VEGETATION PATTERNS AND ENVIRONMENTAL GRADIENTS IN BENIN

Implications for biogeography and conservation

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To my mother Egnonanmédé Sounnou,
my late father Prosper Adomou and
my stepmother Julienne Kossou

CONTENTS

SAMENVATTING

Vegetatiepatronen en omgevingsgradiënten in Benin: gevolgen voor biogeografie en behoud

Begrip van verspreidingspatronen van plantensoorten en de factoren die daaraan ten grondslag liggen is van groot belang voor het behoud en beheer van plantengezelschappen en het ecosysteem. De geografische verspreiding van plantensoorten is niet geheel willekeurig. Er bestaan duidelijke patronen en kunnen worden onderscheiden door zorgvuldige analyse van de verspreidingspatronen van een groot aantal soorten. Met deze chorologische aanpak zoals gebruikt door White (1983), (de ruimtelijke typologie), onderzochten wij de vegetatiepatronen in Benin, gebruik makende van moderne statistische methoden en bespraken de biografische en ecologische gevolgen van deze patronen. Hoofdstuk 1 beschrijft de achtergronden en de doelen van het onderzoek en het gebied waarin het onderzoek plaatsvond.

In Hoofdstuk 2 wordt op basis van de uitkomsten van een Two-Way Indicator Species Analysis (TWINSPAN) en Detrended Correspondence Analysis (DCA) van 598 vegetatie-opnamen een indeling van Benin in 10 fytogeografische districten. Chorologische analyse voldeed als een complementaire benadering bij de karakterisatie van fytosociologisch bepaalde districten en laten toe deze in drie fytochorologische hoofdzones te groeperen, namelijk de Guineo-Congolese en Sudan regio's, verbonden door de Guineo-Sudan overgangszone. Het waargenomen biogeografische patroon is uitgelegd in termen van zowel ecologische factoren (klimaat, geologie en topografie, reliëf) en historische factoren (klimaatsveranderingen in het verleden). De biogeografische uitzonderlijkheid van het district Pobè werd verduidelijkt door de exclusieve aanwezigheid van endemische Guineo-Gongolese genera zoals *Amphimas*, *Anthonotha*, *Distemonanthus*, *Hymenostegia*, *Anthrocaryon*, *Coelocaryon*, en *Discoglypremna.* De enige familie endemisch in de Guineo-Congolese regio die ook in Benin voorkomt is, is die der is Octoknemataceae met *Octoknema borealis*, lijkt in Benin beperkt tot het district Ouémé. De PD's van Bassila en de Atacora bergrug, behorende tot de Sudan regio, blijken ecologisch en biogeografisch uitzonderlijke floristische gebieden te zijn. Het achtste genus endemisch in de Guineo-Congolese regio is *Aubrevillea* met *A. kerstingii*, welke beperkt is tot het PD van Bassila. Het genus *Haematostaphis* met *H. barteri* dat endemisch is in de Sudan-regio en de soort *Thunbergia atacoriensis* endemisch in Benin zijn gevonden in de Atacora bergketen. De voorgestelde floristische gebieden volgen de klimatologische zonering en lijken sterk op de eerdere indelingen, welke op fysiognomie van de planten waren gebaseerd. De verbanden tussen onze floristische gebieden en de regionale chorologische eenheden van White (1983) zijn besproken.

In Hoofdstuk 3 worden de belangrijkste vegetatietypen beschreven op grond van hier voorkomende soorten. Wij concentreerden ons op het verklaren van de gradiënten in soortensamenstelling en de eraan ten grondslag liggende ecologische factoren. Two-Way Indicator Species Analysis (TWINSPAN) uitgevoerd op een matrix van 598 vegetatieopnamen and 1021 plantensoorten resulteerden in 20 onderscheidbare vegetatie-typen. Chorological and Detrended Correspondence Analyses (DCA) van deze vegetatie-typen leidde tot de onderkenning van vier chorologische hoofdgroepen, gegroepeerd langs een klimaatgradiënt. De vier chorologische groepen passen in vier onderscheidbare fyto-chorologische zones: de Guineo-Congolese en Sudan regio's, gescheiden door twee overgangszones. Dit wordt ondersteund door de sterke correlatie tussen de eerste DCA-as en chorologische categorieën. De resultaten toonden aan dat beschikbaarheid van water – uitgedrukt als een functie van regenval, lengte en intensiteit van het droge seizoen, en luchtvochtigheid – de belangrijkste factor is die de vegetatiegradiënt in Benin verklaart, en 80% van de variatie in soortensamenstelling. Regenval op zich verklaart slechts 30% daarvan.

Daarom is het incorrect om de regenval op zich als de belangrijkste factor aan te merken die de soortenverspreiding in West Afrika verklaart. Deze resultaten tonen de voorspellende waarde van het vegetatietype aan in termen van chorologische groepen en klimaat. Fytosociologie en chorologie blijken twee complementaire benadering van de fytogeografie te zijn.

Hoofdstuk 4 benadrukt de verspreidingspatronen in het semi-bladverliezende bos in Benin en hun belang voor de biogeografie. De zes beschreven semi-bladverliezende bostypen en hun floristische samenstelling (zowel op soort- als op familieniveau) zijn vergelijkbaar met die welke worden onderscheiden in andere delen van West Afrika, waar het bladverliezende bos meer aaneengesloten is. De ecologisch dominante families zijn Sterculiaceae, Ulmaceae (nu Celtidaceae), Leguminosae, Moraceae, Ebenaceae, Rubiaceae and Euphorbiaceae. De *Drypetes aframensis-Nesogordonia papaverifera* gemeenschap bleek het type bos te zijn waarin Celtidaceae, Sterculiaceae, Euphorbiaceae, en Violaceae het rijkst zijn vertegenwoordigd. De vele waargenomen Opper-Guineese endemen in de semi-bladverliezende bos-eilandjes zijn duidelijke bewijzen voor de floristische verbanden in het verleden tussen de Dahomey Kloof en de West Afrikaanse regenbosgebieden. Het in de centraal-noordelijke gebieden beperkt voorkomen van de *Khaya grandifoliola-Aubrevillea kerstingii* gemeenschap werd uitgelegd als een resultaat van overeenkomsten in het verleden tussen het Interval en het Opper-Guinea bosgebied. De algemene soortensamenstelling van de semi-bladverliezende boseilandjes in zuidelijk Benin komt grotendeels overeen met de stuifmeelgegevens uit de natte periode van het vroege tot midden-Holoceen (8500-4000 jaar geleden), een periode waarin het Dahomey interval blijkt bedekt geweest te zijn met semi-bladverliezend bos. Wij nemen aan dat de *Terminalia superba-Piptadeniastrum africanum* gemeenschap, welke overeenkomt met het West-Afrikaanse vochtige semi-bladverliezende bos, de vegetatie in het Interval gedurende die periode domineerde. Het terugtrekken naar de rivieroeverbossen wordt uitgelegd als een ecologisch antwoord op het droge klimaat van het Laat-Holoceen, welke de opdeling van het West-Afrikaanse regenbos inluidde. Onze resultaten tonen aan dat moderne kennis van de structuur van de plantengemeenschappen, soortensamenstelling en -voorkomen van essentieel belang is voor het interpreteren van pollengegevens bij de reconstructie van de palaeo-vegetatie.

Hoofdstuk 5 identificeert de plantensoorten en gebieden welke voorrang behoeven bij de natuurbescherming. Niet minder dan 280 bedreigde plantensoorten worden opgesomd, waarvan 90% in de categorieën Bedreigd en Sterk Bedreigd vallen. Dit geeft aan dat het risico van uitsterven voor deze soorten hoog is. Van de genoemde soorten, zijn er 19 van regionaal belang voor behoud, en 10 van belang op wereldniveau, welke ook op de IUCN Rode Lijst staan. Uit de chorologische analyse blijkt dat de Guineese soorten dominant zijn in deze categorieën en 77% uitmaken van de gerapporteerde bedreigde soorten. Dit komt overeen met het veelvuldig in de dichte bosrestanten voorkomen van bedreigde soorten. Tot de gebieden die het rijkst zijn aan de zeldzaamste soorten (soorten slechts op één plek voorkomend) behoren boseilandjes zoals Pobè (17 soorten met begrensd voorkomen), Dangbo (11 soorten), Ewè (9 soorten) en Ahozon (8 van zulke soorten). Nadruk wordt gelegd op de semi-bladverliezende bosrelicten als gebieden met groot belang voor natuurbehoud, omdat deze omstreeks 20% van de Beninese flora bevatten. Andere gebieden van groot belang voor natuurbescherming zijn bijv. het moerasbos van Lokoli, de mangrove van Ouidah, de monolieten (Inselberge) van het fytogeografisch district Zou, en de bergrug Atacora waar de twee soorten endemisch voor Benin voorkomen. Voorts is bewezen dat de meeste van deze gebieden bedreigde plantengemeenschappen herbergen. De studie levert fundamentele botanische informatie op voor de verbetering van het bestaande netwerk van beschermde gebieden.

Hoofdstuk 6 bevat een algemene discussie en conclusies over de kwesties bestudeerd in dit proefschrift. De verspreiding van *Rinorea* (als bio-indicator genus) leverde verder bewijs voor het biogeografische belang van de semi-bladverliezende boseilanden. Wij bespraken verder de implicaties van onze resultaten voor het natuurbehoud in Benin.

SUMMARY

Vegetation patterns and environmental gradients in Benin: implications for biogeography and conservation

Understanding plant species distribution patterns and the underlying factors is a crucial step for the conservation and management of plant communities and ecosystems. The geographical distribution of plant species is not entirely random. Clear patterns exist and can be detected by careful analysis of the distribution patterns of a large number of species. Following this chorological approach suggested by White (1983), we explored the vegetation patterns in Benin using modern statistical tools and discussed the biogeographical and ecological implications. Chapter 1 presents the background, the objectives and the study area.

In **Chapter 2**, we proposed a phytogeographical subdivision of Benin based on multivariate and chorological analyses. Two-Way Indicator Species Analysis (TWINSPAN) and Detrended Correspondence Analysis (DCA) performed well on our data and suggest an objective subdivision of Benin into ten phytogeographical districts (PDs). Chorological analysis proves to be a complementary approach to the characterisation of phyto-sociologically-defined districts and allows their merging into three major phytochorological zones, namely the Guineo-Congolian and Sudanian regions, linked by the Guineo/Sudanian transition zone. The biogeographical patterns observed were interpreted in terms of both ecological factors (climate, soil, geology and land form) and historical factors (past climatic changes). The biogeographical particularity of the PD of Pobè was elucidated by the exclusive presence of the Guineo-Congolian endemic genera such as *Amphimas*, *Anthonotha*, *Distemonanthus*, *Hymenostegia*, *Anthrocaryon*, *Coelocaryon*, and *Discoglypremna*. The only Guineo-Congolian endemic family found in Benin is Octoknemataceae with *Octoknema borealis* (now in Olacaceae), which appears to be restricted to the PD of Ouémé valley. The PDs of Bassila and the Atacora Chain within the Sudanian Region turn out to be ecologically and biogeographically outstanding floristic areas. The 8th Guineo-Congolian endemic genus reported in Benin was *Aubrevillea* with *A. kerstingii*, which is restricted to the PD of Bassila. The Sudanian endemic genus *Haematostaphis* with *H. barteri* and the Benin's endemic species *Thunbergia atacoriensis* were found to be confined to the Atacora Chain. The proposed floristic areas reflect the climatic zonation and express a great similarity to the previous physiognomically-based subdivisions. The relationships between our floristic areas and the regional chorological units as proposed by White (1983) were discussed.

