Bothalia 27,2: 185–193 (1997)

A floristic classification of the vegetation of a forest-savanna boundary in southeastern Zimbabwe

I. MAPAURE*

Keywords: classification, Detrended Correspondence Analysis, forest-savanna boundary, moist forest, savanna, TWINSPAN, vegetation type, Zimbabwe

ABSTRACT

The vegetation of Chirinda Forest boundary was classified into eight types using Two-way Indicator Species Analysis (TWINSPAN) and Detrended Correspondence Analysis (DCA). The moist forest comprises three types: *Strychnos mellodora–Chrysophyllum gorungosanum* Forest on deep dolerite soils; *Chrysophyllum gorungosanum–Myrianthus holstii* Forest on shallow dolerite soils; and *Teclea nobilis–Ehretia cymosa* Forest on drier, but deep dolerite soils. The non-forest vegetation comprises five types: *Themeda triandra* Grassland on shallow dolerite soils; *Psidium guajava* Bushland on sandstone; *Bridelia micrantha–Harungana madagascariensis* Mixed Woodland not restricted to any one particular soil type; *Acacia karroo–Heteropyxis dehniae* Woodland on shallow soils derived from sandstone but sometimes on dolerite; and *Julbernardia globiflora–Brachystegia spiciformis* (Miombo) Woodland on sandstone.

INTRODUCTION

Forest patches occur in many tropical countries, often embedded in a matrix of non-forest vegetation types, forming unique units along their boundaries. Ranney *et al.* (1981) emphasized the importance of forest fringes in the structure and dynamics of forest patches. The boundary creates microclimatic gradients that result in differences in environment between the forest interior and the outside, non-forest areas. In this context, the influence of soil moisture and other edaphic changes at the forest-savanna boundary is particularly important (Furley 1992; Hopkins 1992).

The ecotone between forest and non-forest areas often has high plant densities and diversity, and represents the juxtaposition of two contrasting habitats. Along the ecotone there is generally a high incidence of wind and animal activity, especially mammals and frugivorous birds. As a result, the predation of seed and fruit and the opportunity for their dispersal are both enhanced.

In Zimbabwe, forest patches with sharp boundaries between them and non-forest vegetation are common along the eastern highlands where three main centres of moist forest development can be identified, namely the Nyanga, the Vumba and the Chimanimani massifs. Many other smaller patches of forest occur elsewhere, including Chirinda, the area of this study. The factors responsible for these boundaries vary from place to place, but fire, altitude and edaphic factors are among the most important. Crook (1952) and Phipps & Goodier (1962) discussed the vegetation patterns of the Chimanimani Mountains, with emphasis on the determinants of the forest, woodland, grassland and Ericaceous scrub. Similar situations can also be encountered in the Vumba, Nyanga and Chirinda areas.

Inventories of the vegetation of Chirinda Forest have been compiled by, among others, Goldsmith (1976) and Muller (1991). Much of this work focused mainly on the moist forest proper, with very little attention paid to the surrounding non-forest vegetation. Mapaure (1993) discussed the factors influencing the vegetation of the forest boundary whilst Timberlake *et al.* (1994) described the composition of the forest and some ecological factors affecting the vegetation. A list of flowering plants and ferns found in and around the forest has been compiled by Drummond & Mapaure (1994).

The main objective of this study was to inventory the woody vegetation of Chirinda Forest boundary, including adjacent bushland, grassland and woodland areas and to produce a classification and description of the vegetation types.

STUDY AREA

The study was carried out in Chirinda Forest, situated near Mount Selinda Mission (20° 25′S, 32° 43′E) in southeast Zimbabwe (Figure 1). The forest represents the southern end of moist forest distribution in Zimbabwe and is the best preserved example of medium altitude moist forest (Muller 1991). It is surrounded by pine plantations, Mission settlements, Chako Business Centre, and commercial farmlands. It is a gazetted Forest Land managed by the Forestry Commission, covering 947 ha, of which 606 ha is moist evergreen forest. The forest lies on two broad highlands rising from 1 076 m to 1 250 m in altitude. These form two crests, essentially subdividing the forest into two, a northern and a southern section with a narrow forested saddle in between.

The geology of the area comprises red and purple phyllitic mudstones interbedded with pale fine- to medium-grained feldspathic sandstones of the Upper Argillaceous series of the Precambrian Umkondo System (Watson 1969). Fine-grained dolerite sills have intruded into these sandstones, forming a cap over much of the higher

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MS. received: 1996-10-29.

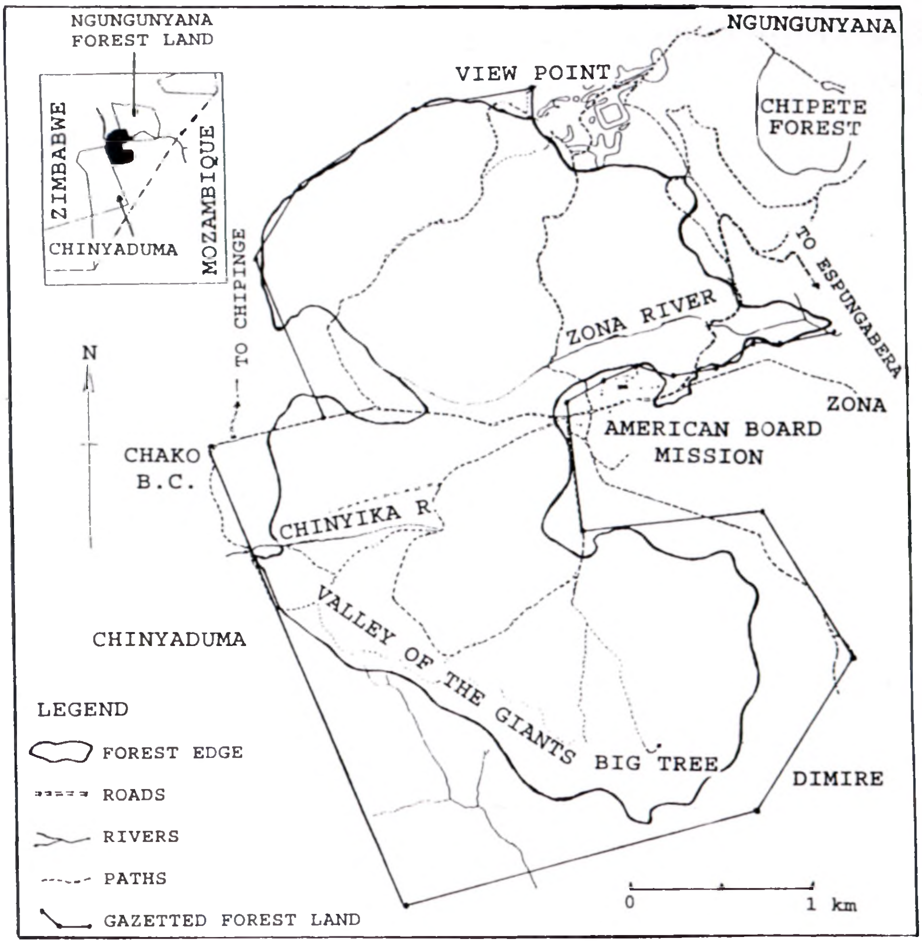

FIGURE 1.—Location of Chirinda Forest in southeastern Zimbabwe.

ground. The moist forest is generally found on dolerite soils.

