African forests. The review is done on a regional basis and in chronological sequence in an attempt to highlight the effects of previous exploitation, the success of the various methodologies that have been used in community studies and to identify areas that have been poorly classified. Geldenhuys' (1985) bibliography is used to determine literature trends. Publications (e.g. Bredenkamp & Theron 1978, 1980) which are listed in the bibliography but deal essentially with formations other than forest are not considered.

The second part of the paper is a description of the sampling strategy adopted for the quantitative community study of the afromontane forests of Transkei. The sampling strategy, which takes into account forest size, has not been used in southern African forests before. This exercise was done in an attempt to evaluate the feasibility of extracting timber from the indigenous forests of Transkei on a commercial basis.

Literature survey

Phytogeography

The forest biome has been defined by the dominance of phanerophytes (Rutherford & Westfall 1986), with trees having a continuous cover (White 1978) and a projected canopy cover of at least 75% (Edwards 1983). In southern Africa canopy height varies between 10 m and 30 m depending on site factors (Acocks 1953; Moll & White 1978; White 1983). Other characteristics of the forest biome include the abundance of climbers and epiphytes (Hall & Swaine 1981) and the absence of fire and C_4 grasses (Huntley 1984). In the early literature (e.g. Sim 1907) the term 'forest' included both high forest (the subject of the present paper), scrub forest and various types of open woodland characterized by *Acacia* and *Protea* spp. Although scrub forest is generally shorter and has a lower canopy cover, it cannot always be distinguished clearly from high forest. White (1983) elaborates on the similarities and differences of these vegetation types.

In southern Africa the forest biome occurs in scattered patches covering some 200 000–300 000 ha on the eastern margin of the country (Figure 1). Huntley (1984) divides it into an afromontane and a lowland component. The afromontane component, which is part of White's (1983) region by the same name, occurs from Louis Trichardt (23°S) to the Cape peninsula (34°S), and the lowland component, which is part of White's (1983) Tongaland–Pondoland regional mosaic, occurs from the mouth of the Limpopo River (25°S) to Port Elizabeth (34°S). Moll & White (1978) recognize five forest types in the lowland forest biome: undifferentiated lowland, dune, swamp, sand and fringing forest. The latter two are restricted to the northern extremity of the biome while swamp forest is found as far south as Transkei. Undifferentiated lowland forest reaches the eastern Cape and dune forest is found throughout the biome. Cooper (1985) further divides lowland forest into two types: coastal and scarp forest on both floristic and faunal differences.

Interest in the phytogeography of southern Africa has been very keen since the 19th century, and according to Bayer (1970) the first vegetation map was published by Drège in 1845. Numerous attempts have since been made at mapping and classifying both the vegetation and the flora, the number of phytochorological taxa