In **Chapter 3**, we classified and described the major vegetation types based on species composition. It focused on elucidating the gradients in species composition and underlying ecological factors. Two-Way Indicator Species Analysis (TWINSPAN) performed on a matrix of 598 relevés and 1021 plant species result in twenty distinct vegetation types. Chorological and Detrended Correspondence Analyses (DCA) of these plant communities lead to the recognition of four main chorological groups patterned along a climatic gradient. The four chorological groups correspond geographically to four distinct phytochorological zones: the Guineo-Congolian and Sudanian regions separated by two transition zones. This was supported by the strong correlation between the first DCA-axis and chorological categories. The results show that water availability – expressed as a function of rainfall,

length and intensity of the dry season, and air humidity – is the major factor determining the vegetation gradient in Benin, and explains 80% of the variation in species composition. Rainfall, considered alone, only accounts for 30% of the variation in species composition along the vegetation gradient. Thus, it is not correct to consider rainfall alone as the prime moisture factor underlying the species distribution in West Africa. This demonstrates the predictive value of vegetation type with regard to chorological categories and climate. Phytosociology and chorology turn out to be two complementary approaches to phytogeography.

Chapter 4 focused on the patterns in semi-deciduous forest and their biogeographical significance. The six semi-deciduous forest types described and their floristic composition (both at species and family levels) are comparable to those recognised in other parts of West Africa where the semi-deciduous forest is more continuous. The ecologically dominant families include Sterculiaceae, Ulmaceae (now Celtidaceae), Leguminosae, Moraceae, Ebenaceae, Rubiaceae and Euphorbiaceae. The *Drypetes aframensis-Nesogordonia papaverifera* community appeared to be the vegetation type in which the Celtidaceae, Sterculiaceae, Euphorbiaceae, and Violaceae are best represented. The record of many Upper Guinean endemic species in the semi-deciduous forest islands provided strong evidence for past floristic connections of the Dahomey Gap with the West African rain forest zones. The restriction of the *Khaya grandifoliola-Aubrevillea kerstingii* community to the centre-northern section was interpreted as resulted from past floristic connections between this area and the Upper Guinean forest block. The overall species composition of the semi-deciduous forest islands situated in southern Benin is in good agreement with the pollen assemblages of the humid period of early-mid Holocene (8500-4000 years BP), a period during which the Dahomey Gap was shown to be covered by a semi-deciduous forest. The *Terminalia superba-Piptadeniastrum africanum* community, which corresponds to the West African moist semi-deciduous forest, was assumed to dominate the vegetation of the gap during this period. Its subsequent retreat to forest stream banks was interpreted as an ecological response to the general dry climate of the late Holocene, which induced the fragmentation of West African rain forest. The results show that knowledge of modern plant community structure, species composition and distribution is vital for the in-depth interpretation of pollen data in the process of palaeo-vegetation reconstruction.

In **Chapter 5**, plant species and areas of conservation priority were identified using the available botanical information. As many as 280 threatened plant species were recorded, of which 90% was categorised as Endangered and Critically Endangered. This indicates that the risk of extinction facing these species is high. Among them, 19 were recognised to be of regional conservation concern while 10 were of globally conservation concern and are on the IUCN Red List. The chorological analysis revealed that the Guinean species are dominant and represent 77% of the threatened species reported. This is in agreement with the high representation of threatened species in the closed forest remnants. The richest sites in rarest species (i.e. species confined to one site) include the semi-deciduous forest islands such as Pobè (17 range-restricted species), Dangbo (11 species), Ewè (9 species), and Ahozon (8 species). Emphasis was put on the semi-deciduous forest relics as of high conservation concern, since they include c. 20% of Benin's flora. Other areas of conservation priority include the swamp forest of Lokoli, the mangrove of Ouidah, the inselbergs of the phytogeographical district of Zou, and the Atacora Chain which harbours the two Benin's endemic plant species. Furthermore, most of these sites proved to harbour threatened plant communities. This study also provides basic botanical information for the improvement of the existing reserve network.

Chapter 6 presented a general discussion and conclusions on issues tackled in this thesis. The distribution of *Rinorea* (a bio-indicator genus) provided further evidence for the

biogeographical significance of the semi-deciduous forest islands. We discussed the implications of our research outputs for biodiversity conservation in Benin.

RESUME

Les patrons de végétation et gradients environnementaux au Bénin: Implications pour la biogéographie et la conservation

La compréhension du patron de distribution des espèces végétales et des facteurs qui les gouvernent sont d'une importance capitale pour la conservation et la gestion des écosystèmes. La distribution des espèces végétales n'est pas entièrement aléatoire. Des patterns de distribution écologiquement interprétables existent et peuvent être identifiés par une analyse minutieuse des patrons de distribution d'un grand nombre d'espèces. En suivant cette approche chorologique proposée par White (1983), nous nous sommes donné pour objectifs i) d'identifier sur la base de listes floristiques les grands types de groupement végétaux au Bénin en utilisant les outils statistiques modernes d'analyse de végétation, ii) d'analyser leur distribution sur l'ensemble du territoire et iii) de discuter des implications biogéographiques et écologiques de cette étude. Le chapitre 1 présente les fondements, objectifs et le milieu d'étude.

Le **chapitre 2**, est une contribution au découpage phytogéographique du Bénin. Il traite essentiellement de l'application de la phytosociologie au découpage phytogéographique à grande échelle. L'analyse numérique utilisant TWINSPAN et DECORANA de 598 relevés phytosociologiques et 1021 espèces végétales a permis de subdiviser le Bénin en 10 districts phytogéographiques (DPs). L'analyse chorologique de la flore des DPs a permis de les fusionner en trois grandes zones phytochorologiques: les zones Guinéo-Congolaise et Soudanienne séparées par la zone de transition Guinéo/Soudanienne. Ces zones phytochorologiques proposées sur base floristique correspondent aux trois grandes zones climatiques reconnues au Bénin. Les facteurs déterminant le patron biogéographique observé sont d'ordre écologique (climat, sol et relief) et historique (les fluctuations climatiques du quaternaire). La particularité biogéographique du DP de Pobè est illustrée par la présence exclusive de genres endémiques à la région Guinéo-Congolaise en occurrence *Amphimas*, *Anthonotha*, *Distemonanthus*, *Hymenostegia*, *Anthrocaryon*, *Coelocaryon* et *Discoglypremna*. Il est important de souligner que la seule famille endémique à la région Guinéo-Congolaise enregistrée au Benin (Octoknemataceae avec *Octoknema borealis*) est confinée au DP de la Vallée de l'Ouémé. Nous avons aussi élucidé les spécificités phytogéographiques des DPs de Bassila caractérisé par l'endémique Guinéo-Congolais *Aubrevillea* avec *A. kerstingii* et de la Chaîne de l'Atacora caractérisé par la présence exclusive de *Haematostaphis* avec *H. barteri* qui est un endémique Soudanien et de *Thunbergia atacoriensis* qui est endémique au Bénin. Nous avons aussi comparé nos unités floristiques aux découpages phytogéographiques antérieurs, particulièrement celui de White (1983).

Le **chapitre 3** s'est appesanti sur la description des groupements végétaux, de leur distribution et surtout de la question de gradients floristiques au Bénin. L'analyse multivariée (DCA et TWINSPAN) de 598 relevés phytosociologiques et 1021 espèces végétales a permis d'individualiser 20 groupements végétaux qui s'ordonnent suivant un gradient climatique. L'analyse chorologique a permis d'agréger ces derniers en quatre groupes chorologiques qui correspondent à quatre zones phytochorologiques. L'analyse de corrélation a montré que l'indice d'humidité de Mangenot (1951) qui intègre la moyenne annuelle des précipitations, la durée de la saison sèche, l'importance des précipitations durant la période sèche et l'hygrométrie atmosphérique explique mieux le changement de la composition spécifique des

groupements végétaux ($R^2 = 0,80$) que la moyenne pluviométrique annuelle ($R^2 = 0,30$). Nous avons donc conclu le total pluviométrique annuel n'est pas le seul facteur climatique qui détermine la distribution des communautés végétales en Afrique subsaharienne. Nous avons aussi clarifié la valeur prédictive des groupements végétaux vis-à-vis des catégories chorologiques et du climat. Cette étude a aussi prouvé que la phytosociologie et la phyto-chorologie constituent deux approches complémentaires à la phytogéographie.

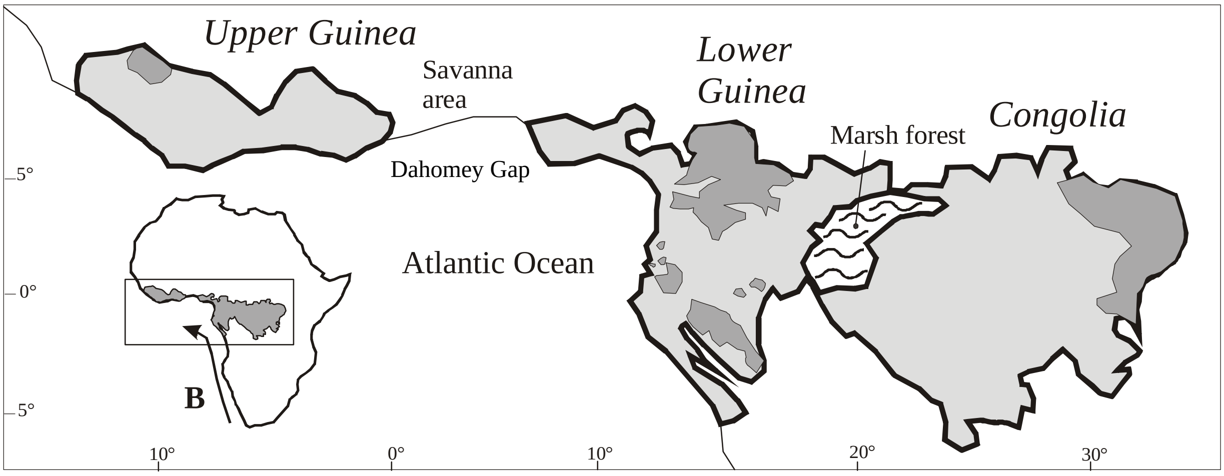
Les patrons de distribution des groupements de forêt dense humide semi-décidue et leurs implications biogéographiques constituent la substance du **chapitre 4**. Les six grands types de groupements végétaux décrits présentent de grandes similarités floristiques (tant au niveau spécifique que des familles) à ceux reconnus dans d'autres pays de l'Afrique de l'Ouest comme la Côte d'Ivoire et le Ghana où la forêt dense humide est moins perturbée en certains endroits. Les familles les plus écologiquement importantes sont: Sterculiaceae, Ulmaceae, Leguminosae, Moraceae, Ebenaceae, Rubiaceae et Euphorbiaceae. Le groupement à *Drypetes aframensis* et *Nesogordonia papaverifera* est identifié comme celui dans lequel les Celtidaceae (ex Ulmaceae), Sterculiaceae, Euphorbiaceae et Violaceae sont mieux représentées en termes de richesse spécifique et densité. La présence exclusive du groupement à *Khaya grandifoliola* et *Aubrevillea kerstingii* dans le district phytogéographique de Bassila est interprétée comme irradiation du bloc forestier occidental durant les phases humides des changements climatiques du quaternaire. La composition floristique des îlots de forêt dense humide semi-décidue du Sud-Bénin et l'ensemble pollinique de la période humide du début Holocène et de l'Holocène moyen sont similaires. Au cours de cette période, le groupement à *Terminalia superba* et *Piptadeniastrum africanum*, qui correspond au type le plus humide de forêt dense semi-décidue en Afrique de l'Ouest, dominerait la végétation du Dahomey-Gap. La position actuelle de ce groupement qui se trouve confiné aux ruisseaux dans les forêts reliques de Pobè, Niaouli et Dangbo est interprétée comme une réponse écologique à la période sèche de l'Holocène récent.

Le **chapitre 5** traite des espèces et communautés végétales menacées de disparition. Nous avons identifié 280 espèces végétales menacées de disparition dont 90% présentent une forte probabilité d'extinction. Par elles, 19 sont d'intérêt régional pour la conservation et 10 sont sur la liste rouge de l'IUCN. L'analyse chorologique a révélé la dominance des espèces guinéennes qui représentent 77% des espèces menacées enregistrées. Ce fait est corroboré par la forte concentration des espèces menacées dans les îlots de forêts denses humides. Les sites les plus riches en «espèces endémiques locales» sont Pobè (17 espèces exclusives), Dangbo (11 espèces exclusives), Ewè (9 espèces exclusives) et Ahozon (8 espèces exclusives). Un accent particulier est mis sur la nécessité de conserver les îlots de forêts dense humide semi-décidues qui abritent environ 20% de la flore nationale. La forêt marécageuse de Lokoli, la mangrove de Ouidah, les inselbergs du DP du Zou et la Chaîne de l'Atacora qui abritent les deux espèces végétales endémiques au Bénin, méritent une attention particulière en matière de conservation de la biodiversité au Bénin. La plupart de ces sites prioritaires pour la conservation de la biodiversité abritent aussi des communautés végétales menacées de disparition. Les données sur la distribution des plantes et communautés végétales menacées de disparition peuvent être capitalisées dans l'amélioration du réseau des aires protégées.