The area receives an average rainfall of 1 470 mm per annum (Anon. 1977). Average winter and summer temperatures are 14°C and 20°C, respectively (Sayce 1987). The prevailing winds are southeasterly.

METHODS

An interpretation of 1:12 500, black-and-white aerial photographs of 1987 was carried out and stratification of the vegetation around the forest was done, based on the textural differences on the photographs. A map was produced based on both the interpretation of the aerial photographs, which aided in the marking of the boundaries of the vegetation types, and field sampling.

Ten belt transects (two through each of the five vegetation units apparent on the aerial photographs), each 200 m long and 20 m wide, were established (Figure 2A–J) so that half the distance was in the forest and the other half in the non-forest vegetation. The edge of the forest was identified by either an obvious noticeable change in species composition or by a difference in vegetation structure, or both. Each belt transect was subdivided into ten 20 × 20 m contiguous quadrats, five on either side of the forest boundary, resulting in a total of 100 quadrats. The appropriateness of this quadrat size was confirmed by a species-area curve.

In each quadrat, the woody species were identified and assigned to height classes as follows: seedlings, saplings (< 0.5 m), understorey (0.5–3.0 m), subcanopy trees (3–10 m), and canopy trees (>10 m). An overall cover-abundance value for each woody species in each quadrat was assessed following the Braun-Blanquet scale (Mueller-Dombois & Ellenberg 1974). Climbers were rated separately according to the number of stems encountered in the stands rather than for a cover value.

Soil depth was determined by augering six quadrats per transect, three on either side of the forest edge. The soils were considered deep if no rocks were encountered down to a depth of 80 cm. The geology was determined from any exposed bedrock and by reference to the geological map of the area.

Data analysis

Vegetation data were analysed using Two Way Indicator Species Analysis (TWINSPAN) (Hill 1979) and Detrended Correspondence Analysis (DCA) (Gauch 1982). TWINSPAN was applied on the full species data set, consisting of 261 plant species belonging to 204 genera and 76 families and DCA was applied on the sixty quadrats from which soil data were collected. Rare species were downweighted and for pseudospecies cut-levels of 0, 1, 3 and 5 were used in the application of TWINSPAN. Cover-abundance values of species were used in both analyses. Minor refinements were done to the TWINSPAN output (Table 1) to improve its clarity, especially the removal, after analysis, of the species which occurred three times or less (except indicator species) and lianes and vines.

RESULTS AND INTERPRETATION

Vegetation classification

Eight vegetation types were identified (Figures 3 & 4) on the basis of the TWINSPAN and DCA analyses. The primary division of the stands by TWINSPAN separated out the moist forest stands from non-forest (woodland and grassland) stands. The second level of division separated out forest stands in the northwestern part of the forest from the rest of the forest stands. These forest stands (Type III) are situated close to the miombo stands, on the drier side of the highland. The third level of division further subdivided the remaining forest stands into a group which occurred in the eastern to southeastern part of the forest (mainly transects E, F, G and H) (Type II). The other group (Type I) consists mostly of forest stands from transects A, B, C and D. The forest stands, therefore, fall into three main types.

Among the non-forest vegetation stands, the second level of division separated out grassland stands, which occurred in the southeastern part of the forest (Type VII), from the rest of the non-forest vegetation. The remaining non-forest stands were divided into a further two groups at the third level of division. One type (Type IV), which consists of a wide mixture of stands from several transects but close to the apparent forest edge, was separated from the rest of the remaining non-forest vegetation. The remaining stands were further divided into two, one of which comprises two types. Type VI consisted of stands mainly from an area close to Chako Business Centre (the sandstone enclave) and stands from the northwestern side forming Types V and VIII. Further subdivision of these types was considered unnecessary because the number of stands in each group was too small to justify the subdivision.

The forest, woodland and grassland types were clearly separate, with some ubiquitous intermediary vegetation types bridging them. Within the three moist forest vegetation types, two were not clearly separated on the basis of species composition but were strongly differentiated on

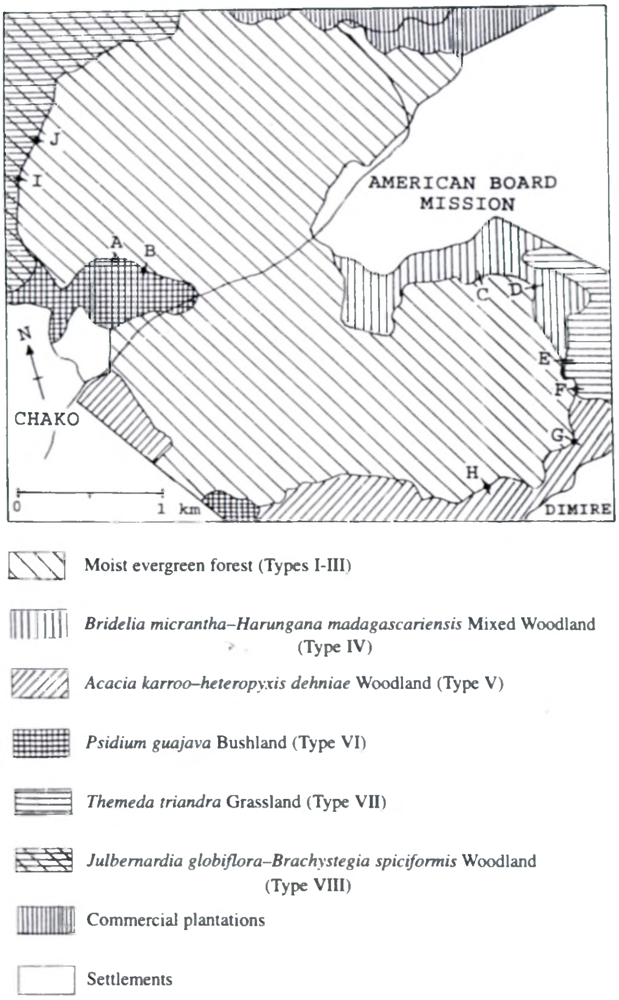

FIGURE 2.—A map showing the major vegetation types in Chirinda Forest area. The positions of the transects (A–J) are indicated.

the relative dominance of the species in the upper canopy and subcanopy strata. *Strychnos mellodora*, *Rothmannia urcelliformis*, and *Chrysophyllum gorungosanum* had higher cover abundance values (averaging about 50%) in forest Type I than in forest Type II, where they averaged 20%. *Myrianthus holstii* had a lower cover value (about 10%) in forest Type I than in Type II (about 25%). Forest Type III occurred in a drier area, had a more open canopy and,

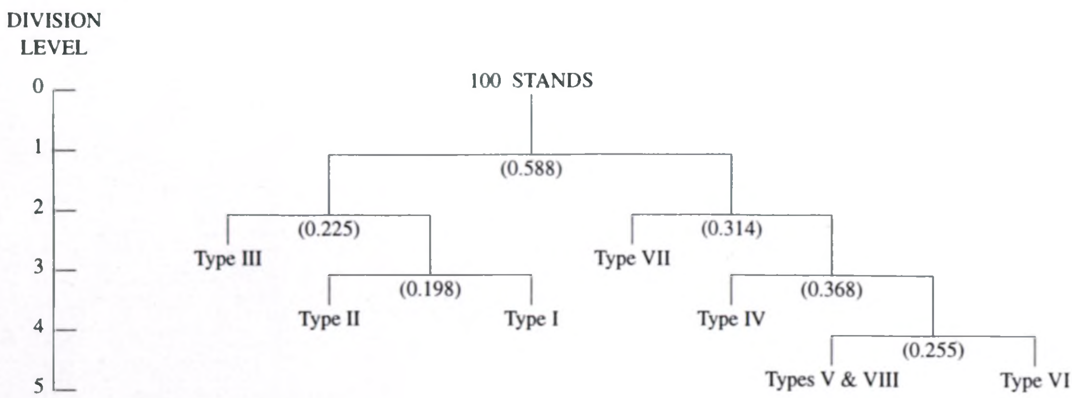

FIGURE 3.—Dendrogram showing the TWINSPAN results of the quadrats in Chirinda Forest (eigenvalues are shown in brackets).