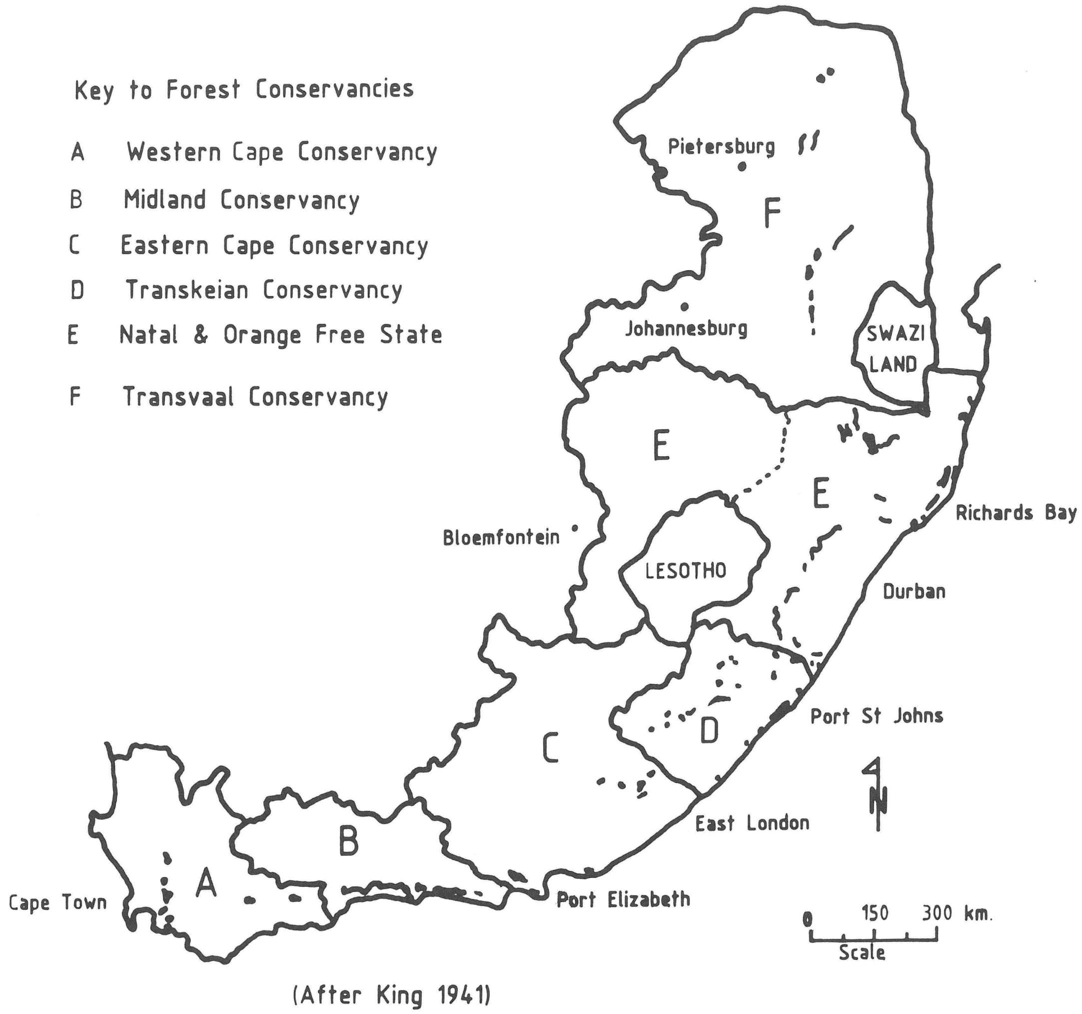

Figure 1 Distribution of the afromontane forest biome and conservancies in southern Africa.

increasing with the burgeoning knowledge of the flora (Werger 1978). The various authors were never unanimous on taxonomic ranks or on the boundaries of their phytochoria. The discrepancies were, to a large extent, due to a lack of consensus on nomenclature, each worker making his own subjective decisions as to the rank and extent of each floristic unit. Another problem was, and still is, that the distribution ranges of plants rarely coincide, adjacent floras tending to merge into one another over broad and diffuse zones of transition (Good 1974).

Werger (1978) divides the South African flora into 6 regions, two of them, the Tongaland–Pondoland Region and the Afromontane Region, encompassing the forest biome. In a departure from the orthodox practice of dividing floras into mutually exclusive phytochoria in a heirarchical system, White (1978, 1983) proposes a non-hierarchical phytochorology which highlights broad transition zones by giving them equal status with centres of endemism. A further innovation in South African phytochorology is the use of multidimensional scaling and cluster analysis by Knight *et al.* (1982). In spite of the differences in approach, the latest floristic classifications are comparable and are based either exclusively or mainly on the distribution of trees.

White's (1978, 1983) Tongaland–Pondoland regional mosaic is widest in the north where it reaches up to 240 km and, in contrast, is never more than 8 km wide in the south. This region, which includes both a tropical and subtropical flora, penetrates into the interior in finger-like projections along the major river valleys. Bews (1921, 1922) regards the sub-tropical flora as derivative from tropical species which, in their southward migration, responded to the colder and drier conditions of the subtropics by becoming xeromorphic; the higher incidence of spinescence, compound leaves and capsular fruit being some of the adaptations to the new climate.

