Veröff.Geobot.Inst.ETH, Stiftung Rübel, Zürich 87 (1986), 205-215

An application of the quarter sampling method to savanna vegetation in Umfolozi Game Reserve, Zululand

Anwendung der Quadranten-Methode für die Savannen-Vegetation im Umfolozi Wildreservat, Zululand

by

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1. INTRODUCTION

Rapid methods for quantitatively sampling large areas of vegetation have been developed in the temperate zone, but have seldom been used in tropical areas, perhaps because of the large number of species and apparent heterogeneity of the vegetation. For example, the point-centered quarter method (COTTAM and CURTIS 1956) has been used for sampling vegetation in temperate zone forests and savannas. This paper describes an application of the quarter method in Umfolozi Game Reserve, Zululand, which is at 28° south latitude and approximately 50 km inland from the Indian Ocean.

This region is characterized by a hot summer and a dry, frost-free 'winter' season. Umfolozi is within the region of tropical forest and savanna according to ACOCKS (1953), and is included specifically in his Lowveld and Zululand Thornfeld types.
Four stands, each approximately two hectares in area, which appeared to have relatively homogeneous vegetation were selected for study. In each stand, most of the trees were 3 to 5 m tall. In all four stands, Acacia species appeared to be more conspicuous than other species. Topographic conditions were similar in the two sets of stands. Stands 1 and 2 were adjacent to one another on an east slope of approximately 5^{o}, stand 1 being higher up the slope than stand 2. Stands 3 and 4 were adjacent to one another On an east slope of 5^{o}, stand 3 being higher up the slope than stand 4. Stands 1 and 2 were several km away from stands 3 and 4.

ACKNOWLEDGEMENTS

This study was carried out while the author was visiting lecturer in Botany at the Univ. of Natal, Pietermaritzburg, and visiting biologist with the Natal Parks, Game and Fish Preservation Board, Republic of South Africa. I thank Dr. Brian Downing for his help in identifying plants and assistance in field sampling.

2. FIELD METHODS

Each of the four stands was sampled by using 20 points with about 25 m between points. This distance was usually long enough to prevent the same tree from being sampled twice. At each point, quarters were demarcated by the direction of the line of pacing and a line crossing it at right angles. The nearest tree or shrub in each quarter having a stem diameter of more than 2.5 cm at breast height was recorded. The distance from the point to the nearest plant (hereafter called tree) in each quarter was measured with a range-finder; thus 80 trees and 80 distances were recorded per stand. From this can be calculated number of trees per hectare.
Basal area or diameter of the trunks of trees is often measured as an indication of the size of trees. In this study, aerial cover or canopy

area was used instead for two reasons. First, with the summer sun nearly overhead in the subtropics at mid-day, the shade cast by tree canopies probably is important in determining the distribution of species growing in the ground layer. Secondly, measurement of basal area or diameter would have been complicated because many of the trees have multiple stems. By measuring the diameter of the crown in two directions (broadest and narrowest spread), canopy area can be calculated.

3. ANALYTIC METHODS AND RESULTS

Quantitative data obtained from the samples permit description and comparison of the stands. The analytic methods used are described by (or modified from) CURTIS and COTTAM (1962). Data calculated for each species are described.

The **frequency** of each species is the number of the 20 points at which the species was recorded in the stand. **Canopy area** for each tree was obtained by taking the square of the average radius of its canopy and multiplying this value by 3 (rather than by π = 3.1416). This value was used because canopy dimensions were thought to have been slightly overestimated during sampling due to irregularity in the canopy edge and gaps in the canopy. The total canopy area for each species was obtained by summing the canopy areas of all individuals of each species. **Average canopy** and **canopy per hectare** (sq. m) were calculated. Tree **density per ha** (for each species, and totals per stand) were calculated.

The distribution of individuals of a species throughout a stand (frequency), and the number (density) and size (dominance) of the individuals are important aspects contributing toward which species are most important in a stand. A cumulative index combining these three measures (as **relative frequency, density** and **dominance** totaling 100% each) into an **Importance Value** of 300 is described by CURTIS (1959), and by CURTIS and COTTAM (1962). This Importance Value was divided by 3 to give an IV expressed as a percentage.