TABLE 1.—A synoptic table of TWINSPAN classification of Chirinda Forest vegetation. Full names of species indicated by mnemonics are given in Appendix 1

		Stand number							
				1					
		2223347111237 1	34444555655666677	899908891237	5 1177889 222333334444567266677999	688888992	111	4555	
		78908090890987897	76789067689078907	078908906666	56453467645345123452345455223412345	112345121	123123	1123	
CEL	MIL	----21-1---12----	-------1---------	-----------1	-----------------------------------	---------	------	----	11111
STR	USA	111111-11211-122-	1---------1------	---1----121-	-----------------------------------	---------	------	----	11111
STR	MEL	22-233-34333-3444	2--111----1-1----	1------1222-	-211-------------------------------	---------	------	----	11111
RIN	FER	-----2-----------	-22--1-----------	------------	1----------------------------------	---------	------	----	11110
PLE	PYC	-111-2-----1-----	1--111-2---------	----------1-	-----------------------------------	---------	------	----	11110
HEI	DIE	23222211---11-1--	211-213222232111-	1--11----1-1	-----------------1-11-1------------	---------	------	----	11110
STR	SCH	13321211---21----	211-1212112212121	1--------1-1	1--------------------11------------	---------	------	----	11110
CHI	BAT	221-1------1--11-	21----11--11-----	1--------21-	---------------------1-------------	---------	------	----	11110
COL	GRE	-------1132---1--	22222------1-----	-1111-------	-1---------------------------------	---------	------	----	11110
TAN	SWY	12-222221-1222-23	21--222212222212-	2--22111-121	-1---1-----------1----1------------	---------	------	---1	11110
FIC	CHI	-------2---3---2-	-----1-2-1-3-----	-2----------	---------------------1-------------	---------	------	----	11110
ARG	MAC	----331---231-1--	212-2121211111---	1--12--1----	-----------------------------------	---------	------	----	11110
MYR	HOL	-2--2-1-211112--1	-223222222222222-	----------2-	1-----------------1--12------------	---------	------	----	11110
CRA	BRE	222121-24223-1--1	3-1133122211211--	13332-1-----	-----------------1------1------1---	---------	------	----	11110
DRA	FRA	1-12-133112131241	13444422144434444	31233-1111-3	-1--11--1-------1-1--111-1---1-1---	---------	------	----	11110
PSE	SUB	2111----121-12221	-12---133222321--	1---1---22--	-1-----------1---------------------	---------	------	----	11110
DID	NOR	-----11----1-----	----1------------	-1--1-------	-----1-----------------------------	---------	------	----	11101
OXY	GOE	-1------------11-	--111--1-1-------	1--11------1	1----1-----------------------------	---------	------	----	11101
DRY	GER	--22221----1-1---	112--1111-2321---	11222-11---1	1-----------------1----11----------	---------	------	----	11101
TIL	FUN	--22-22-2-2------	22222-2---223----	22-22-112-2-	2-----2-22------------2------------	----2----	------	----	11101
KHA	ANT	3---3-1-----1----	--------1-1--222-	2------2-1-1	1----1--------------------1-----1--	---------	------	----	11101
STR	MIT	2332-112---1-2121	121--111112-22-1-	-1-2112--2-1	1---1---1-------------11----11-----	-------1-	------	----	11101
CHR	GOR	12312322211221-21	3333333332-32-222	22222112-311	----11-11--------12---1-1----1-1-1-	---------	------	----	11101
DIO	ABY	22122121111111111	-1-1-1111--1-1-11	-1112213-111	-11111-1211-----------1------------	-------1-	------	----	11101
COF	LIG	1111-11----1-----	11---------------	1-111221-1--	-------------------11----1---------	---------	------	----	11100
TRI	MAD	3-2--12----1-----	1---2---211--221-	---11--2---1	1----1--------1--11---1111-----1--1	---------	------	---1	11011
XYM	MON	1---31-----------	-211--2-2--------	----------21	1-------------1--12-1111---------1-	---1-----	------	----	11011
AGE	PEN	2--2-22----22-22-	2---------------2	----------2-	-2---2---------2-2-------2---------	---------	-----2	----	11011
PAV	COM	1-1--1-1---1-111-	11221---1-1-1122-	-21-1-11-111	11-----1-1-----11---11--11---------	---------	--1---	---1	11011
CRE	TRI	11111-11-------1-	1121--22--111--1-	--1-------1-	1---11--------------1111111------1-	---------	------	----	11011
CEL	GOM	1--------------11	--------22-221--2	----1-------	----1-------1---------11---1-1-----	---------	------	----	11011
RAW	LUC	23121121111112211	21111-312--121---	3-121-1-2231	12111--11-------111--1111----------	---------	------	----	11011
ROT	URC	1333-1221211-2232	1-1--1231211-1-1-	111111121211	11-11111111-1111111---111-1--------	-----1---	--1---	---1	11011
TAB	VEN	11222221111221111	22212111212222112	111111121222	-111111-11-211-11-2-1--111-----1111	---------	--1---	----	11011
BEQ	NAT	2---1------2-----	-----------------	------------	--------------------------------1--	-------1-	------	----	11010
CAR	BIS	111111-----1----1	1111-1211-1--2---	-11--122-11-	111---11----11-1111-1111--1--1---1-	---------	-----1	---1	11001
CNE	POL	-------1-11------	-----------1-----	-----1111---	1------1---------------------------	---1-----	------	----	11000
LOV	SWY	1-------1-1-1-1--	--------1----1--1	---11---1--1	----I11-----11----------1----------	-------1-	------	----	11000
NEW	BUC	2333--2----------	----------------1	2-11122121-2	-12-22------------------1-----1----	----11---	---111	----	11000
OCH	ARB	-----------------	-----------------	---22112----	------1--------------------------11-	-------1-	------	----	101
DOV	MAC	1-11-1---1-111---	11----231---1----	-11---2112-1	2-----1-2----1------111---------111	--111111-	--1---	---1	101
TAR	PAV	--1--11----------	111-112-----11--1	-111111----1	2---11111--12---111121-------1-1---	--------1	------	---1	10011
TRI	DRE	--122-2--2--1----	-3-1--22---12--1-	22-21-----2-	-1-111---11-11-11111-11111--12-1--1	--1------	-1----	---1	10011
XYL	PAR	--11-------------	-----------------	-11111----2-	------131-------1-------1----------	---1-----	------	----	10010
DRA	MAN	1----------------	-----------------	---------111-	------------------111------------1--	---------	------	----	10010
CLE	SWY	-----22---2--222-	-------2--2------	-23232------	--2--2-2-22----2-22-2-------2--2--	---------	---222	----	10010
TEC	NOB	211--2-1-1---1111	1112--31----1---1	-221122342-1	1-12-113221-11----1112-1--------111	--122212-	---111	----	1000
EHR	CYM	-----------------	-----------------	--21131111--	------222-----------------------1-1	--2-2--3-	------	----	0111
CEL	AFR	-----------------	-----------------	22---321---2	-11-112411------------2--2----1-111	--222112-	--11--	----	0111
CAS	BAT	-------------2---	121---2----2-----	-------1-221	21--1-------1111-1112212--1--1---11	1-1-11-1-	---1--	---1	01101
PED	AFR	--11-11------1111	1111-1112-1------	-11-112-112-	112-11121112123222-1211111----1211	--1121121	111111	---1	01101