White's (1978, 1983) Afromontane Region, on the other hand, occurs in the hinterland on the highest mountains except at its southern extremity, where the effect of latitude compensates for altitude allowing for the occurrence of this flora along the coast (White 1978).

The occurrence of afromontane elements at increasingly lower altitudes and the migration of the sub-tropical flora from the coast inland along river valleys led to considerable intermingling of these floras. Seemingly, floristic overlap is much more pronounced in southern Africa than in East Africa because in an account of the afromontane flora of the latter, Moreau (1952) suggests that this flora is so different from the sub-tropical that the two must have evolved independently, yet Goldblatt (1978) quotes Hilliard as being of the opinion that many of the afromontane elements in southern Africa were derived from the lowlands, a view shared by White (1978, 1983). In Transkei, floristic overlap is very pronounced, 11 of the 12 species used by White (1978, 1983) to characterize the afromontane region occurring in the coastal forests. Von Breitenbach (1983) further estimates that 70% of the species in the afromontane region are also found along the coast. In this regard it is interesting to note that the phytochorology by Knight *et al.* (1982) does not differentiate between the afromontane and lowland components of the forest biome.

Despite the transitional nature of the tree flora of Transkei the afromontane forests are fairly distinct from the lowland forests, containing only about 50% of the species of the coastal forests (von Breitenbach 1983). What is more uncertain is the previous extent of forest coverage. Axelrod & Raven (1978) and van Zinderen-Bakker (1978) postulate that forests were more extensive under moister and cooler conditions, but of particular interest to phytosociology is the past coverage of the forests under the present climatic regime.

Clementsian principles have been applied in determining the former extent of the forest biome in southern Africa. Bews (1916, 1920) notes that because of topographic variation there are sharply contrasting climates over short distances and this has resulted in diverse climatic climaxes; the forest and grassland biomes being, by and large, climax in the localities in which they occur. Acocks (1953) concedes that habitats in which high forest can occur are limited and suggests that scrub forest was the actual vegetation over large areas in the high rainfall areas of southern Africa and had been cleared by man over the last five centuries.

Acocks' (1953) views have until very recently been prevalent in southern Africa. However, there has been a growing awareness that edaphic factors may have precluded the actual development of scrub forest even in those areas receiving sufficient rainfall. For example, King (1978) suggests that on ancient landscapes soils are leached to such an extent that they can only support grassland, while van Daalen (1981) has found that soil moisture is an important factor precluding the establishment of forest in fynbos areas. Tinley (1982) proposes that soil moisture balance determines the spatial distribution of various plant formations, 'forest occuring on high water-retaining, but relatively well-drained sites', a view shared by Butzer (1982). Rutherford & Westfall (1986) suggest that in some of the areas traditionally regarded as secondary grassland, winter temperatures are too low for the dominance of phanerophytes. A growing body of archaeological evidence suggests that grasslands have been widespread in some of the areas presumed by Acocks (1953) to have been forested (McKenzie 1984). In Transkei a survey of iron age settlement patterns has indicated that some agency other than human is responsible for the absence of trees in Acocks' (1953) Dohne and Highland sourveld grasslands (Feely & Granger 1984).

A study employing modern island biogeographical theory may be one way to explain the past extent of forest during the present climatic regime. An examination of the alpha diversities of various patches in the different regional complexes might help elucidate whether the patches were once linked up or not. What is certain is that man has been directly or indirectly responsible for modifying both the coverage and composition of southern African forests. This aspect is discussed in the following section.

Utilization and management

Trends in the volume of literature on the utilization and management of indigenous forests in southern Africa are illustrated in Figure 2. Most of the early literature comprised reports by forest conservators. Sim (1907) collated these reports into a single volume. As timber from the indigenous forests became exhausted during the second quarter of this century several reviews on the utilization and management of the indigenous forests were published, notably by Laughton (1937) and King (1938, 1939, 1941).