Table 1 compares for all species in the four stands what I believe to be the most meaningful statistics: Importance Value %, density per hectare, average canopy area in square meters, and relative dominance. Subtotals

	Stand 1				Stand 2				Stand 3				Stand 4			
	IV	D/H	AC	RDo	IV	D/H	AC	RDo	IV	D/H	AC	RDo	IV	D/H	AC	RDo
Acacia burkei	5.3	5.0	51.1	8.8												
A. caffra	1.2	1.5	13.7	.8												
A. gerrardii	12.6	19.2	18.7	12.9					14.0	10.8	13.0	12.4	6.5	8.2	20.0	8.1
A. karroo	3.5	5.0	19.8	3.4	12.7	9.7	23.6	11.6	14.7	12.6	9.2	10.4	2.4	3.3	8.5	1.4
A. nilotica	26.6	33.5	24.1	29.1	29.6	24.4	26.8	33.1	26.8	21.9	16.0	30.4	27.8	39.6	15.4	29.8
A. senegal									13.4	13.6	5.6	6.8				
A. tortilis	10.1	11.2	29.0	11.7	17.7	14.6	27.6	20.4	8.9	5.8	21.4	11.3	25.4	34.6	17.7	29.8
Sub-total																
Acacia species	59.3	75.3	24.6	66.7	60.0	48.7	26.4	65.1	77.8	64.4	12.4	71.3	62.1	85.7	16.5	69.1
(3 leading Acacias)	(49.3	64.0	23.2	53.7)	(60.0	48.7	26.4	65.1)	(49.7	38.0	15.8	54.1)	(59.7	82.4	16.8	67.7)
Grewia monticola	1.2	1.5	13.7	.8												
Euclea daphnoides	1.4	1.5	22.6	1.3												
Euclea divinorum	3.3	5.0	6.1	1.1	1.0	1.0	2.5	.1								
Peltophorum africanum	1.4	1.5	22.6	1.3	5.8	3.0	55.4	8.2								
Ziziphus mucronata	6.5	8.0	23.3	6.7	14.9	12.7	17.0	10.9	2.1	2.0	4.0	.7	7.3	8.2	17.8	7.3
Maytenus heterophylla	2.2	3.2	7.0	.8	3.6	3.0	10.6	1.6	4.5	4.0	10.4	3.6	3.3	5.0	4.6	1.1
Dichrostachys cinerea	11.1	14.3	20.4	10.5	2.4	2.0	11.8	1.2					2.4	3.3	7.3	1.2
Rhus pentheri	10.7	14.3	15.2	7.9	2.2	2.0	6.2	.6					5.6	6.6	15.1	4.9
Sclerocarya caffra	1.6	1.5	33.8	1.9	5.3	2.0	100.1	10.0					3.2	3.3	23.0	3.7
Xeromphis rudis	1.3	1.5	18.0	1.0	1.2	1.0	10.0	.5					2.3	3.3	5.6	.9
Tarchonanthus camphoratus					1.2	1.0	13.7	.7								
Ximenia caffra					1.1	1.0	4.5	.2								
Pappea capensis					1.3	1.0	18.0	.9	1.7	1.0	28.0	2.4				
Dovyalis sp.									3.6	1.0	90.4	7.9				
Phyllogeiton zeyheri									1.9	1.0	33.8	2.9				
Schotia capitata									1.0	1.0	.3	.1				
Spirostachys africana									1.7	1.0	28.0	2.4				
Olea africana									1.1	1.0	4.5	.4	1.2	1.6	7.0	.6
Rhus spinescens									2.5	1.0	54.7	4.8	3.4	3.3	25.8	4.2
Sideroxylon inerme									2.1	1.0	40.2	3.5	1.1	1.6	4.5	.4
Cadaba natalensis													1.2	1.6	10.0	.8
Combretum apiculatum													1.0	1.6	2.5	.2
Grewia occidentalis													1.2	1.6	10.0	.8
Maytenus senegalensis													1.1	1.6	4.5	.4
Schotia brachypetala													2.4	1.6	54.7	4.4
Scolopia zeyheri													1.1	1.6	4.5	.4
Sub total																
non-Acacia species	40.7	52.7	17.6	33.3	40.0	29.2	23.5	34.9	22.2	13.6	23.5	28.7	37.9	46.3	13.7	30.9
Total all species	100.0	128.0	21.8	100.0	100.0	78.0	25.3	100.0	100.0	78.0	14.3	100.0	100.0	132.0	15.5	100.0

are given for the Acacia species. Ecological trends are not necessarily implied by the order in which the species are listed. The ordering is to facilitate seeing which species occurred in which stands.