CRO	SYL	---2-----2-1-2--2	21--213-111-211-2	-1111222-2-1	221111233-1111-12111-111111111-1111	--132222-	-----1	---1	01101
POL	FUL	1--------------1-	-12--1---1---1---	---------1-1	----1------1-1-----111121-1--1-1---	---------	--1--1	---1	01101
ALB	GUM	111---1-11--122--	---------1-------2	11-112211112	-22113321222112232211211221122221111	-11222112	1-2111	--1-	01101
CAS	MAL	---------1----1--	11-2-1-----------	------------	1----------11-1111---111-----------	---------	------	----	01100
HAL	LUC	-----------------	-2---------------	------------	-----------2---------11------------	---------	------	----	01100
SCO	STO	-----------------	1----------------	----------2-	------------------122-1------------	---------	------	---1	0101
RAU	CAF	-----------------	-3---1---11------	----1--2----	12-----2--1-------1-11223---1----1-	---------	------	---1	0101
BER	ABY	--------------1--	-----------------	---1-1------	--1-----------------1----------11-1-	----1--1-	----11	----	0100
OXY	SPE	-----------------	--------1-------1	-----11---1-	-1-111---1-1--11111-1-----------1---	---------	-1----	----	0100
CAL	AUR	1----------------	-------------1---	-----11-----	------132-------------------------1	-2121----	------	----	00111
MEL	LOB	-----------------	-2---------------	-----------2	3---11-----------2---3--1------122	------11-	------	----	00110
SEN	SEP	-----------------	-2-1-------------	------------	-------------1112211--121---------11	-----1---	------	---1	00110
SAP	ELL	---1-------------	-----------------	------------	-----------11-1--21-------1--------	--------1	------	----	00110
PRO	FAL	-----------------	-2---------------	--------1---	3--2-----------11111-2232----------	---------	------	---3	00110
CLA	ANI	-----------------	-1----1------3---	--1--1---11-	1-111112--11121111111111--1122---11	1---21-11	---11-	---1	00110
FIC	SUR	-----------------	-----------------	------2---1-	-----1----------1-1-1---2-1--222---	-----212-	------	----	00110
CUS	SPI	-----------------	-----1-----------	----------12-	-----1-----22122322-2--11-2---11---	--------1	------	---1	00110
KEE	GUE	1----------------	-1---------------	----------11-	--1-1--1--12111111-1---1--1-1--11-1	--11--111	-11---	----	00110
BRI	MIC	--------2-----1--	-2---------------	-----2--22-2	--1-1211-2233233233223232333222112	221221213	11121-	---2	00110
MAC	CAP	-----------------	--------21--2--22	---------1--	-2--23-----221---2-----231-11212-2-	1--------	1---11	---1	00110
CLU	SWY	-----------------	-----------------	----------1-	----------------1---------------32---	---------	------	----	00100
DES	SET	-----------------	-1---------------	----------1-	------------11-32-22---1---11---2---	---------	------	-1--	00100
CRY	LIE	----1------------	11---------------	------------	1-1-1---------1122211121-----1-----	---------	------	---1	00100
ARG	TOM	-----------------	-----------------	------------	-----11-------------------12-1-111	-----1---	------	----	00011
TRI	PIN	-----------------	-----------------	------------	-------------1-----------1----2-111	------1--	------	----	00011
FLE	GRA	-----------------	-----------------	------------	----1----------11-----------1---1-1--	--------1	------	----	00011
CAT	EDU	-----------------	-----------------	------------	---112------1-11---1-----2-41-2211-	--1---1--	------	----	00011
HYP	ARI	-----------------	-----------------	------------	------------12--22-------4---14-----	---------	----1-	----	00011
ANT	VEN	-----------------	-----------------	------------	----1------1--1211--------1---11---	-----1---	------	----	00011
ACA	SIE	-----------------	-----------------	------------	--1--2-----223--2-----2-2--12------	---2-----	------	----	00011
DOM	BUR	-----------------	----------------1	------------	1---1-1-------2-----11-111-12221-1-	1---21--1	------	1---	00010
SPH	PRU	-----------------	-----------------	------------	------------32--------------2-------	--------3	------	----	00010
RUT	FUS	-----------------	-----------------	------------	----------------1-1--1--------------	---------	---11-	----	00010
TRE	ORI	-----------------	-----------------	------------	2------------1--12-----2------------	---2-----	------	----	00010
COM	MOL	-----------------	-----------------	------------	-------------2--1-----------1-------	-1-------	------	----	00010
DIC	CIN	-----------------	-----------------	------------	------------1--1-----------1------1-	------1-1	------	----	00010
HAR	MAD	-----------------	-----------------	----------2-	2---2------11-322221---12-212211111	--------3	---2-1	-22-	00010
RUB	RIG	-----------------	-----------------	------------	2---2-221-22-2-2-2-2323233233332233	2--2222-2	---2--	----	00010
PTE	ROT	-----------------	-----------------	------------	----------12222----1---2--2---2----	--2------	----1-	2---	00010
ERY	LYS	-----------------	-----------------	------------	1-1--1---1-1--22---1-1121---2------	--------1	-112--	-1--	00010
MAY	HET	-----------------	-----------------	------------	------------12111111-1-----1--------	-2------1	-1----	----	00010
RHO	REV	-----------------	-----------------	------------	---------3----222--2323-3-2232-----	3--3322-2	2-----	2--2	00010
LAN	CAM	---1-------------	-2---------------	---------22--	--211-3---3-33213121232332-33312---	322233-2-	222---	--12	00010
OCI	GRA	-----------------	-----------------	------------	---------------------------------1-1	------11-	------	----	00001
PHY	NUM	-----------------	-----------------	------------	---------------------------11------	------11-	------	----	00001
PRO	LAR	-----------------	-----------------	------------	------------11-----------------1----	---1----2	------	----	00001
PRO	PLU	-----------------	-----------------	------------	----------------1-------------------	---------	---111	----	00001
RHU	TRA	-----------------	-----------------	-----------1	---11----1132-211-1111-11-222222122	22323-212	------	---1	00001
PRU	AFR	-----------------	-----------------	------------	---------------------21-11-------22-	--2-1--1-	--1---	---1	00001
IND	SWA	-----------------	-----------------	------------	----1----1111-1---1--------2---1111-	2----1112	-1111-	----	00001
HET	TRI	-----------------	-----------------	------------	-1--1----------1-----1------1------1	1--------	1-----	----	00001
RHA	PRI	-----------------	-----------------	------------	--11--------------------------------	-----1---	11-111	----	00001

TABLE 1.—A synoptic table of TWINSPAN classification of Chirinda Forest vegetation. Full names of species indicated by mnemonics are given in Appendix 1 (continued)