Une discussion générale de tous les aspects abordés dans la thèse est présentée au **chapitre 6**. La distribution des *Rinorea* au Bénin corrobore l'hypothèse selon laquelle les îlots de forêt dense humides semi-décidue sont des vestiges de groupements végétaux issus de la fragmentation forestière engendrée par la période sèche de l'Holocène récent. Nous avons discuté de l'intérêt que nos résultats présentent pour la conservation de la biodiversité au Bénin.

Chapter 1

GENERAL INTRODUCTION



The African lowland rain forest (light grey), divided in 3 regions, Upper Guinea, Lower Guinea and Congolia. Dark grey: hills and plateaus; B: Benguela current. *Source*: Leal (2004)

1.1. BACKGROUND

There is general agreement that biodiversity is under assault on a global basis, and that species are being lost at a greatly enhanced level (Lawton & May 1995, Royal Society 2003). Around a tenth of the world's bird species and a quarter of its mammals are listed by the World Conservation Union (IUCN) as threatened with extinction (IUCN 2002). Between half (0.5%) and one (1%) percent of the world's tropical forest are still being lost each year (FAO 2001a, Achard et al. 2002). The process of deforestation in Africa, which is mainly due to shifting cultivation and timber exploitation, is proceeding at an alarming rate. From 1990 to 2000, 12 millions hectares of forest have been cleared in West Africa (FAO 2001b). The FAO's study conducted from 1990 to 1995 showed that the highest annual rate of African forest and woodland destruction occurred in West African countries such as Togo (1.44%), Ghana (1.26%), Benin (1.25%), Guinea (1.12%), Gambia (0.86), and Nigeria (0.86) (FAO 1995). The last estimate of forest cover change reported that Benin has lost 6990 km^2 of forest within the period of 1990-2000, which correspond to an annual deforestation rate of 2.3% (FAO 2001b). In addition to this high rate of deforestation, the vegetation of Benin and Togo has been considerably influenced by the Holocene climatic changes (Salzmann & Hoelzmann 2005).

Southern Benin belongs to the Dahomey Gap, which can be defined as the climatically dry corridor separating the West African rain forest into the Upper and Lower Guinean forest blocks (White 1983, Poorter et al. 2004). It is regarded as an important ecogeographical barrier to species exchange between the two forest blocks and is, as such, of a crucial significance for their distribution patterns in West Africa (van Bruggen 1989, Martin 1991, Jenik 1994). The lowland vegetation of the Gap is completely devoid of evergreen rain forest and its associated plant and animal species. It is largely dominated by farms, fallows and grasslands intermingled with small islands of semi-deciduous forest. The phenomenon of the Dahomey Gap and extensive deforestation make the natural flora of Benin – which is being estimated to encompass c. 3000 plant species – relatively poor in comparison with neighbouring countries such as Nigeria, Ghana and Ivory Coast (Project Flora of Benin 2001). The flora of Benin is expected to be comparable to that of Togo, which has been estimated at 3085 plant species (Afidégnon et al. 2003, Earth Trends-Togo 2003). With the growing awareness of the problem, the biodiversity conservation in Benin has become an issue of increasing priority both at national and international level.

The conservation of habitats and landscapes constitutes one of the major targets (target 4) of the Convention on Biological Diversity (CBD 2002) through its global strategy for plant conservation. Meeting this biodiversity conservation target requires every country or state to engage in systematic conservation planning and related conservation action. Some of the key measures needed to achieve the “target 4” include: (1) identification and classification of habitats types (or vegetation types), (2) mapping areas of habitat types, (3) assessing the conservation values of habitat types, (4) assessing threats, and (5) devising ideal conservation networks. Understanding plant species distribution patterns and the underlying factors is a crucial step for the conservation and management of plant communities and ecosystems. Conservation planning will be greatly strengthened if biogeographical models are predictive, which requires assessment of processes likely to influence the distribution and survival of species in the future (CBD 2002).

In general, studies on the vegetation of Benin are sparse and are only available at local level (Paradis 1983, Adjakidjè 1984, Akoègninou 1984, Sinsin 1993, Sokpon 1995, Houinato 2001, Akoègninou et al. 2002, Oumorou 2003). Hardly any general vegetation analysis based on detailed inventories has been done. FAO/PNUD (1980) and Adjanohoun et al. (1989) described the major physiognomic units in terms of the most abundant species. A recent study on natural forests has provided details on climatic patterns and appears to be the only vegetation study based on a countrywide floristic survey (Akoègninou 2004). Hitherto no specific aspects of gradients in species composition and underlying factors controlling plant distribution patterns have been studied. Furthermore, information on plant species and communities of conservation concern is almost completely lacking. Therefore, assessing plant species and community distribution patterns, ecological processes sustaining these patterns, and their conservation value should be regarded as an important step forward towards plant biodiversity conservation in Benin.

Research objectives

The main objective of this research is to contribute to a better knowledge of the vegetation patterns in Benin, and to elucidate the underlying environmental factors and implications for biodiversity conservation. More specifically, the aims of this thesis are:

- To propose a phytogeographical subdivision of Benin based on plant species composition;
- To describe the major plant communities in Benin and elucidate their relationships with species distribution range types and ecological factors;
- To elucidate the semi-deciduous forest patterns in terms of ecological factors and past climatic changes with emphasis on the Dahomey Gap;
- To identify plant species with conservation priority such as threatened plant species and communities;
- To provide baseline biological information essential for plant biodiversity conservation.

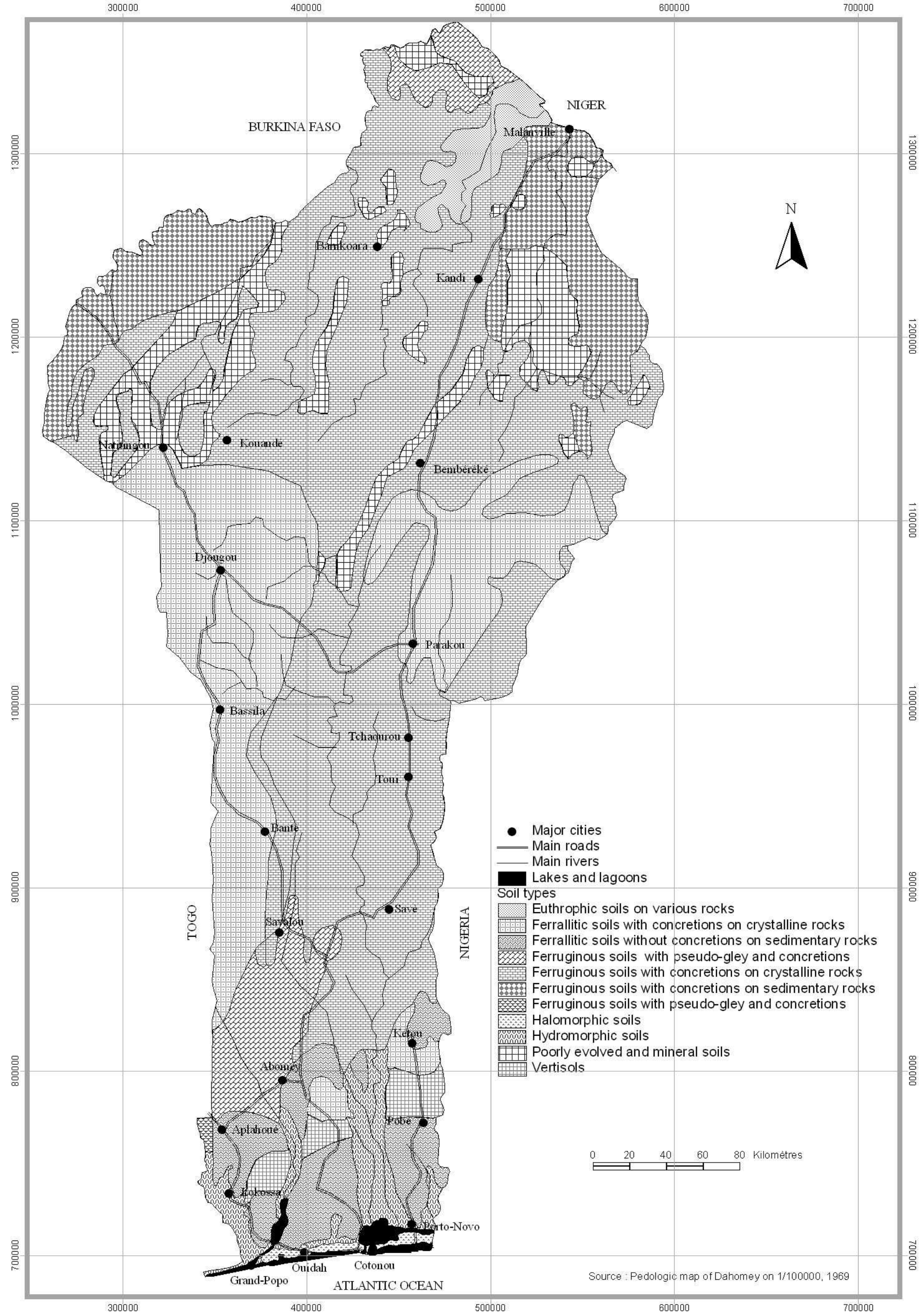
1.2. STUDY AREA

1.2.1. Location and area

The Republic of Benin is situated in West Africa between the latitudes 6°10’N and 12°25’N and longitudes 0°45’E and 3°55’E. It is bordered by the republics of Togo in the west, Nigeria in the east, Atlantic Ocean in the south, Burkina Faso and Niger in the north. It covers a land area of 112 622 km^2. The population has been estimated at 6 752 569 inhabitants with an average density of 57 inhabitants per km^2 (INSAE 2002).

1.2.2. Soils and geology

In general, the profile of the country is an undulating plateau with a few scattered hills in the centre and the north. The altitude varies from sea level to 400-650 m in the northwest, where the Atacora chain is the outstanding feature. Geologically the southern part refers to the West African Continental Terminal with sedimentary rock while the northern section refers to the Precambrian Shield (from 7-7°30’N northwards) with granito-gneissic rock, which can be found as outcrops (inselbergs). Four major groups of soils can be distinguished (Willaine & Volkoff 1967): (1) ferrallitic soils covered by semi-deciduous forest, (2) ferruginous soils covered by dry forest, woodland, and savannah, (3) vertisol in the depression of Lama covered by a particular dry type of semi-deciduous forest, and (4) hydromorphic soils covered by swamp and riparian forests (Figure 1.1).



Source : Pedologic map of Dahomey on 1/100000, 1969

Figure 1.1: Map of Benin showing the major soil types.

1.2.3. Climate

The mean annual rainfall varies from 900 to 1300 mm. Its lowest values are recorded in the south-westernmost section and in the far north (900-950 mm). The highest precipitation (1200-1300 mm) is confined to Southeast Benin as well as the tract Bassila-Djougou (Figure 1.2). The mean annual temperatures range from 26 to 28°C and may exceptionally reach 35-40^{o}C in northern localities such as Kandi and Malanville. The annual temperature amplitude is low in the southern part (5-10^{o}C) while it is higher (11-13^{o}C) in the northern part (from the latitude 8^{o}N northwards). As in most West-African countries, the climate is primarily determined by the annual cycle of the "Inner Tropical Convergence Zone" (ITCZ). Three climate zones can broadly be distinguished (Adjanohoun et al. 1989, Akoègninou 2004):

(1) The southern zone: From the coast up to the latitude 7°N, the climate is Guinean or subequatorial with two rainy seasons alternating with a long dry season (December-February). The short dry season (July-August) rarely exceeds two months.