Canopy per hectare per species is equivalent on a percentage basis to relative dominance. Since canopy per hectare is obtained by multiplying average canopy by numbers per hectare, it is a direct reflection of both density and dominance or canopy size. As pointed out by GREIG-SMITH (1964), relative frequency, density and dominance can be combined in markedly different ways to give the same IV. Further, since frequency is a controversial measurement, and since the shade aspect of canopy is important in savannas, it is possible that frequency (and therefore IV) should not be used. In that case, relative dominance (i.e., relative canopy per hectare) may be the best indication of the contribution made by each species to the composition of a stand.

The use of relative dominance to indicate importance in the savanna is equivalent to the use of dominance as an indication of importance which was described in a study of the coast forests of Natal (ROGERS and MOLL 1975). However, in the forest study, relative dominance was calculated from the basal areas of the trunks of the trees, whereas in the savanna study it is calculated from canopy areas. In each case, it is the easiest quantitative measure of 'size', and in addition may be the single aspect which best reflects the relative importance of the species. Note that IV and RDo give similar rankings for species importance, however.

Since there are few quantitative data published on this type of savanna community in southern Africa, a summary average of the results from the four stands is given. An average of 16 species of woody plants, of which 4 or 5 were Acacia species, was sampled in a two hectare stand. The

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Table 1 (page 208). Comparison of importance value % (IV), tree density per hectare (D/H), average canopy area in square meters (AC), and relative dominance % (RDo) for all species in the four stands. The three leading species in each stand based on relative dominance (all Acacia) are underlined and totals are shown for them.

Tab. 1 (S. 208). Vergleich der Importanzwertes % (IV), der Baumdichte/ha (D/H), des Kronenschlusses in m^2 (AC) und der relative Dominanz % (RDo) aller Arten in den vier Beständen.
Die drei vorherrschenden Arten in jedem Bestand, basierend auf der relativen Dominanz (alle Acacia), sind in der Tabelle unterstrichen und die Summe ist angegeben.

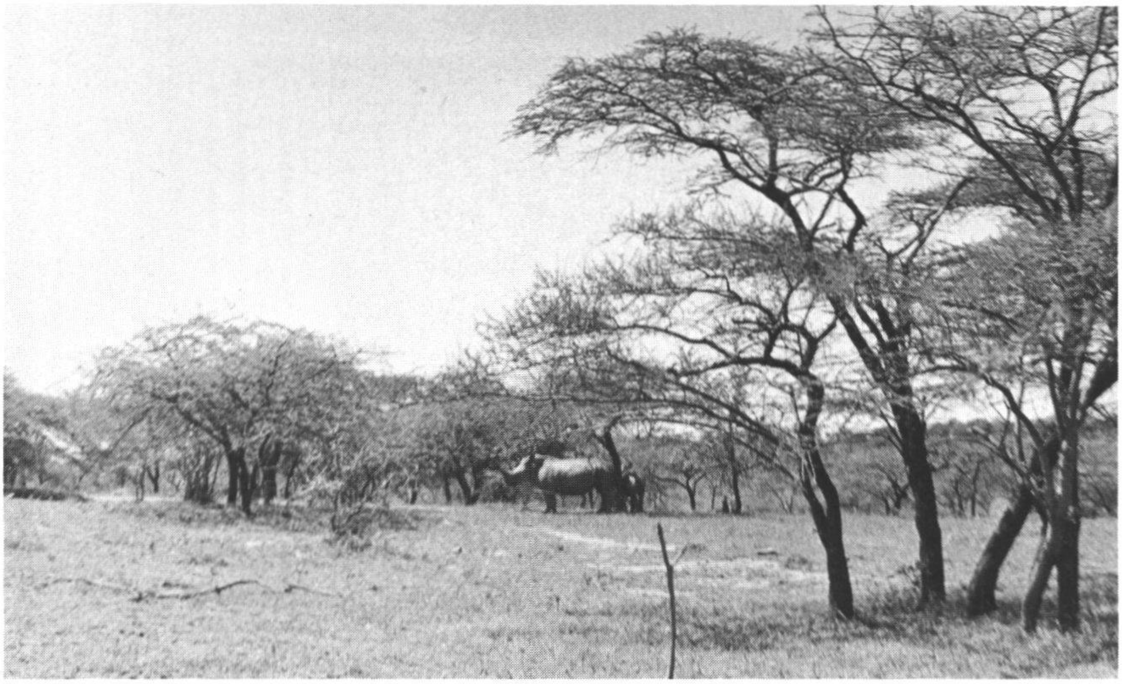


Fig. 1. A white rhinocerous, Ceratotherium simum, 5 to 6 feet tall at the shoulders, rests in the shade at mid-day in stand number 1. The grazing of white rhinos is partly responsible for the short herb-layer. A group of Acacia tortilis trees is in the right foreground.