	Stand number							
			1					
	2223347111237 1	34444555655666677	899908891237	5 1177889 2223333344445672666677999	688888992	111	4555	
	78908090890987897	76789067689078907	078908906666	56453467645345123452345455223412345	112345121	123123	1123	
VAN INF	-----------------	-----------------	------------	--------------------1--------------	-111--11-	------	----	00001
FAU SAL	-----------------	-----------------	------------	-----------------------------------	-322221--	------	----	00001
ACA KAR	-----------------	-----------------	------------	-------1-----------222-----3331-222	31221222-	--1-1-	1--1	00001
HET DEH	-----------------	-----------------	------------	2---222------2--22--------2----122-	133323221	--1--1	--1-	00001
RHU LON	-----------------	-----------------	------------	---------1-1-1------------------12-	-1223121-	-1----	----	00001
JUL GLO	-----------------	-----------------	------------	-----------------------------------	-3-------	------	----	00001
VER COL	-----------------	-----------------	------------	-------------1-------11-1---111-111	1--11-1--	1-----	---1	00001
SEN SIN	-----------------	-----------------	------------	------------------------------11---	--1---11-	1-----	----	00001
BRA SPI	-----------------	-----------------	------------	-----------------------------------	------2--	------	----	00001
VAN API	-----------------	-----------------	------------	-1-1----1--1-11-1-1111111-2--1--221	112212122	1111--	-1--	00001
EUC DIV	-----------------	-----------------	------------	1---1-1--1-111111--111111---1121111	112211111	1111--	1111	00001
DIO LYC	-----------------	-----------------	------------	----1-1--1-11-111--111----1-111111-	12211-111	111111	112-	00001
CAN MUN	-----------------	-----------------	------------	4-22--1--1-22----3--------2--------	-1111--11	231244	-2--	00001
PAR CUR	-----------------	-----------------	------------	--212-31-1----------------1---121-2	112322211	223222	--1-	00001
CYM CAE	-----------------	-----------------	------------	-------------------22--------------	---------	------	2333	00000
SEN LAT	-----------------	-----------------	------------	-------------------2---------------	---------	------	2121	00000
IND HED	-----------------	-----------------	------------	-------------------1---------------	---------	------	1111	00000
ERI NUT	-----------------	-----------------	------------	-----------------------------------	---------	------	1222	00000
ATH ROS	-----------------	-----------------	------------	-------------------22--------------	---------	------	2221	00000
ASP PLU	-----------------	-----------------	------------	-------------------1---------------	---------	------	121-	00000
GRE OCC	-----------------	----------------1	------------	----1------------1-------1-----11--	-----112-	------	---1	00000
PSE HOO	-----------------	-----------------	------------	------------1------11-----1--------	---------	------	11-1	00000
RHY SWY	-----------------	-----------------	------------	-----------22--------------2--22--2	2-------3	------	2--2	00000
TEP LON	-----------------	-----------------	------------	-----------------------------------	------1-1	-1----	-11-	00000
THE TRI	-----------------	-----------------	------------	-------------------22---------2----	-2-------	------	-344	00000
STR SPI	-----------------	-----------------	------------	----1------------------------------	-1-------	11----	1---	00000
RUB COR	-----------------	-----------------	------------	----------------------------22-----	2-----2-2	------	2--2	00000
ANN SEN	-----------------	-----------------	------------	-----------11-1----1---1--11----111	1111111-1	------	1111	00000
SYZ GUG	-----------------	-----------------	------------	--1--1--------1---------------111--	---1--1--	------	12--	00000
MAY SEN	-----------------	-----------------	------------	-1----22--------------------1-----1	-1--11---	------	--2-	00000
PSO FEB	-----------------	-----------------	------------	----1----------1----1-----11--11---	11---11-1	--1-1-	1-11	00000
LIP JAV	-----------------	-----------------	------------	----------1--------12---------1----	1111--1-1	-11---	1221	00000
MAE LAN	-----------------	---------1-------	------------	-1--------1-1-1-1--11--11-11111--1-	2---1-1-1	11--1-	1211	00000
RHU TEN	-----------------	-----------------	------------	------1----------------------------	-----2---	111---	1---	00000
FAD CIE	-----------------	-----------------	------------	-----------1--1--------------------	-11------	111---	1---	00000
PSI GUA	-----------------	-1---------------	------------	-1-21-1--21222212-1332121-211111-11	2-1212113	333332	3433	00000
	00000000000000000	00000000000000000	000000000000	11111111111111111111111111111111111	111111111	111111	1111	
	00000000000000000	00000000000000000	111111111111	00000000000000000000000000000000000	000000000	000000	1111	
	00000000000000000	11111111111111111	000000001111	00000000000000000000000000000000000	111111111	111111		
	00000001111111111	00000000011111111	00000111	00000000011111111111111111111111111	000000000	111111		
	00001110000001111	00000011100000001	01111	01111111100000000000000000111111111	000000001	000111		
Stand Type	I	II	III	IV	V/VIII	VI	VII	

hence, its species composition and undergrowth development were somewhat different from the other two forest types. *Dracaena fragrans* was the most abundant shrub species with an average cover abundance value of more than 50% in forest Type II, especially where the soils were shallow and the terrain steep. The vegetation types are described below.

Strychnos mellodora–Chrysophyllum gorungosanum Forest (Type I)

This forest consists of a lower upper canopy of various species with occasional emergents. The average height is generally lower (about 30–40 m) than the other forest types (which are about 50–60 m in most areas) except for

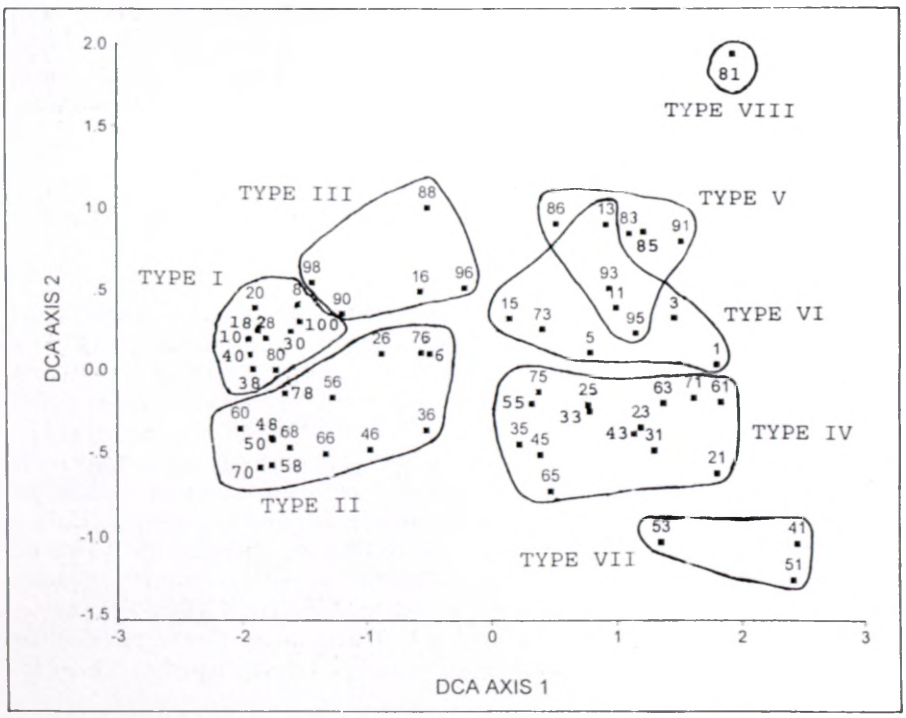

FIGURE 4.—A DCA ordination diagram showing the grouping of stands.

the emergents. It is dominated by *Strychnos mellodora, Chrysophyllum gorungosanum, Craibia brevicaudata* and *Tannodia swynnertonii.* Emergent species include *Strychnos mitis, S. usambarensis* and strangler *Ficus* spp., in particular *F. chirindensis.* The lower layer (which is not markedly different from the upper canopy) is dominated by *Strychnos mellodora, Rawsonia lucida, Heinsenia diervilleoides* and *Tabernaemontana ventricosa.* This forest type is found mainly in the area surrounding the sandstone enclave. Common shrubs include the young of the canopy species and low densities of *Dracaena fragrans. Acacia pentagona* and *Landolphia buchananii* are the most common lianes.