The large volume of literature on indigenous forests dating from 1960–1979 mostly reflects concern over the conservation status of the biome. Approximately half of these articles deal with the forests of Natal. Interest in the exploitation of the sand dunes of the same province led to the publication of a series of articles on dune forest ecology and management (e.g. Weisser 1978a, b; Weisser & Marques 1979). During the present decade most publications deal with the management of southern Cape forests often with emphasis on their conservation (e.g. Geldenhuys 1980, 1982a, b, 1983a, b, c; Grewar 1982, 1983).

For administrative purposes the Cape Colony was divided at the beginning of this century into four forest conservancies, namely: the Western, Midland, Eastern and Transkeian (Sim 1907). Later the conservancies of Natal, the Orange Free State and Transvaal were created (Figure 1). The conservancies largely reflect the regions as they exist today. Utilization of the forests by Europeans began in the Western conservancy and later spread eastwards and then north-eastwards, exploitation in the Transvaal commencing last. A brief history of the utilization and management of the forests is given here with emphasis placed on the order in which exploitation occurred.

Most of the indigenous forests of the Western conservancy were heavily exploited within a hundred years of the establishment of a revictualling station in the Cape Peninsula in 1652 (Laughton 1937; Immelman *et al.* 1973; Hartwig 1973; von Breitenbach 1974). The larger forests of the Midland conservancy were first commercially exploited in 1772 (King 1941). Von Breitenbach (1974) describes the history of these forests as one of 'destruction and devastation on the one hand, and of a continuous struggle for their conservation on the other'. Although most of the timber was worked by hand, several sawmills were established from 1873 onwards and were moved from forest to forest as timber became exhausted (Laughton 1937; King 1941). In 1941