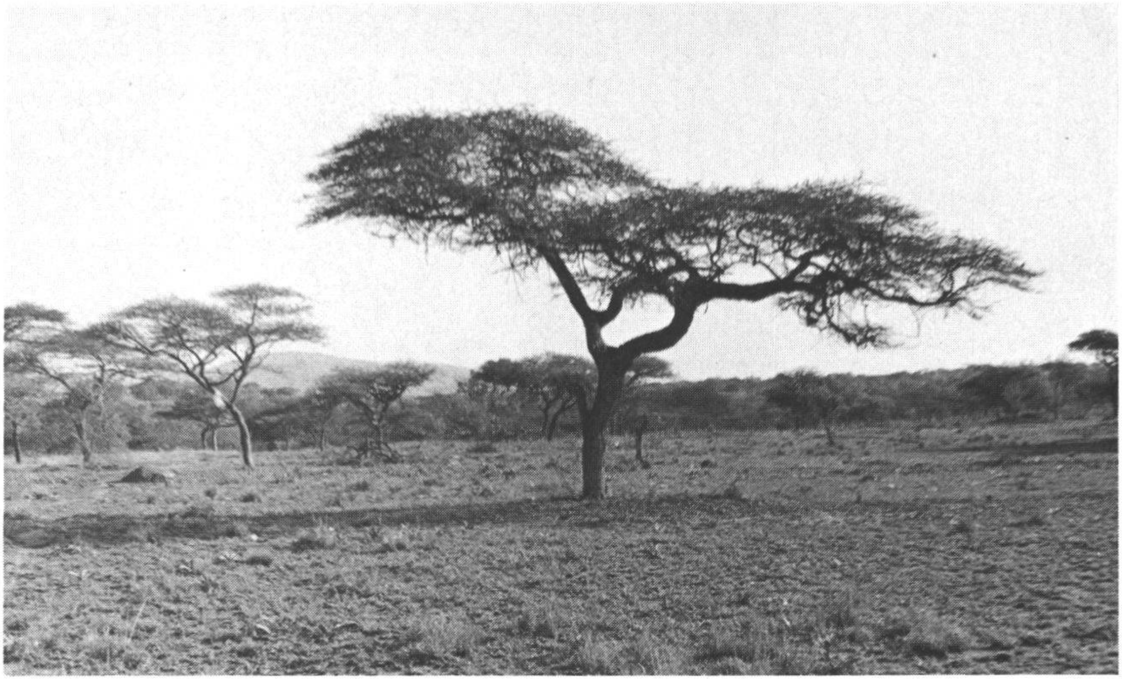
Abb. 1. Ein Breitmaul-Nashorn, Ceratotherium simum, Schulterhöhe 150-180 cm) hält Mittagsrast im Schatten von Bestand Nr. 1. Ihre Weidewirkung ist mitverantwortlich für die niederwüchsige Krautschicht. Eine Baumgruppe mit Acacia tortilis zeigt sich vorne rechts.