Chrysophyllum gorungosanum–Myrianthus holstii Forest (Type II)

This forest is dominated by *Chrysophyllum gorungosanum, Myrianthus holstii, Strombosia scheffleri* and *Craibia brevicaudata* in the upper canopy stratum. The area covered by this type coincides with the wetter parts of the forest. *Khaya anthotheca* is quite common in some places. *Dracaena fragrans* is the dominant shrub and apparently locally excludes other shrubs due to its high densities. *Strychnos mellodora* is largely absent from the subcanopy, which is instead dominated by *Heinsenia diervilleoides, Rothmannia urcelliformis, Tannodia swynnertonii* and *Tabernaemontana ventricosa. Cola greenwayi* and *Drypetes gerrardii* are also fairly common. The most common lianes are *Acacia pentagona, Hippocratea goetzei, H. pallens* and *Oncinotis tenuiloba.*

Teclea nobilis–Ehretia cymosa Forest (Type III)

This forest consists of a mixture of species of apparently drier forest affinities. It is dominated by *Teclea nobilis* and *Ehretia cymosa.* Common associates include *Chrysophyllum gorungosanum, Diospyros abyssinica* and *Ochna arborea.* It is found in the northwestern part of the forest adjacent to an area which seems to have been cultivated during the 1940s. *Celtis africana, Newtonia buchananii* and *Peddiea africana* form the dominant group in the shrublayer. There is high prevalence of small trees of pioneer species such as *Newtonia buchananii* and *Croton sylvaticus.*

Bridelia micrantha–Harungana madagascariensis Mixed Woodland (Type IV)

This woodland, which appears to be more of a secondary nature, is more developed in the area just south of the Mount Selinda Mission on a north-facing slope, where it forms a belt extending towards the southeastern part of the forest boundary. It is characterized by large, but widely spaced, *Bridelia micrantha* trees with occasional *Macaranga capensis* and *Cussonia spicata.* The lower stratum is dominated by *Harungana madagascariensis.* Thickets of *Toddalia asiatica, Asparagus falcatus* and, sometimes, *Smilax anceps* are a common feature of the shrub layer. *Harungana madagascariensis,* however, ceases to be dominant in some localities where *Pterocarpus rotundifolius* trees and *Albizia gummifera* saplings form an important component of the woodland. *Peddiea africana* shrubs and *Croton sylvaticus* seedlings are also common.

Acacia karroo–Heteropyxis dehniae Woodland (Type V)

This woodland, which is dominated by *Acacia karroo, Heteropyxis dehniae* and *Faurea saligna,* is on the drier side of the forest and just merges into the miombo woodland (dominated by *Julbernardia globiflora, Uapaca kirkiana, U. sansibarica* and *Brachystegia spiciformis*). It is mostly found between the moist forest proper and well-defined non-forest associations. It contains a wide variety of species including pioneer species such as *Bridelia micrantha, Albizia gummifera, Croton sylvaticus* and *Newtonia buchananii.* A form of this vegetation type also occurs in small patches elsewhere around the forest, with varying degrees of dominance among the component species. Occasional emergents include *Parinari curatellifolia, Catha edulis* and *Prunus africana.* Shrubs are represented by *Psidium guajava, Vangueria apiculata, Rhus longipes* and *R. transvaalensis.*

Psidium guajava Bushland (Type VI)

This bushland is dominated by the exotic *Psidium guajava* and by *Canthium mundianum* bushes and sometimes assumes the structure of a low woodland. It is found in the sandstone enclave. A few emergent trees of *Parinari curatellifolia* and *Albizia gummifera* occur. Thickets of *Toddalia asiatica, Lantana camara* and *Rubus rigidus* are common, particularly near the boundary with the moist forest. *Peddiea africana* and *Pteridium aquilinum* are also common.

Themeda triandra Grassland (Type VII)

This bushed grassland vegetation is dominated by *Themeda triandra* and *Cymbopogon caesius.* It occurs on shallow dolerite soils with occasional exposed boulders. There is local variation in grass species dominance, with *Loudetia simplex* apparently becoming more dominant on east-facing slopes of the southern part of the forest where the soils are deeper and mostly sandy, sometimes with *Parinari curatellifolia* bushes. Other woody species found within the *Themeda* grassland include *Psidium guajava, Eriosema nutans, Pseudarthria hookeri* and *Athrixia rosmarinifolia.*

Julbernardia globiflora–Brachystegia spiciformis Woodland (Type VIII)

An additional woodland type to those apparent in the TWINSPAN classification was identified by DCA, a miombo woodland dominated by *Julbernardia globiflora* and *Brachystegia spiciformis* with *Uapaca kirkiana, Heteropyxis dehniae* and *Faurea saligna* as common associates in the canopy layer. It is relatively open, with poorly developed shrub and herb layers. Common trees in the subcanopy layer include *Heteropyxis dehniae, Faurea saligna, Canthium mundianum, Julbernardia globiflora* and *Brachystegia spiciformis.* Grasses include *Digitaria gazensis* and *Themeda triandra.* The TWINSPAN analysis lumps this type with *Acacia karroo-Heteropyxis dehniae* Woodland (Type V) but DCA clearly separates it from the rest.

Ordination

The first DCA axis, which accounted for 63% of the observed variation, separated the forest and adjacent non-forest vegetation types, with a wide gap of up to one DCA unit between them (Figure 4). In general, stands close to the forest edge, from either side, were closer to the centre of Axis 1 than stands further from the forest edge. Nevertheless, the stands lying adjacent to one another along the forest edge were quite separate with 0.5–2 DCA units between them. Three groups of forest stands were distinguishable, corresponding to those identified in the classification by TWINSPAN. These groups are not separated along the first DCA axis but are distinguishable along the second DCA axis, which accounted for 19.6% of the variation. A similar pattern is also apparent in the ordination of the woodland groups of stands.

Miombo woodland is clearly separated from other woodland stands along the second DCA axis. The grassland stands are, likewise, clearly separated from the woodland stands. There is considerable overlap between the stands from the sandstone enclave and those from the northwestern part of the forest (i.e. the *Psidium guajava* Bushland (Type VI) and *Acacia karroo–Heteropyxis dehniae* Woodland (Type V).

The existence of the *Chrysophyllum gorungosanum–Myrianthus holstii* Forest (Type II) on the southeastern to the southwestern sides adjacent to the grassland was associated with a higher altitude and a wetter moisture regime, regardless of the shallow soils. *Psidium guajava* Bushland (Type VI) occurred where the soils were predominantly sandstone and relatively deep. Where the sandstone soils were steeper and shallower, miombo and sometimes *Acacia karroo–Heteropyxis dehniae* Woodland (Type V) occurred. On dolerite, with the same conditions, *Strychnos mellodora–Chrysophyllum gorungosanum* Forest (Type I) occurred, whereas the *Teclea nobilis–Ehretia cymosa* Forest (Type III) occurred where it was drier. The *Bridelia micrantha–Harungana madagascariensis* Mixed Woodland (Type IV) occurred on predominantly dolerite soils with other factors being intermediate. This was also found in what appeared to be geological transitional zones.