(2) The transition zone: Between the latitudes 7°and 9°N, the climate becomes subhumid or subsudanian with a tendency to a pattern of one rainy season and one dry season. The two rainfall peaks tend to merge into one peak, which indicates a unimodal rainfall regime.

(3) The northern zone is characterised by a truly Sudanian climate with a unimodal rainfall regime. The rain season lasts 7 months (on average) and covers the period April-October with the optimum around August/September.

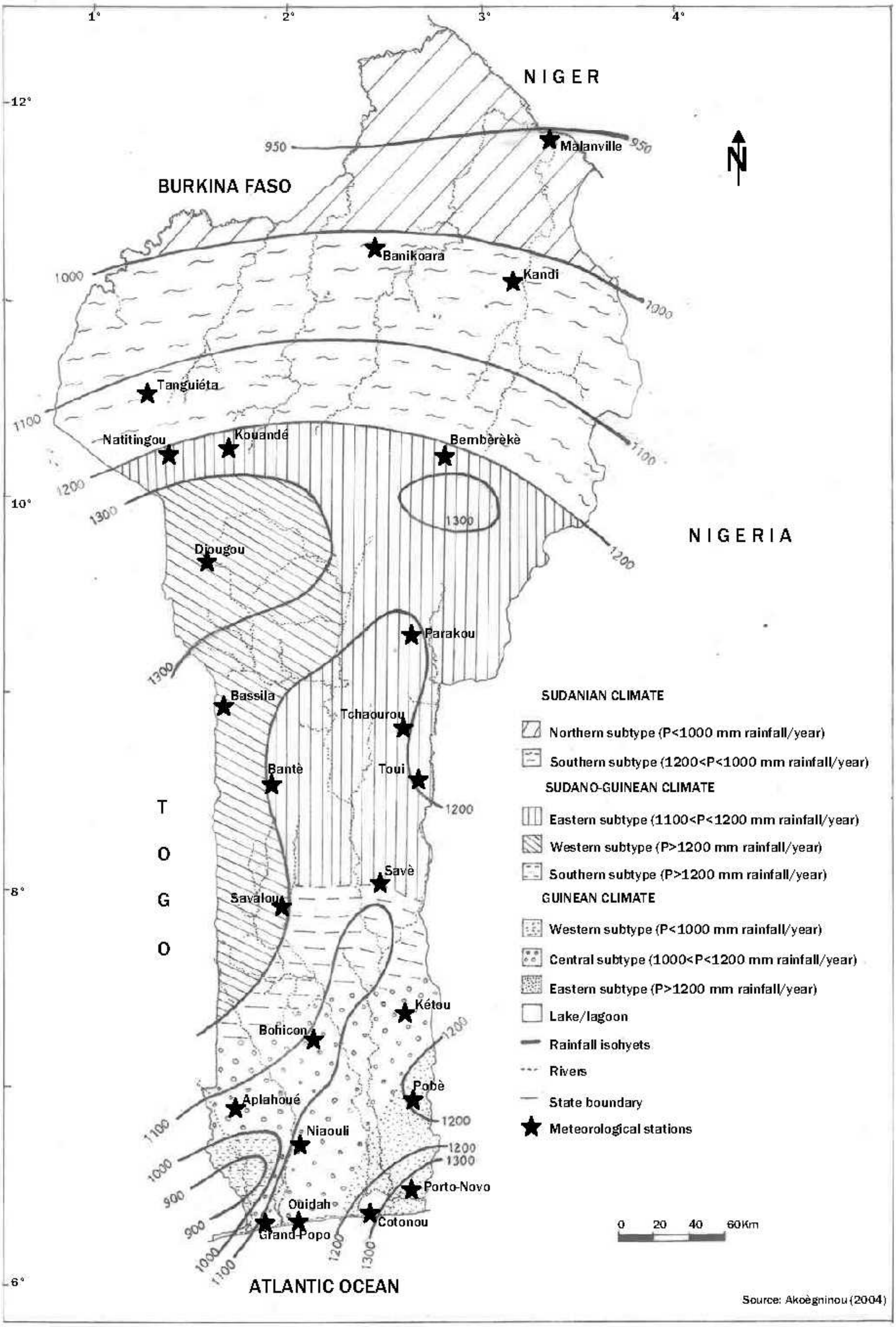
1.2.4. Vegetation

Following White (1983), three major vegetation zones can be distinguished in Benin (Figure 1.3):

(1) The zone of mosaic of lowland rain forest and secondary grassland: Most of the original vegetation has been replaced by secondary grasslands or thickets due to the phenomenon of the Dahomey Gap and human activities such as shifting agriculture and logging. The extant natural plant formations are represented by patches of semi-deciduous and swamp forests. The common species include *Triplochiton scleroxylon, Celtis zenkeri, Cola gigantea, Milicia excelsa, Antiaris toxicaria, Ceiba pentandra, and Albizia* spp. "Undisturbed" swamp forest dominated by *Alstonia congensis, Xylopia rubescens*, and *Syzygium owariense* is rare. In the extreme south, there is a sandy coastal strip with thickets dominated by *Chrysobalanus icaco* var. *icaco*. The mangrove vestiges are dominated by *Rhizophora racemosa and Avicennia germinans*.

(2) The zone of Sudanian woodland with abundant *Isoberlinia* spp.: Associated species include *Monotes kerstingii* and *Uapaca togoensis*. *Berlinia grandiflora* and *Cola laurifolia* are common in riparian forest (Natta 2003). The dry forest dominated by *Anogeissus leiocarpa* also occurs and generally fringes the riparian forest. Parklands dominated by *Vitellaria paradoxa*, *Parkia biglobosa*, *Khaya senegalensis* and *Afzelia africana* are common in the area (Wezel & Böcker 2000). Beside the expansion of crop land, the traditional use of fuel is another important factor in the reduction of woodlands. In 1995, 93% of the total fuel energy used in Benin came from fire-wood and charcoal (Worldbank 1998).

(3) The zone of undifferentiated Sudanian woodland devoid of *Isoberlinia* except in few small pockets: The commonest species include *Combretum* spp., *Acacia* spp. *Hyparrhenia* spp., *Loudetia* spp. and *Andropogon* spp.



Source: Akoègninou (2004)

Figure 1.2: Map of Benin showing the climatic zones and the rainfall patterns.

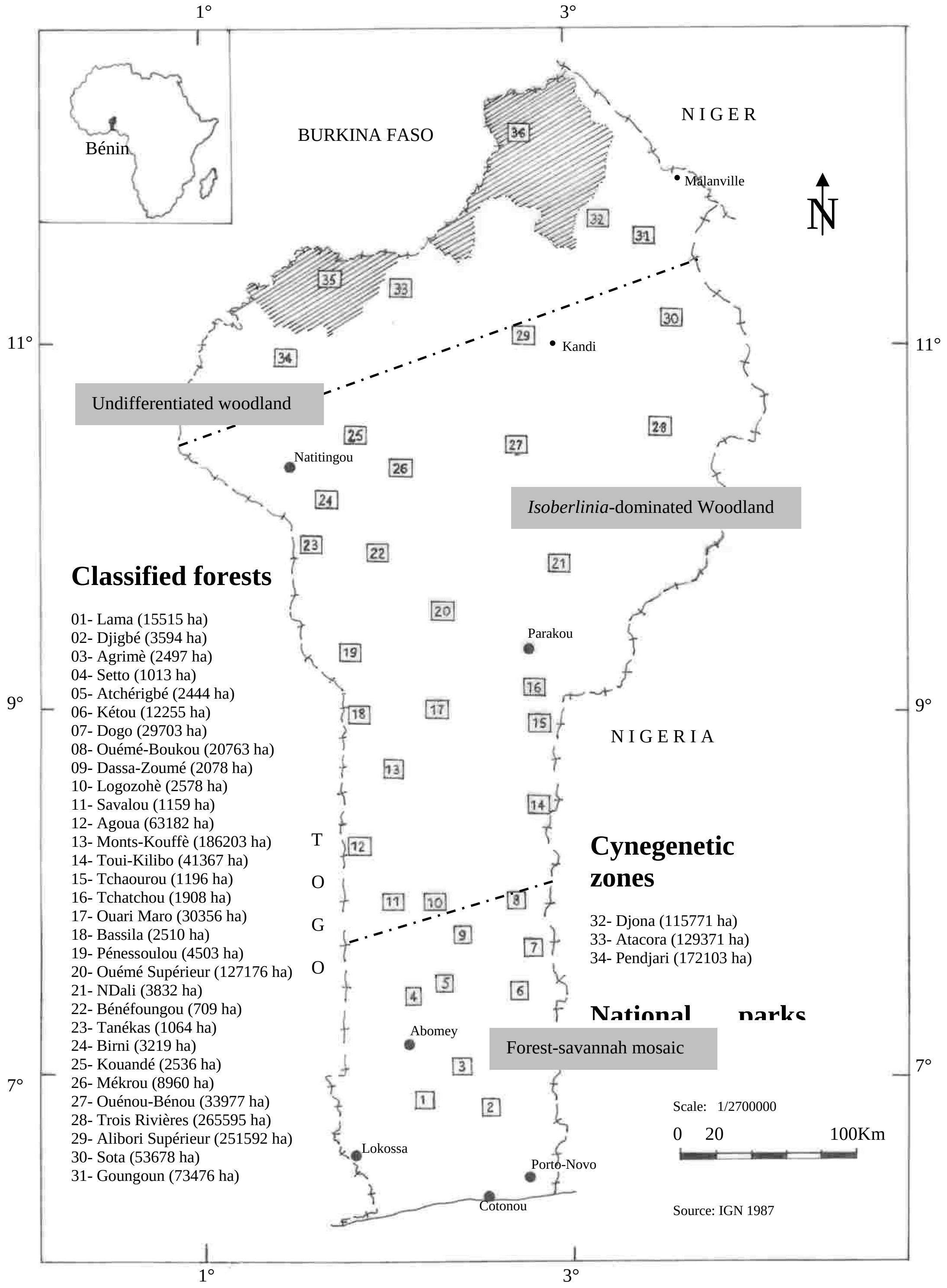


Figure 1.3: Map of Benin showing the three major vegetation zones according to White (1983) and the locations of protected areas.

The country covers a land area of 112 622 km^2, of which 24% is covered by forest (Earth Trends-Benin 2003). About 22.7% of the total land area is legally protected (CENATEL 1992, FAO 2001b) (Figure 1.3). The vegetation in several of the protected sites has almost entirely vanished and has even been invaded by settlements; typical cases include Alibori Supérieur and Goungoun. Some sites such as Atchérigbé and Agoua are simply replaced by plantations.

Chapter 2

PHYTOSOCIOLOGICAL AND CHOROLOGICAL APPROACHES TO PHYTOGEOGRAPHY: A STUDY AT MESO-SCALE IN BENIN

Submitted to “*Systematics and Geography of Plants*”

Chapter 2

PHYTOSOCIOLOGICAL AND CHOROLOGICAL APPROACHES TO PHYTOGEOGRAPHY: A STUDY AT MESO-SCALE IN BENIN

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Abstract

This study is based on 598 phytosociological relevés and 1021 plant species taken during an extensive vegetation survey in the Republic of Benin. Site selection was primarily directed towards forest reserves on purpose, to understand the potential vegetation patterns countrywide. Distributional patterns numerically assessed by means of Two-Way Indicator Species Analysis (TWINSPAN) and Detrended Correspondence Analysis (DCA) suggested a meaningful subdivision of Benin into ten phytogeographical districts (PDs). Chorological analysis proved to be valuable as a complementary approach to the characterisation of the phytosociologically-defined districts and allowed their merging into three major phytochorological zones, namely the Guineo-Congolian and Sudanian regions, linked by the Guineo/Sudanian transition zone. The phytochorological zonation reflects the general climatic patterns. While the climate seems to be the primary factor, a more complete interpretation of the observed patterns should include the joint effect of several ecological factors (climate, soil, geology, and land form) as well as historical factors (past climatic fluctuations). The biogeographical particularity of the PD Pobè in southern Benin was elucidated by the exclusive presence of the Guineo-Congolian endemic genera such as *Amphimas*, *Anthonotha*, *Distemonanthus*, *Hymenostegia*, *Anthrocaryon*, *Coelocaryon*, and *Discoglypremna*. The PDs Bassila and Atacora Chain turned out to be of great ecological and biogeographical relevance within the Sudanian regional centre of endemism. We provided evidence for a former floristic connection of these two PDs to the Upper Guinean West African forest block. Benin's endemic plant species *Thunbergia atacoriensis* (Acanthaceae) was found to be confined to the Atacora Chain. The results show how the phytosociology approach through numerical analysis of a large dataset constitutes an effective methodological tool for clarifying phytogeographical patterns at meso-scale.