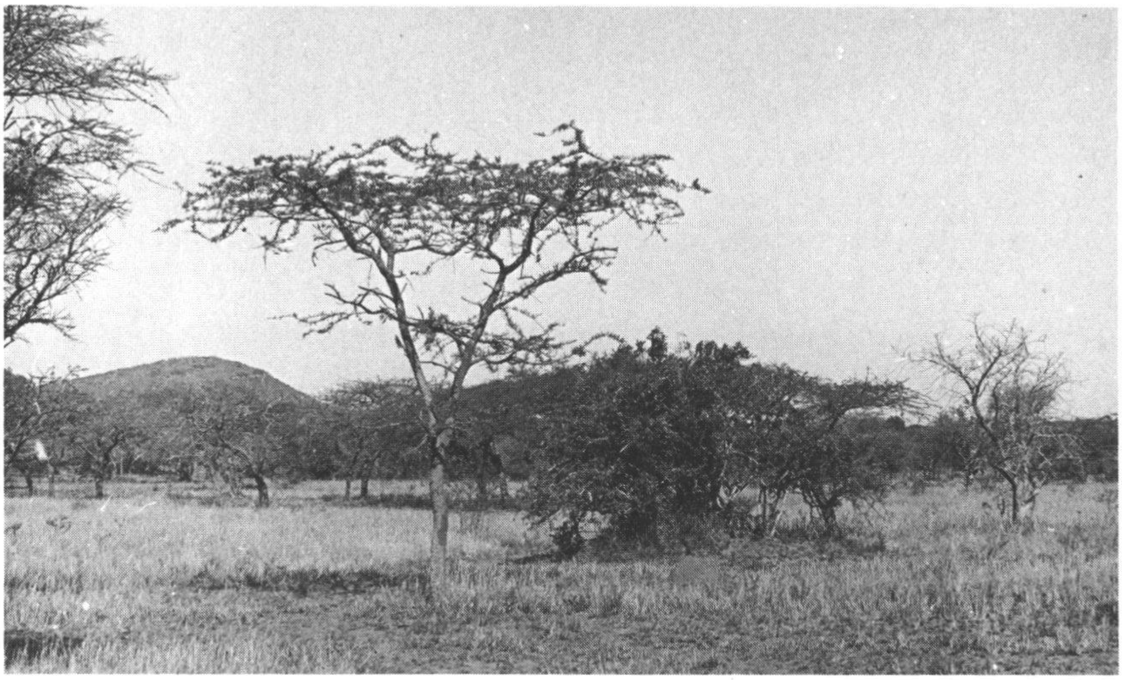
Fig. 2 (p. 211). The wide flat canopy of an Acacia tortilis is seen in stand 3. Note at left a termite mound: termites also are responsible for considerable clipping of grass.

Abb. 2 (p. 211). Die breite flache Krone von Acacia tortilis fällt im Bestand Nr. 3 auf. Man beachte den Termitenhügel links: Auch Termiten sind z.T. mitbeteiligt am ständigen Verbiss der Grasnarbe.

Fig. 3 (p. 211). Stand 4 with a flat-topped Acacia gerrardii in the foreground. To the right of it is a small bush-clump containing several species.

Abb. 3 (S. 211). Bestand Nr. 4 mit flachkroniger Acacia gerrardii im Vordergrund. Rechts vom Baum erscheint eine kleine Buschgruppe mit verschiedenen Arten.





stands averaged 104 trees per hectare of which 69 were Acacia. The average total canopy per hectare was 1949 sq. m, thus shading approximately 19% of the ground. The average tree had a canopy area of 19.2 sq. m, i.e., a canopy radius of about 2.5 m.

Figures 1-3 give an indication of the appearance of this mixed-Acacia community in 3 of the 4 stands. Although the study was conducted in January, the photos were taken in August, toward the end of the long dry 'winter' season. Note that most of the trees are deciduous and that the grass cover is fairly poor for several reasons; it is the non-growing season; white rhinos tend to overgraze certain areas, and the termites remove the grass cover in the vicinity of their mounds.

4. DISCUSSION

The four stands studied may be described as a mixed-Acacia savanna in that the several species of Acacia collectively are the dominant species, averaging 68% RDo. Acacia nilotica is the dominant species in each of the four stands. Even though the slopes occupied by the stands are slight, there is an indication that Acacia gerrardii is more prevalent toward the upper (drier) end of the slopes (stands 1 and 3), and that Acacia tortilis is more common toward the lower end of the slopes (stands 2 and 4).

Ziziphus mucronata and Dichrostachys cinerea are non-Acacia species which occur most frequently as isolated savanna trees. Rhus and several other species, all of which are generally multiple-stemmed, often grow in close proximity to form dense, bush-clumps. Several such bush-clumps may be scattered over a hectare. The percentage canopy value is actually underestimated in that only the nearest species, of the several species comprising a clump, was recorded in a quarter just as if it were growing alone. We should have sampled to the center of a clump, measured total clump canopy, and pro-rated the canopy among all the species in the clump. Although canopy may have been underestimated, the percentages of canopy for each of stands 1-4 (27%, 19%, 11%, 20%, average 19%) are well below 50%, and thus fit the definition of savanna given by CURTIS (1959) as 'arborescent communities having less than 50% canopy'.