DISCUSSION

Vegetation types

The vegetation of Chirinda Forest boundary has been classified into eight types. This represents only those types occurring within 100 m on either side of the forest edge.

The TWINSPAN analysis clearly separated forest from non-forest stands. The stands close to the forest edge, however, were not clearly separated on the basis of whether they were just inside or just outside the forest, as might have been expected. The apparent lack of clear differentiation may be due to the existence of some species that are transitional between forest and woodland. Such a vegetation unit, which normally consists of both fire-tolerant savanna and fire-tender forest tree species (Hopkins 1992), represents a mosaic of communities of each of the two vegetation types. The transitional vegetation between savanna and forest shows great variation in both structure and species composition from place to place around the forest. Some of the types described in this category are restricted in extent whereas others occur widely, though in patches.

The transitional vegetation includes forest pioneer species. Most pioneer species in Chirinda Forest are Afromontane endemics or near-endemics which are absent or rare in lowland forests. These include *Albizia gummifera, Anthocleista grandiflora* and *Maesa lanceolata*. Hence, the forest has sometimes been labelled a 'transitional' forest because of the co-existence of both lowland and Afromontane forest species (White 1978). Even though the majority of the moist forest species have lowland phytogeographic affinities, several species such as *Chrysophyllum gorungosanum* (which is one of the commonest), *Casearia battiscombei, Drypetes gerrardii, Halleria lucida, Myrianthus holstii, Prunus africana, Strombosia scheffleri* and *Xymalos monospora* are Afromontane in origin. Chirinda Forest is, therefore, Afromontane in origin and character but with lowland phytogeographic affinities.

The southern section of the forest supports *Chrysophyllum gorungosanum–Myrianthus holstii* Forest (Type II), with more *Khaya anthotheca* and *Trichilia dregeana*, whereas the northern section mainly supports the *Strychnos mellodora–Chrysophyllum gorungosanum* Forest (Type I) with more *Craibia brevicaudata* and *Strychnos mitis*. Perhaps the greatest difference between these forest types manifests itself in the variation in species composition of the understorey. This difference seems to be determined by soil depth and slope, which also influence the moisture regime. Shallow and steep sites drain faster than areas of moderate slope, leading to differences in the undergrowth species composition. Understorey species are therefore important in defining the limits of these two types.

The forest and woodland vegetation types share only a few species between them. Greater overlap in species composition was observed between the forest and the ecotonal vegetation than between forest and, for instance, miombo woodland. Shared species appear to occur mostly as seedlings, and less so as trees, in those habitat types to which they do not characteristically belong. Some of these, such as *Croton sylvaticus, Harungana madagascariensis* and *Bridelia micrantha* are, however, true pioneers which thrive well under gap conditions in forests.

Ordination

Forest generally occurs in wetter environments, and savanna in drier ones (Backeus 1992). In Chirinda, the amount of precipitation received from rainfall in the area is lower than the normal requirement for forest development. The extra moisture comes in the form of orographic drizzle, made possible by several factors: the high ground, the southeasterly aspect, and the tall trees which facilitate the release of this extra moisture from the low clouds. The southern section of the forest has shallower soils, but a higher average altitude and receives more moisture from the south-easterlies, advected in from the Mozambique Channel, than the northern section. In general, Chirinda receives up to 28% more moisture than the average of five surrounding stations, much of which can be attributed to orographic drizzle (Mapaure 1993).

Miombo Woodland (Type VIII) was clearly classified separately from the *Acacia karroo–Heteropyxis dehniae* Woodland (Type V) by DCA but not by TWINSPAN. This might have been due to the apparent importance attached to *Heteropyxis dehniae* by TWINSPAN in Types V and VIII, resulting in the recognition of these types as one. Also of much interest, is the distance of separation between the dominant forest type [*Chrysophyllum gorungosanum–Myrianthus holstii* Forest (Type II)] and the rest of the non-forest types on the DCA ordination diagram. The DCA distance between the stands represents the average standard deviation of the species turnover, where a full species turnover occurs in about four DCA units (Gauch 1982). Thus, the DCA units between the types in Chirinda Forest represent about a 50% change in sample species composition, indicating a more or less abrupt change. This change may indicate the strength of geology in determining the extent of the forest, since all forest stands occurred on dolerite.

ACKNOWLEDGEMENTS

I am grateful to the German Academic Exchange Service (DAAD) who provided the funds to carry out this research.

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APPENDIX 1.—Full names of plants appearing in Table 1. Synonyms in square brackets.

MNEMONIC	FULL NAME AND AUTHORITY
ACA KAR	Acacia karroo *Hayne*
ACA SIE	Acacia sieberiana *DC.*
AGE PEN	Agelaea pentaphylla *(Lam.) Baill.*
ALB GUM	Albizia gummifera *(J.F.Gmel.) C.A.Sm.*
ANN SEN	Annona senegalensis *Pers.*
ANT VEN	Antidesma venosum *Tul.*
ARG MAC	Argomuellera macrophylla *Pax*
ARG TOM	Argyrolobium tomentosum *(Andrews) Druce*
ASP PLU	Aspilia pluriseta *Schweinf.* subsp. pluriseta
ATH ROS	Athrixia rosmarinifolia *(Walp.) Oliv. & Hiern*
BEQ NAT	[*Bequaertiodendron natalense* (Sond.) Heine & J.H.Hemsl.] Englerophytum natalense *(Sond.) Pennington*
BER ABY	Bersama abyssinica *Fresen.*
BRA SPI	Brachystegia spiciformis *Benth.*
BRI MIC	Bridelia micrantha *(Hochst.) Baill.*
CAL AUR	Calpurnia aurea *(Aiton) Benth.* subsp. aurea
CAN MUN	Canthium mundianum *Cham. & Schltdl.*
CAR BIS	Carissa bispinosa *(L.) Desf. ex Brenan* subsp. bispinosa
CAS BAT	Casearia battiscombei *R.E.Fr.*
CAS MAL	Cassipourea malosana *(Baker) Alston*
CAT EDU	Catha edulis *(Vahl) Endl.*
CEL AFR	Celtis africana *Burm.f.*
CEL GOM	Celtis gomphophylla *Baker*
CEL MIL	Celtis mildbraedii *Engl.*
CHI BAT	Chionanthus battiscombei *(Hutch.) Stearn*
CHR GOR	Chrysophyllum gorungosanum *Engl.*
CLA ANI	Clausena anisata *(Willd.) Hook.f. ex Benth.*
CLE SWY	Clerodendrum swynnertonii *S.Moore*
CLU SWY	Clutia swynnertonii *S.Moore*
CNE POL	Cnestis polyphylla *Lam.*
COF LIG	Coffea ligustroides *S.Moore*
COL GRE	Cola greenwayi *Brenan*
COM MOL	Combretum molle *R.Br.*
CRA BRE	Craibia brevicaudata *(Vatke) Dunn* subsp. baptistarum *(Büttner) J.B.Gillett*
CRE TRI	Cremaspora triflora *(Thonn.) K.Schum.*
CRO SYL	Croton sylvaticus *Hochst.*
CRY LIE	Cryptocarya liebertiana *Engl.*
CUS SPI	Cussonia spicata *Thunb.*
CYM CAE	Cymbopogon caesius *(Hook. & Arn.) Stapf*
DES SET	Desmodium setigerum *(E.Mey.) Harv.*
DIC CIN	Dichrostachys cinerea *(L.) Wight & Arn.*
DID NOR	Didymosalpinx norae *Swynn.*
DIO ABY	Diospyros abyssinica *(Hiern) F.White*
DIO LYC	Diospyros lycioides *Desf.*
DOM BUR	Dombeya burgessiae *Harv.*
DOV MAC	Dovyalis macrocalyx *(Oliv.) Warb.*