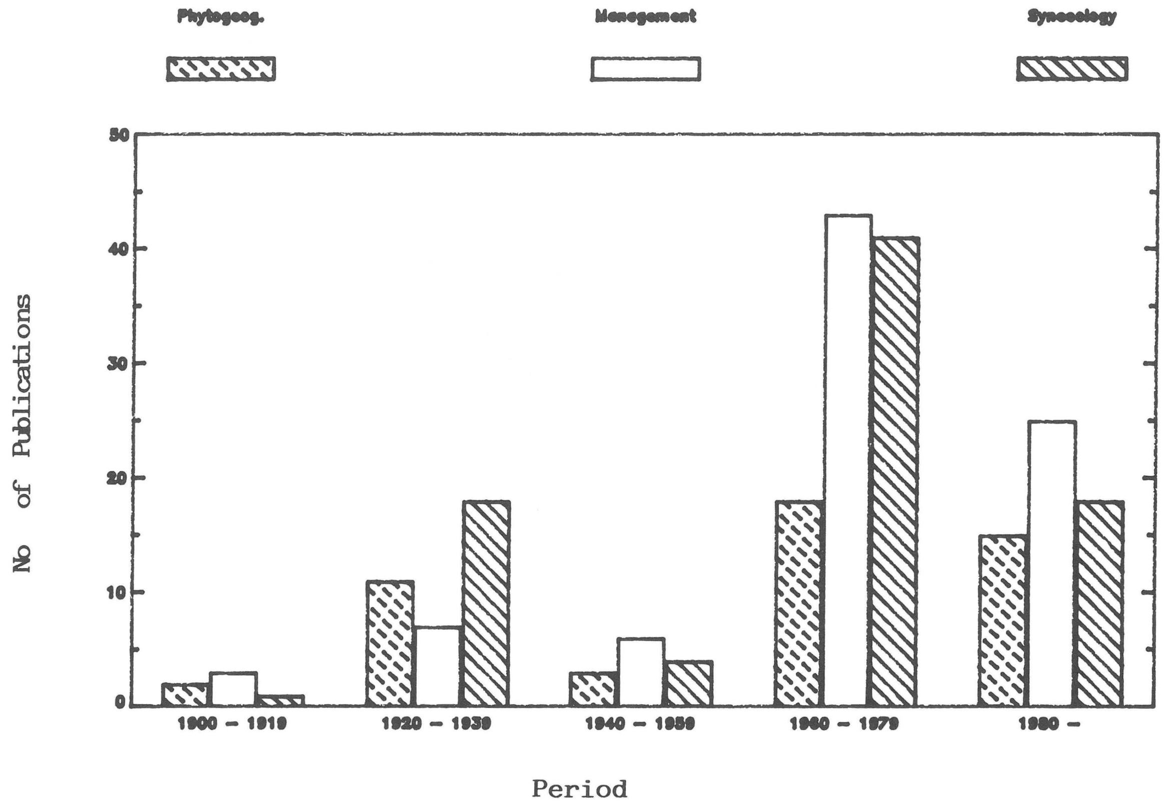

Figure 2 Literature trends on several aspects of the ecology of the indigenous forests of southern Africa.

it was estimated that only 19% of the 65 000 ha of forest were still exploitable (i.e. in near virgin condition) the rest either having been exhausted or reduced to scrub (King 1941; Grut 1965).

The forests of the Eastern conservancy are much smaller and comprise an inland afromontane component and an undifferentiated coastal lowland component (King 1941; White 1983). Commercial exploitation in these forests began shortly after 1847 and by 1938 it was estimated that 88% of them had been exhausted (King 1941). Other than commercial logging these forests had been utilized for many years by the indigenous population for hut building; saplings being cut by the thousand for this purpose. With the notable exception of Manubi forest which was strictly protected by paramount chief Sarili of the Gcaleka tribe until his defeat by the British in 1878 (King 1940), exploitation in the Transkeian conservancy followed a pattern similar to that of the eastern Cape; uncontrolled commercial and subsistence exploitation only being checked after the establishment of a forestry service in 1888. King (1941) estimates that by 1941 only 15% of the afromontane forests had not been exhausted of commercial timber while the coastal forests had suffered less because of the lower quality of timber.

The Orange Free State had very few indigenous forests, but both Natal (including Zululand) and Transvaal had considerable areas of high forest. The arrival of Europeans in these two areas coupled with mining and sugarcane development were largely responsible for large tracts of forest being cleared and large quantities of timber being removed from the remaining forests. In contrast to other conservancies most of the forests in Natal and the Transvaal were sold to private individuals and were consequently devastated to a larger degree (King 1941). Cooper (1985) found most of these privately owned forests in very poor condition and that the owners of the land on which they occur are generally ignorant of their ecological significance.

From the foregoing it is obvious that the greater percentage of the indigenous forests of southern Africa have been disturbed and although this did not lead to the local extinction of species, it certainly must have had considerable effect on population structure. Grut (1965) states that although the annual average cut might have been low on an area basis it was 'enough to affect the quality of the forests, for the rate of growth was slow, the methods of exploitation very wasteful, and the principles of good sylviculture were not adhered to'. In light of the above it is essential that quantitative species data be collected in any forest community study. Previous classifications have largely ignored this aspect as is pointed out in the following section.

Plant community studies

The earliest studies of forest communities in southern Africa were done from a utilitarian point of view, many of the subtropical forests along the coast often being described as 'poor' on account of their low stocking of commercially valuable species, while afromontane forests were described as high quality (e.g. Fourcade 1889; Sim 1907).

Studies of indigenous forests from an ecological perspective began during the first decade of this century, and were greatly influenced by Clements' (1916) ideas of plant succession. (e.g. Phillips 1931). Phytosociological studies using the Zurich–Montpellier method began with van Zinderen-Bakker's (1971) study of the afromontane forests of the Orange Free State. Myre (1964, 1971) used the technique in the coastal forests of southern Mozambique and numerous studies have been carried out in the afromontane forests of the western Cape (e.g. Boucher 1972; Werger *et al.* 1972; Glyphis 1976; McKenzie *et al.* 1976, 1977; Campbell & Moll 1977; McKenzie 1978). Association analysis (Williams & Lambert 1959, 1960), the first quantitative multivariate classificatory technique to be used in South African forests, was employed by Granger (1976) in small patches of afromontane forests and scrub in Natal. Scotcher (1983) classified several small forest patches of Natal using Sokal & Sneath's (1963) average linkage, weighted pair method, Orloci's (1967) within-group sum of squares method and Orloci's (1976) clustering algorithm TRGRPS.