Key words: Phytosociology, phytogeography, chorological analysis, TWINSPAN, DCA, Benin Republic, West Africa.

2.1. Introduction

One of the reasons for making vegetation maps has always been that vegetation faithfully portrays the character of the environment. Indeed, vegetation mapping is the only effective method to represent the ecological order of our living space (Küchler 1988). This is true, because only on a map the extent and the distribution of plant communities can be shown objectively.

Important contributions to the phytogeographical division of Africa include, among many others, the work of Chevalier (1933), Lebrun (1947), Aubréville (1949a & 1949b), Monod (1957), Trochain (1970), and White (1979 & 1983). These authors attempted to divide the African continent into a number of chorological units such as Regions (or Phytochoria), Domains, and Sectors. These units display a degree of endemism and climatic distinctiveness that decrease from Region level to sector level (Braun-Blanquet 1932; Trochain 1970; Guinko 1983). A district, which is the lowest recognisable phytogeographical rank, is characterized by some infra-specific endemism and an absence of climatic particularities (Lacoste & Salanon 1969). It can be a result of floristic irradiations from surrounding centres of endemism. The most outstanding contribution to the African phytogeography is the chorological map of White (1983) who developed a system of regional centres of endemism, Transition zones, and Regional mosaics. White (1979) first stipulated the criteria of a Regional Centre of Endemism: it should both have more than 50% of its species confined to it, and a total of more than 1000 endemic species. At regional scale, the Republic of Benin (West Africa) falls into three phytochorological zones: the Guineo-Congolian regional centre of endemism, the Guinea-Congolia/Sudania regional transition zone and the Sudanian regional centre of endemism (White 1983).

Major local phytogeographical studies in Benin include the work of Adjanohoun *et al*. (1989), Wezel *et al*. (1999), Houinato *et al*. (2000) and Akoègninou (2004). Based on field experience and literature review involving the work of Keay (1949) in Nigeria, Ern (1979) in Togo, Hall & Swaine (1981) in Ghana, Adjanohoun *et al*. (1989) distinguished ten major vegetation types grouped into four floristic zones including the Coastal zone, the Guineo-Congolian zone, the Guineo/Sudanian transition zone and the Sudanian zone. Based on the work of Adjanohoun (1989) and satellite image interpretation, Wezel *et al*. (1999) recognised six major vegetation zones in Benin. Houinato *et al*. (2000), documenting the map established by Adjanohoun *et al*. (1989), recognised ten phytogeographical districts, using the distribution of *Eragrostis* in Benin. Based on the work of Adjanohoun *et al*. (1989) and climate zonation, Akoègninou (2004) subdivided the country in ten sectors. None of these studies were performed on a phytosociological basis and the units defined were held together just by a certain physiognomic or climatic similarity, not by floristic relationships. It is important that phytogeographical analysis be made on floristic grounds, as taxa and communities generally provide the best assessment of the environment (Daubenmire 1968, Hill 1977). Natural regions are best defined by functional relationships between physical factors of the environment and biological components such as vegetation and animal communities (Rowe & Sheard 1981).

Floristic patterns have interested phytogeographers for centuries, and the subject has been approached in several ways, for instance by examining the phytogeographical distribution of individual species, physiognomic features or plant communities (Preston & Hill 1997, Ojeda *et al*. 1998, Dahl 1998). The description and interpretation of distributional data for many species at biogeographical scales represent a holistic approach to biogeography that can provide hypotheses to be tested by further observation and by experimental, deductive, and historical studies (Birks 1976). The foundation of quantitative phytogeography lies in the fact that all range-limited species, genera, and families are related to certain communities, and these communities indicate the boundaries of biogeographical units. The analysis of general patterns in biogeography thus involves considering many species at the same time at many sites, and hence, inevitably involves the use of multivariate methods (Myklestad & Birks 1993). Here we report a phytogeographical subdivision for Benin, based for the first time on an extensive phytosociological survey and numerical-chorological approaches. It is assumed that clear patterns exist, and can be detected by careful analysis of the distribution patterns of large number of species. Thus, this paper aims to explore how well numerical analyses based on phytosociological data perform at meso-scale (i.e. country level) in retrieving the major phytogeographical units and splitting them into lower phytogeographical ranks such as district. Our purpose was to develop a comprehensive, phytosociologically and chorologically-based phytogeographical subdivision in Benin.

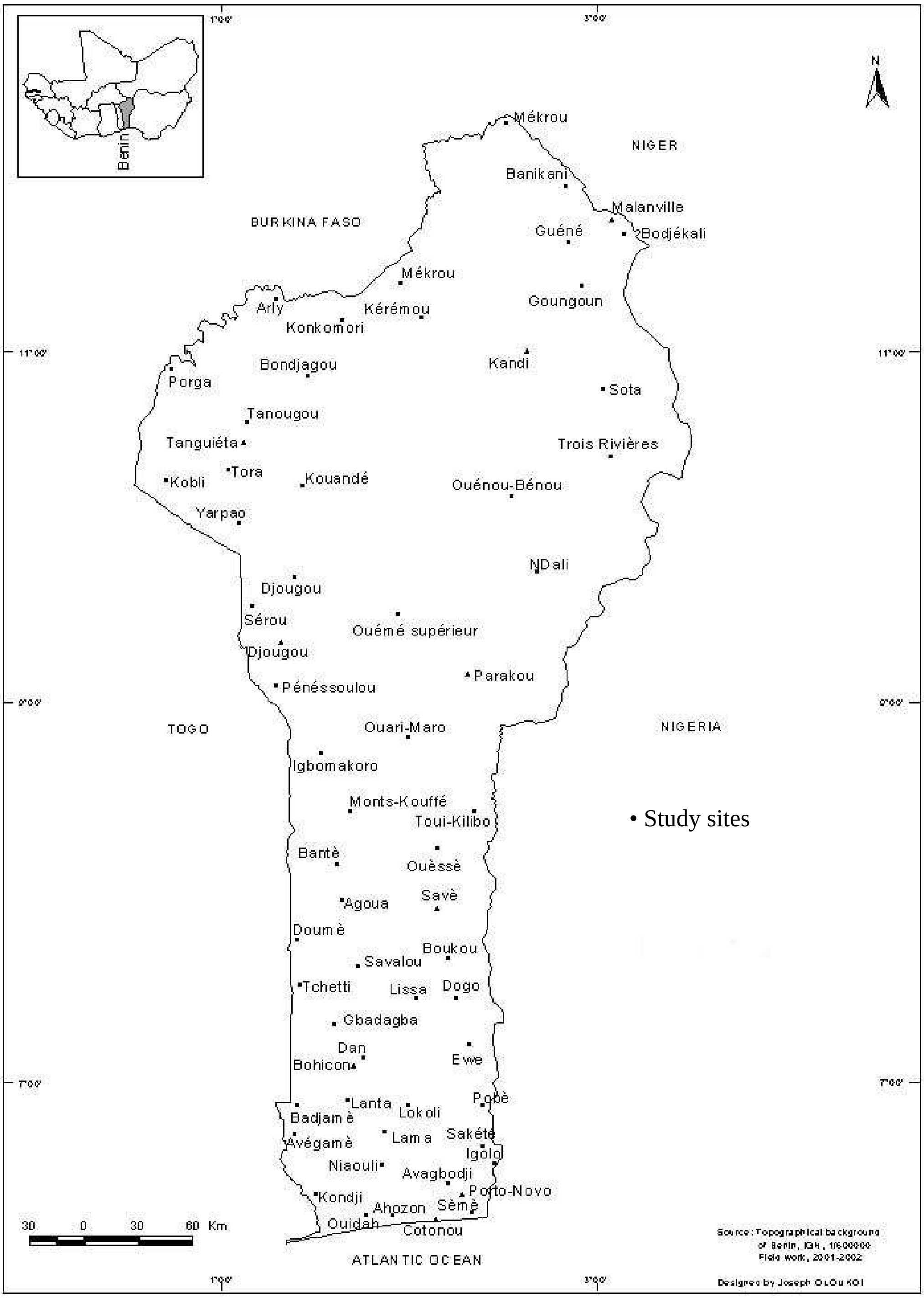
2.2. Materials and Methods

2.2.1. Survey area

The study was conducted in the Republic of Benin, situated in West Africa between latitudes 6^o10’N and 12^o25’N and longitudes 0^o45’E and 3^o55’E (Figure 2.1). In general, the profile of the country is an undulating plateau except for a few scattered hills in the centre and the north. The altitude varies from sea level to 400-650 m in the northwest, where the Atacora chain is the outstanding feature. Four major groups of soils can be distinguished (Willaine & Volkoff 1967): (1) ferrallitic soils covered by semi-deciduous forest, (2) ferruginous soils covered by dry forest, woodland, and savannah, (3) vertisols in the depression of Lama covered by a particular type of semi-deciduous forest, and (4) hydromorphic soils covered by swamp and riparian forests.

The mean annual rainfall varies from 900 to 1300 mm. Its lowest values (900-950 mm) are recorded in the southwest and in the far north. The highest precipitation (1200-1300 mm) is confined to Southeast Benin as well as to the tract Bassila-Djougou. East-west and south-north rainfall gradients can be distinguished. The mean annual temperature ranges from 26 to 28°C and can exceptionally reach $35\text{-}40^o$C in northern localities such as Kandi. The annual temperature amplitude is low ($5\text{-}10^o$C) in the southern part while it is high ($11\text{-}13^o$C) in the northern part (from the latitude 8^oN northwards). As in most West-African countries, the climate is primarily determined by the annual cycle of the “Inner Tropical Convergence Zone” (ITCZ). Three climate zones can broadly be distinguished (Adjanohoun et al. 1989; Akoègninou 2004): (1) From the coast up to 7°-7°30’N, the climate is subequatorial with two rainy seasons alternating with a long dry season (December-February), and a short dry season (July-August), which rarely exceeds two months. (2) Between the latitudes 7°-7°30’and 9°, the climate becomes subhumid or subsudanian with a tendency to a pattern of one rainy season and one dry season. (3) The northern section is characterised by a truly Sudanian climate with a unimodal rainfall regime.

Benin’s southern part belongs to the Dahomey gap, which is the dry wedge that separates the West African rain forest belt into the Upper Guinea and Lower Guinea/Congolian Forest Blocks (White 1983). As a result, this part of the country (from the coast up to c. 7°30’N) consists of savannah, grassland, farmland, and fallow intermingled with small islands of closed forest (semi-deciduous and swamp forests). From c. 7°30’N to 12^o25’ N, the natural vegetation is essentially made of a patchwork of woodlands and savannahs with belts of riparian forest along rivers.



Source: Topographical background of Benin, IGN, 1/600000
Field work, 2001-2002

Designed by Joseph OLOUKOI

Figure 2.1: Map of Benin indicating the various study sites.

2.2.2. Data collecting

The vegetation map of Benin (FAO/PNUD 1980) was used as the basis for site selection. Guided by field experience of local botanists and ecologists, we made a checklist of protected areas, sacred or communal forests, and all unprotected areas hosting a tract of relatively "undisturbed" vegetation. To be certain that all the major vegetation zones were covered, we prepared a map showing the distribution of the localities where "undisturbed vegetation" is likely to be found. At each locality, we avoided vegetation plots with strong human interference in the choice of sites and placement of sample plots.