This paper has not fully explored the aspect of whether an adequate sample was achieved or not. Nearly all plant communities are heterogeneous, and this is especially true in the subtropics and tropics. However, a few Acacia species clearly dominate each stand, having relatively higher numbers, importance values and relative dominance compared to a larger number of individually less important species. It is seen in Table 1 that it is only 3 or 4 species of Acacia that are the most important species in the four stands on the basis of relative dominance, compared to 11 to 16 other species per stand which have a total lower importance. It would thus seem that these stands are differing facets of a relatively-unified Acacia-dominated plant community. It therefore appears that enlarging the sample (i.e., adding more points and sampling a larger area) probably would only continue to add more of the same few dominant Acacia species and would continue to add very low numbers of additional new species. From this standpoint, it could be considered that an adequate sample was achieved in this study.

A certain few species, then, dominated each stand of semi-arid savanna, while relatively more species (different species, varying from stand to stand) collectively are less important. Similar conclusions were reached in a study of more mesic forests on the nearby Natal coast (ROGERS and MOLL 1975). Both the savanna and forest communities seem to be heterogeneous when all the large woody species are considered within or between stands. However, the stands may be interpreted as being relatively less heterogeneous (i.e., more homogeneous) when it is emphasized that only 3 Acacia species (about 20% of the species) represent well over 50% of the 'importance' in each stand. I would conclude on the basis of studies of South African forest (ROGERS and MOLL 1975) and savanna (this study), that it is possible to quantify community data using this interpretation of homogeneity relative to heterogeneity.

Much quantitative information was rapidly obtained in this application of the quarter method. It is a simple method in the field with a rangefinder being the only major item of equipment necessary. The quarter method is perhaps preferable to a quadrat method in savanna vegetation, in that with only 78 to 132 trees per hectare, quadrats would have to be excessively large or extremely numerous. If all the trees in one hectare were measured, this would still indicate only what was in that one hectare, whereas with the quarter method, several hectares could be sampled. However, if the purpose of the study were a detailed analysis of

one stand of savanna vegetation, a 100% count and measurement of trees in the stand would no doubt be preferable.
The best application of the quarter method would be in a comparative study of many stands of savanna. In a study including the understory, grasses and forbs could be sampled using small quadrats, some in the shade of the trees and some in the open. In addition, soil samples could be collected for analysis and other environmental data could be taken in each stand. Information regarding the distribution of tree and understory species compared with the environmental data could thus be gathered by this method. It is concluded that the quarter method is potentially useful for obtaining quantitative information in a comparative study of several stands of subtropical savanna vegetation.

SUMMARY

Four stands of mixed-Acacia in Umfolozi Game Reserve, Zululand, Natal, were sampled by means of the quarter method. Quantitative results for the trees and large shrubs including numbers, size and importance values are shown and discussed. A total of 33 woody species over 2.5 cm d.b.h. was measured, with a range of 15 to 19 species per stand. An average of 104 trees per hectare was found to shade approximately 19% of the ground. Seven species of Acacia were encountered in the study. However, each stand was clearly dominated by the same 2 or 3 species of Acacia, using relative canopy cover as the measure of importance. Relatively few species are thus dominant in each stand, and the apparent heterogeneity is mainly due to the larger number of individually relatively unimportant species which differ from stand to stand. Within the interpretation of homogeneity thereby derived, it appears that a quantitative description is feasible. It is concluded that the quarter method is potentially useful for the comparative study of stands of subtropical savanna vegetation.

ZUSAMMENFASSUNG

Im Umfolozi-Wildreservat (Zululand/Natal, Südafrika) wurden vier Acacia-Mischbestände mit der "point-centered-quarter method" aufgenommen. Quantitative Ergebnisse von Bäumen und grösseren Sträucher (Zahl, Grösse, Importanzwert) wurden zusammenfassend diskutiert. Insgesamt wurden 33 Holzarten mit BHD >2.5 cm erfasst und mit einer Spanne von 15-19 Arten/ Aufnahmefläche, die mit durchschnittlich 104 Bäumen/ha etwa 19% der Bodenoberfläche beschatten. Bei sieben angetroffenen Acacia-Arten dominieren in jedem Bestand ca. 2-3 Arten, falls man den Kronenschluss als Mass für die Bedeutung nimmt. Demnach sind in jedem Bestand verhältnismässig wenige Acacia-Arten herrschend, und die scheinbare Uneinheitlichkeit der

untersuchten Bestände ist somit bedingt durch die relativ hohe Zahl von wenig wichtigen Arten der übrigen Gattungen, deren Kombination stark wechselt. Unter der so fassbaren Homogenität scheint die quantitative Beschreibung angemessen zu sein. Daraus folgt, dass die angewendete quantitative Methode für das vergleichende Studium von subtropischen Savannenbeständen recht gut gebraucht werden kann.

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