Most of the phytosociological works quoted above led to rapid classifications based essentially on presence and absence data, but did not yield practical classifications because of the lack of quantitative data which is vital to forest management.

Save for Phillips' (1931) subjective classification, neither the Braun–Blanquet technique nor any of the recent multivariate classificatory techniques have been employed in the southern Cape although this region contains some of the largest tracts of afromontane forest in the subcontinent. These techniques have not been employed in Natal (apart from the minor classifications referred to above) or Transkei, both of which have considerable areas of indigenous forest.

Ordination has been used more frequently in both the afromontane and coastal forests of Natal (Moll 1968, 1969, 1971, 1978a, b, 1980a, b, c). Other ordination studies in Natal included the work by Moll & Woods (1971) and Morris (1969) while McKenzie (1978) carried out an ordination of the afromontane forests of the south-western Cape. The technique employed in all these studies was polar ordination developed by Bray & Curtis (1957).

The volume of literature on community studies in southern Africa over the past 85 years is illustrated in Figure 2. The decrease in the volume from 1940–1960 was partially due to the exhaustion of timber in the forests, rendering them less important economically. The resurgence of ecological studies beginning in the 1960's was motivated mainly by academic interest and the growing concern over the conservation status of the forests. Other studies were initiated as an aid to planning (e.g. Moll 1965, 1971; Edwards 1967).

Sampling design

The present study represents the first attempt at using a multivariate classificatory technique in substantial areas of forest in southern Africa. The sampling design described below has not been used before, the selection of forest stands in the past having been done subjectively, preference being given to the 'best' patches of forest (usually synonymous with the largest), and interpatch relationships scarcely being considered. Transkei has hundreds of patches of afromontane forests ranging from 0,5 ha to several hectares in size. For a number of reasons it was essential to survey both the smaller and larger forests. Firstly, it was presumed that the heaviest commercial exploitation had occured in the larger forests and consequently the composition of their canopy was more drastically altered than in smaller forests. Secondly, the smaller forests are often found close to existing sawmill operations and thus needed to be considered for their exploitation potential. The sampling strategy thus had to cover as broad a spectrum of forest sizes as possible.

Afromontane forest patches in Transkei comprise both demarcated and undemarcated forests. The demarcated forests were surveyed and mapped at the beginning of the century, records of their areal extent being kept by the government whereas undemarcated forests were never surveyed and their total area is unknown. Demarcated forests are high-quality timber forests whereas undemarcated forests are scrubby and of low economic value (Sim 1907). In the present study only the demarcated forests were considered. The demarcated forests comprised 541 patches scattered along a 300-km escarpment covering some 2 000 km^2 (Figure 3). The time available to the survey allowed for only two hundred 0,04-ha plots to be sampled and the sampling design thus had to cater for the objective location of these plots in the 541 patches. The forests were sampled using a three-stage technique following the method suggested by Hansen & Hurwitz (1943).

Stratification into geographical zones

The study area was stratified into six geographical zones. Each zone comprised a fairly distinct group of forests, which were presumed to differ floristically (Figure 3). Zone A comprised a group of small forests at the south-western extreme of the study area where rainfall is generally low. Zone B comprised much larger forests which receive higher rainfall. The forests in zone C occur on a range of hills further from the sea than zone B and were therefore probably drier. Forests in zone D were expected to contain a substantial admixture of sub-tropical species. Miller's (1922) observation that *Ocotea bullata* (Burch) E. Mey. is more abundant in zone D than elsewhere gave more credence to the idea that these forests were floristically distinct. The patches in zone E occur furthest inland and at the highest altitude and were therefore presumed to differ from the rest. Zone F was considered floristically distinct on account of the greater abundance of *O. bullata* and *Podocarpus henkelii* Stapf ex Dallim. & Jacks (Sim 1907).