Phytosociological relevés according to Braun-Blanquet's (1932) approach were carried out at sites hosting the major plant formations such as mangrove, swamp forest, semi-deciduous forest, dry forest, riparian forest, woodland, and savannah (Aubréville 1957). At each site we selected representative and homogeneous sample stands, following the variations in dominant species and the major environmental factors such as soil texture, outcrops, topography etc. The geographical coordinates and altitude were noted using a GPS (Global Positioning System). General information related to soil conditions (texture, flooding, outcrops etc.) and topography (plateau, slope, and valley) was noted. The vegetation structure (number of layers, their cover and height) was described. We visually estimated the cover of each species using the Braun Blanquet cover/abundance scale (Westhoff & van der Maarel 1978): +: rare, less than 1% cover, 1: 1-5% cover, 2: 5-25% cover, 3: 25-50% cover, 4: 50-75% cover, and 5: 75-100% cover. In total 598 floristic relevés were, in most cases, performed within quadrates of 30 x 30 m except in riparian forest, where rectangular plots of 50 x 10 m were laid out. The relevé points were spread over the whole country in such a way that they can be considered as representative of the major vegetation types.

Climatic data (rainfall, temperature and air humidity) for the period 1956-1996 were obtained from 24 meteorological stations. The dataset, which consists of monthly climate values, is available from the Laboratory of Botany at the University of Abomey-Calavi (Benin). Akoègninou (2004) provided a synthesis (climatic map) of these data. The major soil types were derived from the pedological map of Benin (Willaine & Volkoff 1967).

2.2.3. Data processing

Identification of floristic patterns

A dataset including 598 relevés and 1021 plant species was set up using the version 2.0 of the software "Community Analysis Package (CAP)" (PISCES Conservation LTD 2002). In order to work out the major floristic units or trend at country level, we excluded from the overall analysis the 236 relevés taken from a-zonal formations such as swamp forest (29 relevés), mangrove (2 relevés), riparian forest (133 relevés) and its fringing dry forest (72 relevés). But they were included in the chorological and similarity analyses later on. Each major floristic unit was partially analysed to generate smaller floristic units, which geographically correspond to phytogeographical districts.

The classification and ordination were respectively performed using the Two-Way Indicator Species Analysis (TWINSPAN) (Hill 1979a) and the Detrended Correspondence Analysis (DECORANA or DCA) (Hill 1979b). The purpose of the classification was to categorise the relevés into clusters based on their plant species composition. The purpose of the ordination was to obtain, for each vegetation relevé, a numerical score indicating its position along an axis representing the main trend of variation in the floristic data. The numerical techniques adopted here have been successfully applied to data at biogeographical scales (Pedersen 1990, Hill 1991, Ojeda *et al.* 1998; Lawesson & Skov 2002). They are all based on the weighted-averaging eigenvector ordination technique of correspondence analysis (CA) (Hill 1973 & 1974, Jongman *et al.* 1995) that attempts to recover major patterns or structure as the first few ordination axes, and to relegate individual responses and noise within the data to later axes (Gauch 1982).

The geographical interpretation of TWINSPAN classification and DECORANA ordination was based on the spatial distribution of the clusters (vegetation relevés). The mapping of these clusters and the phytogeographical subdivisions per se were performed using the software Arc View.

Exclusive species ─ i.e. species completely or almost completely confined to a given phytogeographical district (Braun-Blanquet 1932) ─ were used to floristically characterise each phytogeographical district.

Patterns of (dis)similarities among phytogeographical districts

Once the country was divided into to a number of recognisable phytogeographical districts, the degree of distinctiveness of their floras was explored. This is an evaluation of the floristic relationships among the phytogeographical districts based on their overall floristic content. The plant species recorded from all the major vegetation types (zonal and a-zonal) were involved in this analysis. We set up a presence/absence matrix consisting of a number of defined phytogeographical districts and 1021 plant species. The pattern of (dis)similarities in species composition among phytogeographical districts was assessed using the index of similarity of Jaccard (1901), which is given by the formula:

$$P_j = 100 \text{ x } \frac{c}{a + b - c}$$

where P_j is Jaccard's community coefficient, a is the number of species present in the community A, b is the number of species in the community B, and c is the number of species shared by A and B.

The coefficient of dissimilarity (D) is merely defined as:

$$D = 1- P_j$$

The computation was automatically performed with the software CAP (PISCES Conservation LTD 2002). This index has proved to be a consistently good measure of similarity for presence/absence data (Mucina & van der Maarel 1989).

Chorological spectrum of phytogeographical district

It should be stressed that the phytogeographical districts defined by means of multivariate analyses should be regarded as reference points and not as definitive entities. The chorological (distribution range types) characterisation was decisive to fully understand the floristic patterns. We used the publications of Keay & Hepper (1954-1972), White (1983), and Aké Assi (2001 & 2002) to determine the chorotype (i.e. distribution range type) of each species. The five main chorotypes used are as follows: GC: Guineo/Congolian species, S: Sudanian species, SZ: Sudano-zambesian species, SG: Guinea-Congolia/Sudanian transition species i.e. linking elements between the Guineo-Congolian and Sudanian Regions, and Wd: Species with wide distribution such as Cosmopolitan, Pantropical, and Paleotropical. The proportions of the various chorotypes were calculated using the species checklists compiled for each phytogeographical district. The merging of the phytogeographical districts into chorological zones was based on the variation in the proportions of GC, S and *SZ.*

Climatic data handling

Climatic data including rainfall, temperature and their distribution over the year were summarized in the form of ombrothermograms (or climatic diagrams). The climatic diagrams display monthly averages for temperature and rainfall over the year. When the rainfall curve supersedes the temperature curve, it delimits an area, which corresponds to the period of the rainy season. When the rainfall curve falls under the temperature curve, the area between them indicates the dry season (Gaussen 1955, Walter 1963).

2.3. RESULTS

2.3.1. Preliminary analysis

The TWINSPAN classification of the 362 relevés and 865 plant species from zonal formation resulted in four main clusters, which correspond to the second dendrogram level. The DCA ordination shows that these clusters are patterned along a climatic gradient (Figure 2.2).

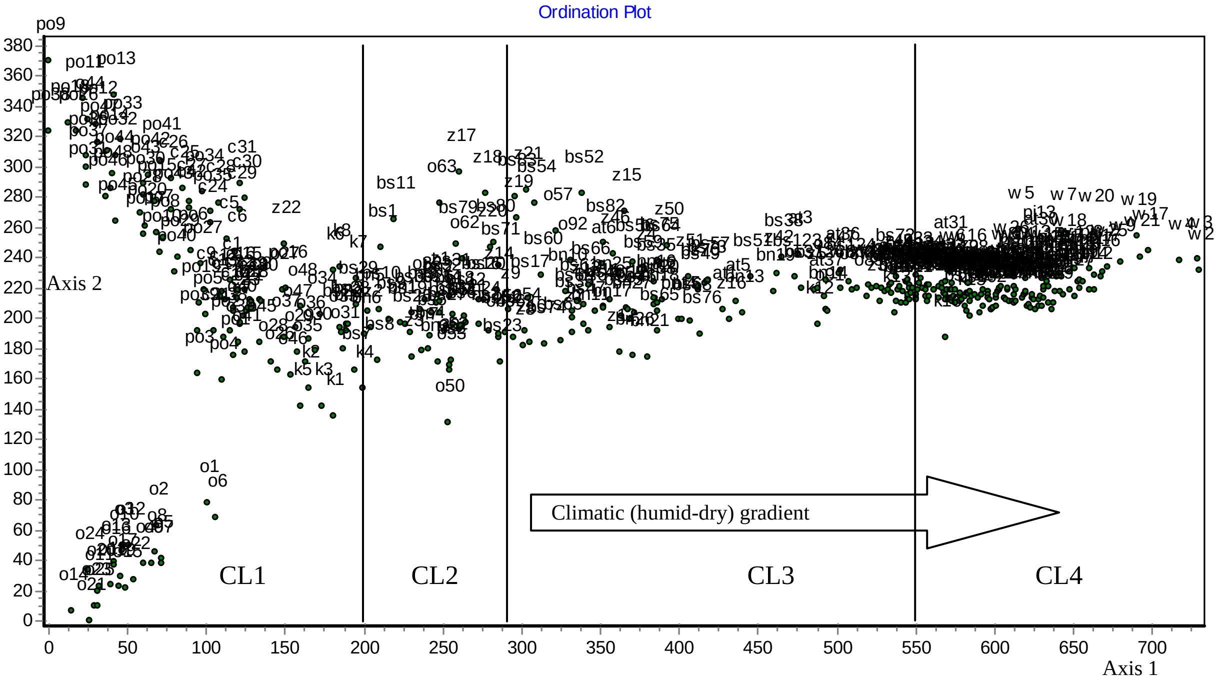


Figure 2.2: DCA ordination of 362 relevés and 865 plant species taken from zonal formation in Benin, showing four clusters. CLl: Semi-deciduous forest, CL2: dry semi-deciduous forest, CL3: Woodland, savannah woodland and tree savannah, CL4: Tree and shrub savannah. Note: The geographical interpretation of these four clusters is presented in Figure 2.3.

The four clusters can be described as follows:
(1) Cluster CL1: includes the 136 semi-deciduous forest relevés from the southern part of the country. The most frequent species within this cluster are *Triplochiton scleroxylon*, *Cola gigantea*, *Trichilia prieureana*, *Celtis zenkeri*, *Celtis prantlii*, *Antiaris toxicaria*, *Dialium guineense*, *Lecaniodiscus cupanioides*, and *Rothmannia longiflora*. The most differential species is *Triplochiton scleroxylon*. This cluster geographically corresponds to the floristic zone “So” (Figure 2.3), where the rainfall regime is bimodal with a rainfall gradient from east (1300 mm/year) to west (900 mm/year). The soil is ferrallitic without concretions.

(2) Cluster CL2: includes the 40 dry semi-deciduous forest relevés from the centre-western part of the country. The common species encompass *Cola gigantea*, *Celtis zenkeri*, *Celtis toka*, *Antiaris toxicaria*, *Holoptelea grandis*, *Erythrophleum suaveolens*, and *Khaya grandifoliola*. This cluster is characterised by the absence of *Triplochiton scleroxylon* and the exclusive presence of *Khaya grandifoliola* and *Aubrevillea kerstingii*. It geographically corresponds to the floristic zone “Nw” (Figure 2.3), where the rainfall regime is unimodal with an annual rainfall of 1200-1300 mm. The soil is ferralitic with concretions.

(3) Cluster CL3: encompasses the 96 relevés from woodland, savannah woodland, and tree savannah dominated by *Isoberlinia* spp. The tree layer is 8-15 m tall and its cover ranges from 40 to 80%. The common species within this cluster include *Isoberlinia doka*, *Isoberlinia tomentosa*, *Anogeissus leiocarpa*, *Pterocarpus erinaceus*, *Vitellaria paradoxa*, *Burkea* a*fricana*, *Prosopis* a*fricana*, *Pericopsis laxiflora*, *fzelia* a*fricana*, and *Kaempferia aethiopica*. The exclusive species are *Isoberlinia* spp. It geographically corresponds to the floristic zone “Cn” (Figure 2.3), where the rainfall regime is unimodal with an annual rainfall of 1000-1200 mm. The soil is ferruginous.

(4) Cluster CL4: includes the 90 relevés from tree and shrub savannahs, in which *Isoberlinia* spp. is scarce. The tree layer is very sparse (cover less than 20%) or practically absent. The common species within this cluster are *Anogeissus leiocarpa*, *Vitellaria paradoxa*, *Pterocarpus erinaceus*, *Lannea acida*, *Burkea africana*, *Combretum collinum*, *Combretum nigricans*, *Balanites aegyptiaca*, *Combretum glutinosum*, *Detarium microcarpum*, *Crossopteryx febrifuga*, *Acacia* spp., and *Bombax costatum*. The exclusive species include *Haematostaphys barteri*, *Erythrophleum africanum*, *Terminalia brownii*, *Albizia chevalieri*, *Balanites aegyptiaca*, and *Lonchocarpus laxiflora*. It geographically corresponds to the floristic zone “Fn”, where the rainfall regime is unimodal with an annual rainfall of 1000-900 mm. The soil is ferruginous.