DRA FRA	Dracaena fragrans *Ker Gawl.*
DRA MAN	Dracaena mannii *Baker*
DRY GER	Drypetes gerrardii *Hutch.*
EHR CYM	Ehretia cymosa *Thonn.* var. divaricata *(Baker) Brenan*
ERI NUT	Eriosema nutans *Schinz*
ERY LYS	Erythrina lysistemon *Hutch.*
EUC DIV	Euclea divinorum *Hiern*
FAD CIE	Fadogia cienkowskii *Schweinf.*
FAU SAL	Faurea saligna *Harv.*
FIC CHI	Ficus chirindensis *C.C.Berg*
FIC SUR	Ficus sur *Forssk.*
FLE GRA	Flemingia grahamiana *Wight & Arn.*
GRE OCC	Grewia occidentalis *L.* var. occidentalis
HAL LUC	Halleria lucida *L.*
HAR MAD	Harungana madagascariensis *Poir.*
HEI DIE	Heinsenia diervilleoides *K.Schum.*
HET DEH	Heteropyxis dehniae *Suess.*
HET TRI	Heteromorpha trifoliata *(H.L.Wendl.) Eckl. & Zeyh.*
HYP ARI	Hypoestes aristata *(Vahl) Roem. & Schult.*
IND HED	Indigofera hedyantha *Eckl. & Zeyh.*
IND SWA	Indigofera swaziensis *Bolus*
JUL GLO	Julbernardia globiflora *(Benth.) Troupin*
KEE GUE	Keetia gueinzii *(Sond.) Bridson*
KHA ANT	Khaya anthotheca *Baker f.*
LAN CAM	Lantana camara *L.*
LIP JAV	Lippia javanica *(Burm.f.) Spreng.*
LOV SWY	Lovoa swynnertonii *Baker f.*
MAC CAP	Macaranga capensis *(Baill.) Sim*
MAE LAN	Maesa lanceolata *Forssk.*
MAY HET	Maytenus heterophylla *(Eckl. & Zeyh.) N.Robson*
MAY SEN	Maytenus senegalensis *(Lam.) Exell*
MEL LOB	Mellera lobulata *S.Moore*
MYR HOM	Myrianthus holstii *Engl.*
NEW BUC	Newtonia buchananii *(Baker) G.C.C.Gilbert & Boutique*
OCH ARB	Ochna arborea *DC.* var. oconnorii *(E.Phillips) Du Toit*
OCI GRA	Ocimum gratissimum *L.* var. gratissimum
OXY GOE	Oxyanthus goetzei *K.Schum.* subsp. goetzei
OXY SPE	Oxyanthus speciosus *DC.*
PAR CUR	Parinari curatellifolia *Planch. ex Benth.*
PAV COM	Pavetta comostyla *S.Moore* subsp. comostyla var. comostyla
PED AFR	Peddiea africana *Harv.*
PHY NUM	Phyllanthus nummulariifolius *Poir.*
PLE PYC	Pleiocarpa pycnantha *(K.Schum.) Stapf*
POL FUL	Polyscias fulva *(Hiern) Harms*
PRO FAL	[*Protasparagus falcatus* (L.) Oberm.] Asparagus falcatus *L.*
PRO LAR	[*Protasparagus laricinus* (Burch.) Oberm.] Asparagus laricinus *Burch.*
PRO PLU	[*Protasparagus plumosus* (Baker) Oberm.] Asparagus plumosus *Baker*
PRU AFR	Prunus africana *(Hook.f.) Kalkman*
PSE HOO	Pseudarthria hookeri *Wight & Arn.*
PSE SUB	Pseuderanthemum subviscosum *(C.B.Clarke) Stapf*
PSI GUA	Psidium guajava *L.*
PSO FEB	Psorospermum febrifugum *Spach*
PTE ROT	Pterocarpus rotundifolius *(Sond.) Druce*
RAU CAF	Rauvolfia caffra *Sond.*
RAW LUC	Rawsonia lucida *Harv. & Sond.*
RHA PRI	Rhamnus prinoides *L'Hér.*
RHO REV	Rhoicissus revoilii *Planch.*
RHU LON	Rhus longipes *Engl.*
RHU TEN	Rhus tenuinervis *Engl.*
RHU TRA	Rhus transvaalensis *Engl.*
RHY SWY	Rhynchosia swynnertonii *Baker f.*
RIN FER	Rinorea ferruginea *(Baker f.) M.Brandt*
ROT URC	Rothmannia urcelliformis *(Hiern) Bullock*
RUB RIG	Rubus rigidus *J.E.Sm.*
RUB COR	Rubia cordifolia *L.* subsp. conotricha *(Gand.) Verdc.*
RUT FUS	Rutidea fuscescens *Hiern*
SAP ELL	Sapium ellipticum *(Hochst.) Pax*
SCO STO	Scolopia stolzii *Gilg*
SEN LAT	Senecio latifolius *DC.*
SEN SEP	Senna septemtrionalis *(Viv.) Irwin & Barneby*
SEN SIN	Senna singueana *(Delile) Lock*
SPH PRU	Sphedamnocarpus pruriens *(A.Juss.) Szyszyl.*
STR MEL	Strychnos mellodora *S.Moore*
STR MIT	Strychnos mitis *S.Moore*
STR SPI	Strychnos spinosa *Lam.*
STR USA	Strychnos usambarensis *Gilg*
STR SCH	Strombosia scheffleri *Engl.*
SYZ GUG	Syzygium guineense (*Willd.*) *DC.* subsp. guineense
TAB VEN	Tabernaemontana ventricosa *Hochst. ex A.DC.*
TAN SWY	Tannodia swynnertonii *(S.Moore) Prain*
TAR PAV	Tarenna pavettoides *(Harv.) Sim* subsp. affinis *(K.Schum.) Bridson*
TEC NOB	Teclea nobilis *Delile*
TEP LON	Tephrosia longipes *Meisn.* subsp. swynnertonii *(Baker f.) Brummitt*
THE TRI	Themeda triandra *Forssk.*
TIL FUN	Tiliacora funifera *(Miers) Oliv.*
TRE ORI	Trema orientalis *(L.) Blume*
TRI DRE	Trichilia dregeana *Sond.*
TRI PIN	Triumfetta pilosa *Roth* var. nyasana *Sprague & Hutch.*
TRI MAD	Trilepisium madagascariense *DC.*
VAN API	Vangueria apiculata *K.Schum.*
VAN INF	Vangueria infausta *Burch.*
VER COL	Vernonia colorata *(Willd.) Drake*
XYL PAR	Xylopia parviflora *(A.Rich.) Benth.*
XYM MON	Xymalos monospora *(Harv.) Baill.*