Allocation of plots to zones

The 200 plots were allocated to the zones in proportion to the amount of demarcated forest in each zone as follows:

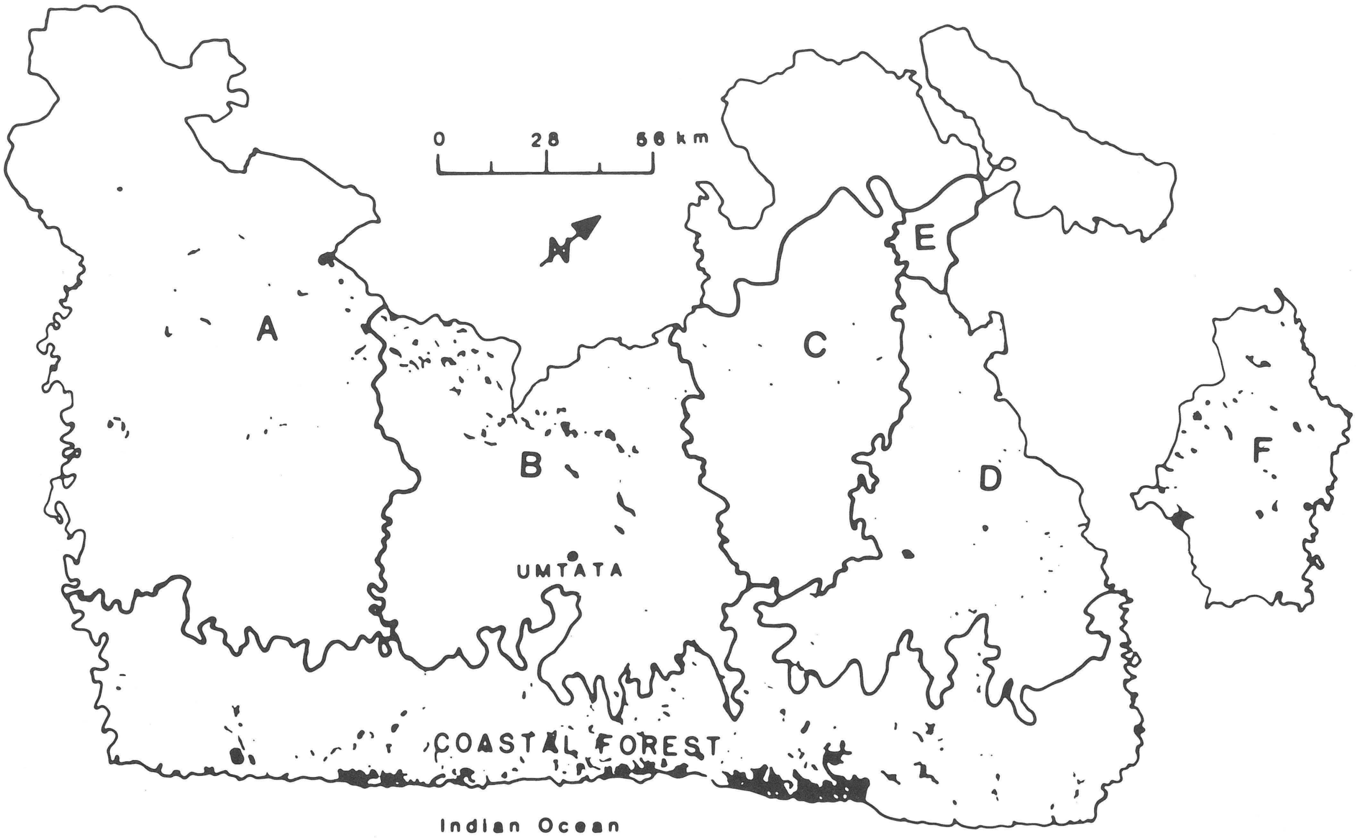

Figure 3 Distribution of indigenous forests and sampling zones in Transkei.