The four clusters described above are geographically separated and correspond to four distinct floristic zones (Figure 2.3).

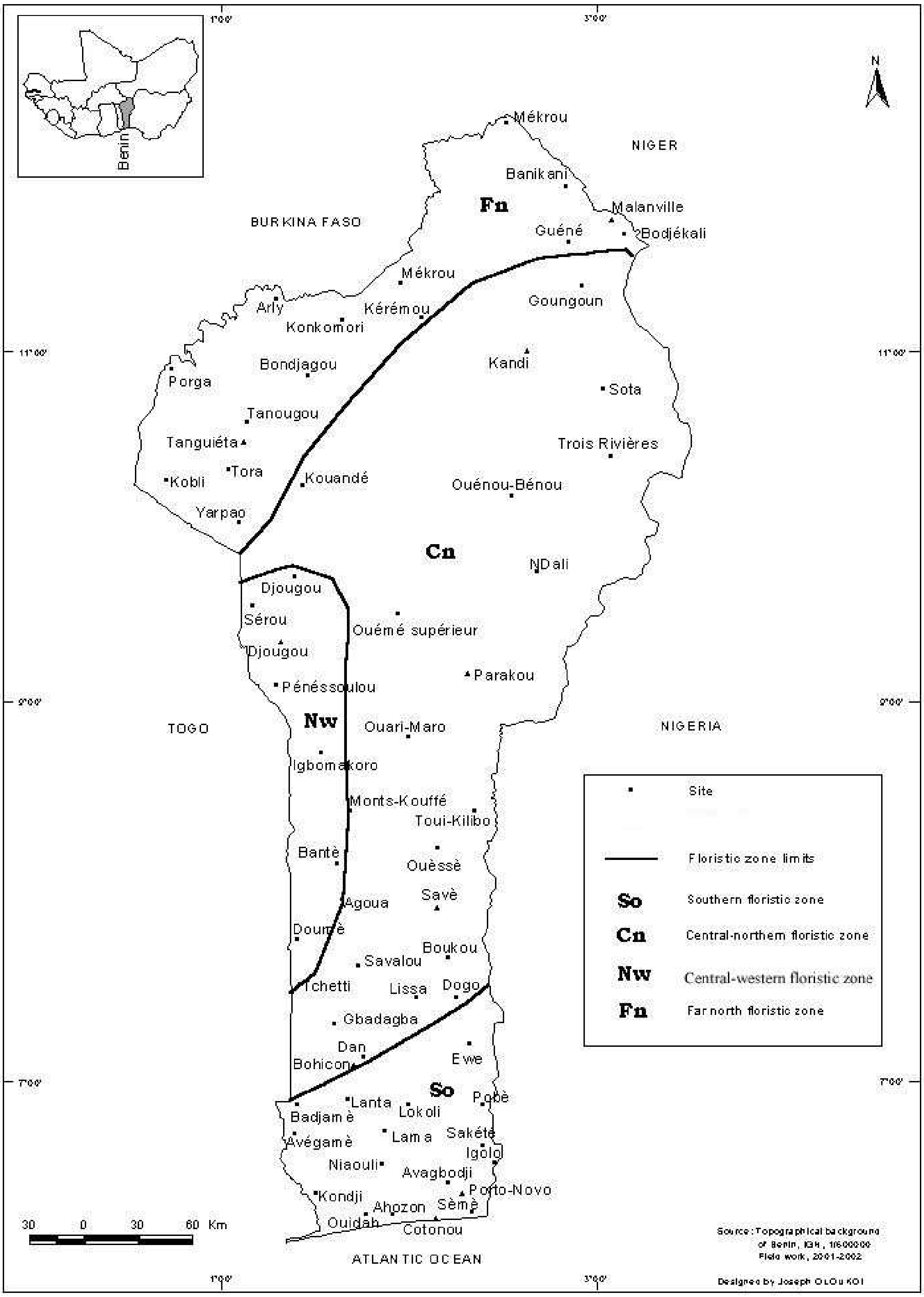


Figure 2.3: The four proposed floristic areas of Benin based on major plant community patterns. Major vegetation types in each floristic area: So: Semi-deciduous forest, Cn: Woodland & Savannah woodland, Nw: Dry semi-deciduous forest, Fn: Tree & shrub savannahs.

2.3.2. Analysis of the relevés of the floristic zone “So”

167 vegetation relevés are involved in this analysis; 136 relevés from semi-deciduous forest, 29 relevés from swamp forest and 2 from mangrove. The DCA ordination and TWINSPAN classification of these 167 relevés and 561 plant species shows five vegetation types (Figure 2.4) occurring in four geographically separated areas. We considered these areas as phytogeographical districts.

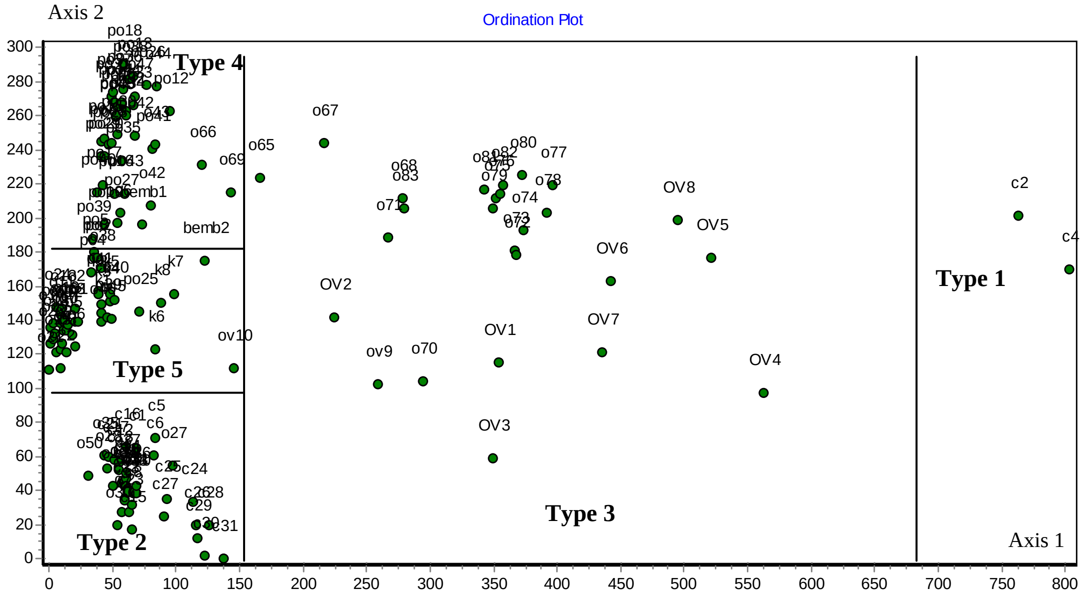


Figure 2.4: DCA ordination of 167 vegetation samples and 561 plant species from the floristic zone “So”, showing 5 vegetation types. Type 1: Mangrove, Type 2: Coastal semi-deciduous forest, Type 3: Swamp forest, Type 4: Semi-decidous forest under an annual rainfall of 1200-1300 mm, Type 5: Semi-deciduous forest under an annual rainfall of 900-1100 mm.

They can be described as follows:

* Types 1 & 2: include the relevés of mangrove (type 1) and relevés of coastal forest (type 2). Characteristic species of mangrove include *Rhizophora racemosa* and *Avicennia germinans*. Those of the coastal forest include *Syzygium guineense* var. *littorale*, *Chrysobalanus icaco* subsp. *icaco*, *Diospyros tricolor*, and *Trichoscypha oba*. These two vegetation types geographically correspond to a distinct floristic sub-zone, which we refer to as the phytogeographical district “Côtier”. The annual rainfall ranges from 900-1300 mm. The hygrometry is very high (80% on average) due the proximity of the sea. The soil is sandy.

* Type 3: includes the relevés of swamp forest on hydromorphic soil. Exclusive species encompass *Mitragyna ledermannii*, *Uapaca paludosa*, *Syzygium owariense*, *Xylopia rubescens*, *Anthostema aubryanum*, and *Rothmannia munsae*. The annual rainfall ranges from 1100-1300 mm. It geographically corresponds to a distinct floristic sub-zone, which we refer to as the phytogeographical district “Vallée de l’Ouémé” (or Ouémé Valley).

* Type 4: includes the relevés of semi-deciduous forest of south-eastern Benin. The most exclusive species include *Strombosia pustulata*, *Distemonanthus benthamianus* and *Canarium schweinfurthii*. The annual rainfall is 1100-1300 mm. The soil is ferrallitic on sedimentary rock. It geographically corresponds to a distinct floristic sub-zone, which we refer to as the phytogeographical district “Pobè”.

* Type 5: consisted of other relevés of semi-deciduous forest in southern Benin. Exclusive species include *Celtis mildbraedii*, *Rinorea brachypetala*, *Dennetia tripetala* and *Griffonia simplicifolia*. It is better described by the absence of the exclusive species of the vegetation type 4. The annual rainfall ranges from 900-1100 mm. The soil is ferrallitic on sedimentary rock. It geographically corresponds to a distinct floristic sub-zone, which we refer to as the phytogeographical district "Plateau".

2.3.3. Analysis of the relevés of the floristic zone "Nw"

The DCA ordination and TWINSPAN classification of 40 semi-deciduous forest relevés and 178 plant species result in three vegetation types without clear geographical patterns. The three vegetation types can be characterised by *Aubrevillea kerstingii*, *Khaya grandifoliola*, and *Erythrophleum suaveolens* respectively. The annual rainfall is 1200-1300 mm and the soil is ferrallitic on crystalline rock. Since it is not possible to divide this floristic zone unit into further geographical subunits, we refer to it as the phytogeographical district Bassila.

2.3.4. Analysis of the relevés of the floristic zone "Cn"

The TWINSPAN classification of 96 relevés (from woodland, savannah woodland and tree savannah) and 393 plant species discriminate three vegetation types. The DCA ordination shows that these vegetation types are patterned along a south-north climatic gradient (Figure 2.5). Within the floristic zone "Cn" (Figure 2.3), the climate gradually changes from a tendency to unimodal rainfall regime in the southern part to a truly unimodal rainfall regime in the northern part. Consequently, the species composition change is gradual along this climatic gradient.

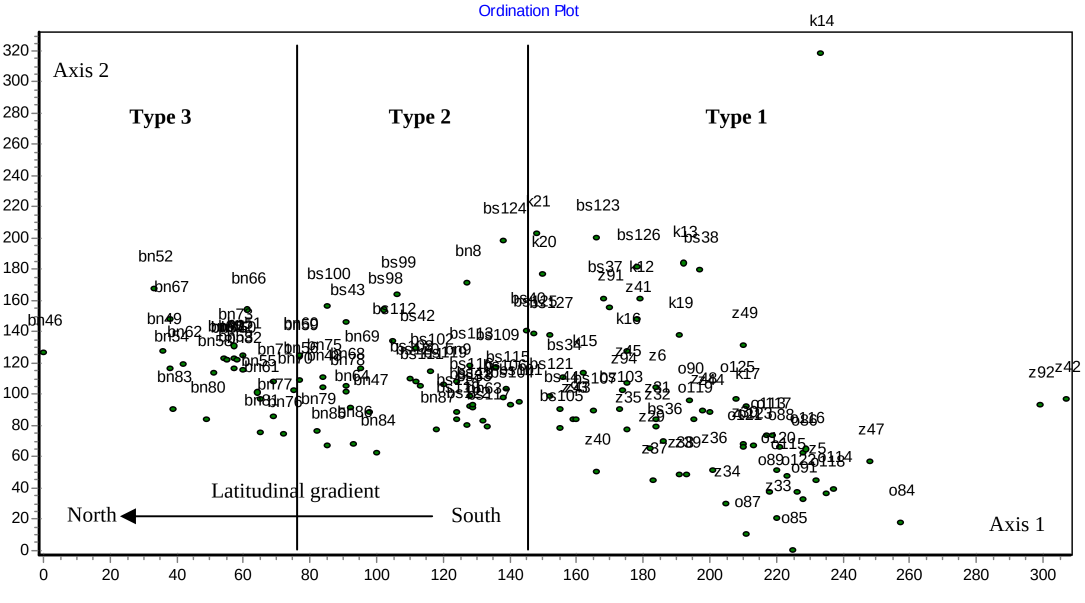


Figure 2.5: DCA ordination of 96 vegetation relevés (from woodland, savannah woodland and tree savannah) and 393 plant species from the floristic zone "Cn", showing three vegetation types. Type 1: Relevés from the area between the latitudes 7°–7°30' and 8°–8°30'N, Type 2: Relevés from the area between the latitudes 8°–8°30'N and 9°30'-10°N, Type 3: Relevés from the area between the latitudes 9°30'-10°N and the northern limit of the floristic zone "Fn" (Figure 2.3).