$$Q_i = 200\ (\sum_j a_{ij})\ /\ \sum_{ij} a_{ij}$$

where Q_i is the number of plots in the ith zone, a_{ij} is the area of the jth demarcated forest in the ith zone, $\sum_j a_{ij}$ is the total area of demarcated forest in the ith zone and $\sum_{ij} a_{ij}$ is the area of demarcated forest in all zones. The number of plots allocated to the six zones is presented in Table 1.

Allocation of plots to forests

In each zone the plots were allocated to the forests such that the probability of allocating a plot to a particular forest was proportional to the size of that forest. This was accomplished by allocating a set of D_{ij} numbers to each forest such that D_{ij} was proportional to the area of the ith forest in the ith zone, and a cumulative sum of D_{ij} was calculated from the first forest to the last from which a set of Q_i numbers was randomly drawn; the number of plots allocated to a forest being equal to the set of randomly selected numbers corresponding to it. The set of D_{ij} numbers was calculated as follows :

Let a_{ij} = the area of the ith forest in the ith zone, and $A_i = \sum_j a_{ij}$ = the total area of forest in the ith zone

then $p_{ij} = a_{ij} / A_i$ = proportion of jth forest area out of total area of forest in the ith zone.

Let C be a constant such that Cp_{ij} is a convenient integer

Table 1 The area of demarcated forest, the number of forests, the number of selected forests and the number of plots chosen for each of the six zones

Zone	Area (ha) of demarcrated forest	Number of demarcrated forests	Number of forests selected	Number of plots
A	3 442	108	23	27
B	9 922	204	42	77
C	4 180	101	21	33
D	3 743	81	18	29
E	509	21	4	5
F	4 420	26	14	29
Total	26 316	541	122	200

Table 2 Comparative size distribution between demarcated and selected forests in Transkei

Forest size (ha)	No. of forests in Transkei	No. of forests selected
50 & less	410	47
50–99	63	25
100–149	33	21
150–199	12	6
200–249	5	5
250 & larger	18	18
Total	541	122

then $D_{ij} = Cp_{ij}$ = integer associated with the proportional area of the ith forest in the ith zone.

A set of D_{ij} numbers was allocated to the ith forest of the ith zone as follows:

j th forest	set of D_{ij} numbers
1	1 to D_{i1}
2	$(D_{j1} + 1)$ to $(D_{i1} + 1 + D_{i2})$
3	$(D_{i1} + D_{i2} + 2)$ to $(D_{i1} + D_{i2} + 2) + (D_{i3})$

$$k \quad \sum_{j=k-2}^{k-1} D_{ij} + (k-1) \text{ to } \sum_{j=k-2}^{k} D_{ij} + (k-1)$$

The results of this procedure are summarized in Table 2. In the population of demarcated forests 76% were less than 50 ha and only 32 were equal to or greater than 250 ha. In the sample only 38% of the forests were less than 50 ha and 14% were equal to or greater than 250 ha. Furthermore, all forests equal to or greater than 200 ha were sampled, but only a fraction of the smaller forests was sampled.

Sampling within a forest

Lack of time precluded the objective placement of plots within each selected forest and consequently the plots were placed subjectively in visually assessed homogeneous and representative stands. Details of the data collected within each plot and the method of analysis are discussed elsewhere (Cawe & McKenzie 1989).

Conclusions

Past exploitation of indigenous forests in southern Africa has greatly affected the composition of the forests especially in terms of population structure. Any regional survey of the forests needs to take into account both the larger and smaller forest patches and data collected should be quantitative. Most classifications to date have concentrated on the larger patches of forest and used qualitative data. The sampling design used in Transkei allowed for a broad spectrum of forest sizes and locations to be sampled and its success (Cawe & McKenzie 1989) suggests that it could be more widely used in regional studies of the vastly disjunct forest biome.

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