The three vegetation types 1, 2 and 3 are ecologically and geographically separated and correspond to three distinct floristic sub-zones, which we refer to as the phytogeographical districts Zou, Borgou-Sud and Borgou-Nord respectively. They can be described as follows:

* Type 1: includes the vegetation relevés from the area between the latitudes 7°–7°30’N and 8°–8°30’N. It is characterised by the absence of species such as *Isoberlinia tomentosa*, *Hexalobus monopetalus*, *Uapaca togoensis*, and *Grewia cissoides*. The most exclusive species is *Aframomum latifolium*.

* Type 2: includes the vegetation relevés from the area between the latitudes 8°–8°30’N and 9°30’N. It can be characterised by the exclusive absence of species such as *Combretum glutinosum*, *Ozoroa insignis*, *Acacia ataxacantha*, and *Acacia macrostachya*. The most exclusive species is *Tetrapleura andongensis*.

* Type 3: includes the vegetation relevés from the area between the latitude 9°30’N and the southern limit of the floristic zone “Fn” The most exclusive species is *Cordyla pinnata*.

2.3.5. Analysis of the relevés of the floristic zone “Fn”

TWINSPAN and DCA of 90 relevés (from tree and shrub savannahs) and 336 plant species discriminate two vegetation types (Figure 2.6):

* Type 1: includes the relevés from the Atacora Mountains. The most exclusive species encompass *Haematostaphys barteri*, *Erythrophleum africanum*, *Terminalia brownii*, and *Commiphora pedunculata*.

* Type 2: includes the relevés from the plateau. The exclusive species include *Albizia chevalieri*, *Lonchocarpus laxiflora*, *Balanites aegyptiaca*, and *Guiera senegalensis*.

These two vegetation types are ecologically and geographically separated and correspond to two distinct floristic sub-zones, which we refer to as the phytogeographical districts Atacora Chain and Mékrou-Pendjari.

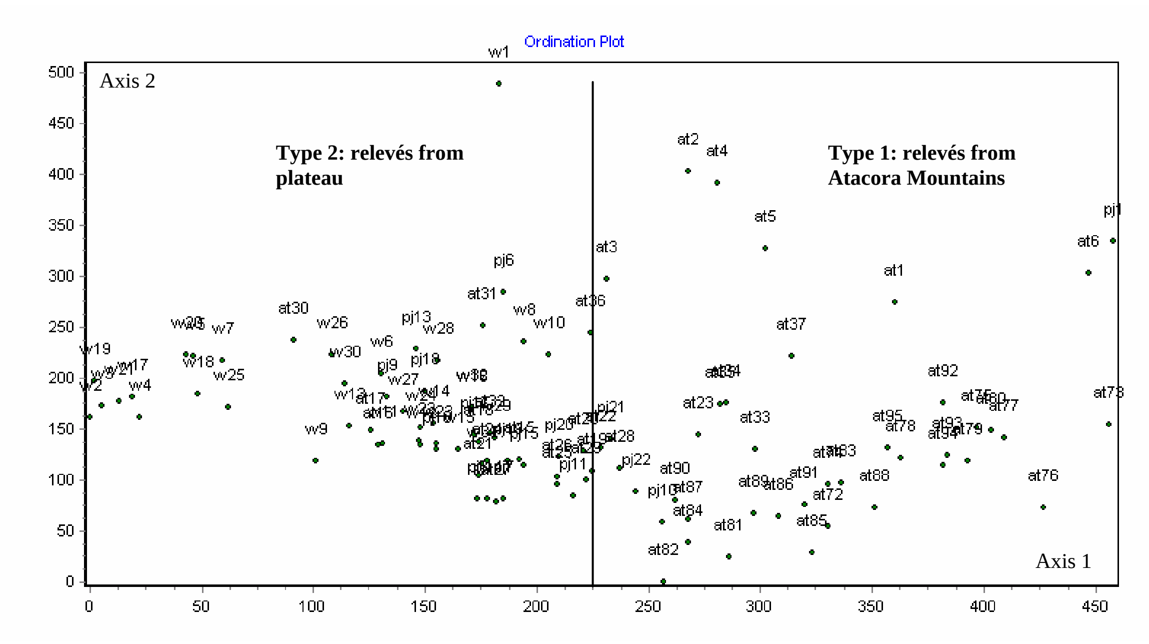
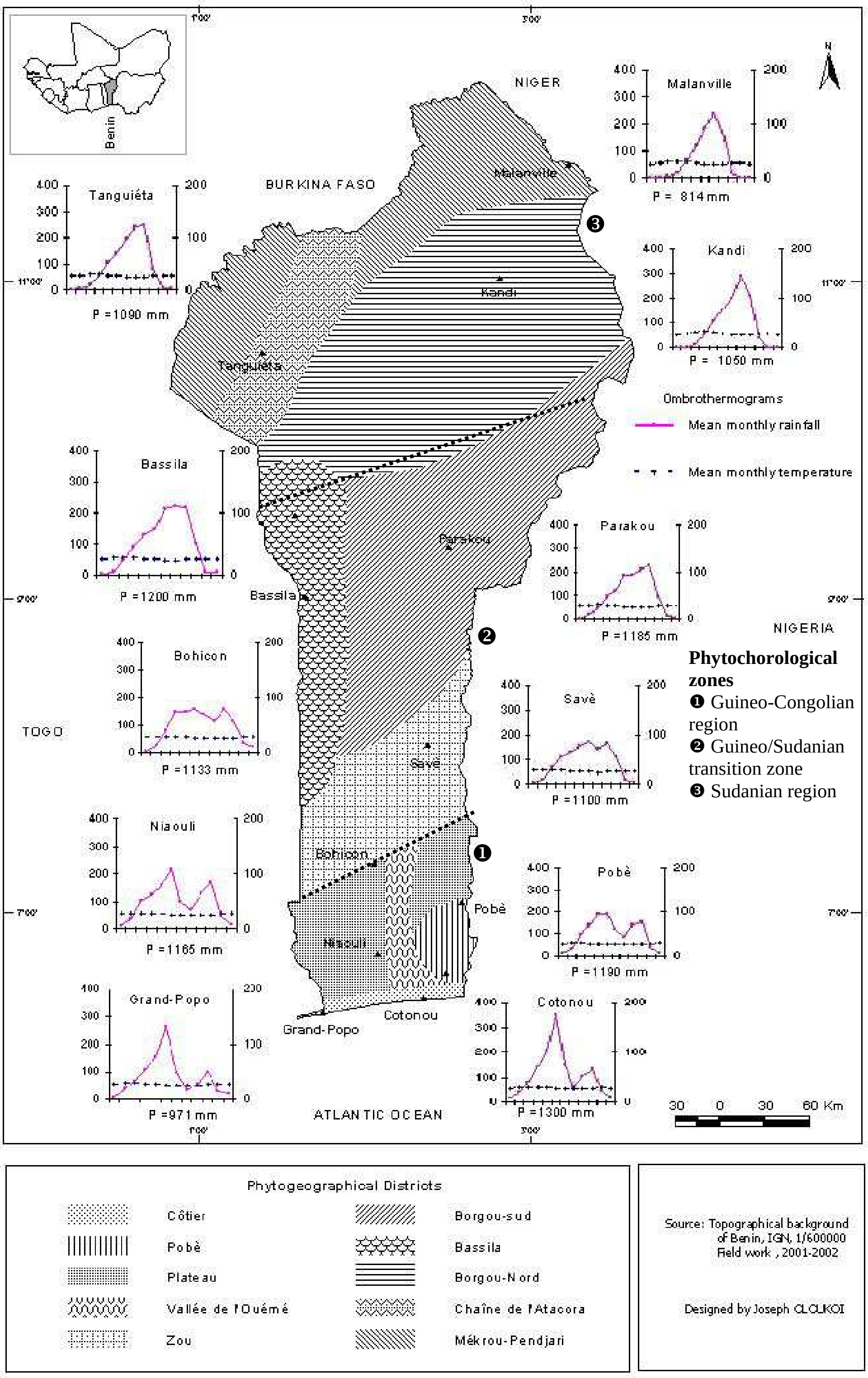


Figure 2.6: DCA ordination of 90 relevés (from tree & shrub savannahs) and 336 plant species, showing two vegetation types.

2.3.6. Spatial interpretation of the clusters or vegetation types

The major floristic zones So, Nw, Cn and Fn (Figure 2.3) were respectively subdivided into four (4), one (1), three (3) and two (2) phytogeographical districts (hereafter PD) on the basis of species composition (Figure 2.7).



Source: Topographical background of Benin, IGN, 1/600000
Field work , 2001-2002

Designed by Joseph OLOUKOI

Figure 2.7: Proposed subdivision of Benin into phytogeographical districts and phytochorological zones based on plant species composition

For each PD, the ombrothermograms (climatic diagrams) of some localities are displayed reflecting the south-north climatic gradient. The localities were chosen such that the climatic diagram reflects the general climatic conditions within each PD.

2.3.7. Floristic relationships among phytogeographical districts (PD)

Table 2.1 displays the patterns of ß-diversity among phytogeographical districts using Jaccard’s similarity coefficient. The floristic distance (D) between any two phytogeographical districts is more than 50%. So, each of the ten PDs can stand as floristically distinct unit. The higher the value of the floristic distance, the more important the ecological difference (soil, climate and land form) between PDs.

Table 2.1: Matrix of dissimilarity between phytogeographical districts based on species composition using the similarity index of Jaccard

Phytogeographical districts	CO	PO	PL	VO	BA	ZO	BS	BN	AT
CO									
PO	67								
PL	71	52							
VO	78	71	75						
BA	79	70	61	82					
ZO	83	81	69	87	53				
BS	87	86	78	89	56	54			
BN	90	90	83	91	61	61	51		
AT	89	90	82	91	63	65	61	55	
M-P	97	96	90	97	74	71	69	56	63

CO: Côtier, PO: Pobè, PL: Plateau, VO: Vallée de l’Ouémé, BA: Bassila, ZO: Zou, BS: Borgou-Sud, BN: Borgou-Nord, AT: Chaîne de l’Atacora, M-P: Mékrou-Pendjari. Highest and lowest values of dissimilarity are shaded.

2.3.8. Chorotypic composition of the phytogeographical districts (PDs)

Table 2.2 presents the proportions of the main chorological types in each PD.

Table 2.2: Chorological spectrum of the phytogeographical districts

Phytogeographical districts		%					
	N	GC	SG	S	SZ	S & SZ	Wd
Pobè	284	78	13	1	1	2	7
Vallée de l'Ouémé	209	76	16	0	2	2	6
Côtier	191	68	16	1	3	4	12
Plateau	396	61	19	3	6	9	11
Zou	351	26	25	12	24	36	13
Bassila	424	36	23	11	19	30	11
Borgou-Sud	335	20	24	15	26	41	15
Borgou-Nord	316	12	25	18	30	48	14
Chaîne de l’Atacora	330	18	24	16	32	48	10
Mékrou-Pendjari	244	3	27	22	31	53	17

N: Number of species recorded in each phyotgeographical district, GC: Guineo-Congolian species, S: Sudanian species, SZ: Sudano-zambezian species, SG: Guinea-Congolia/Sudania transition species, Wd: widespread species. Shaded lines indicate the phytogeographical districts where major floristic changes occur.

Reading the table from top to bottom i.e. from south to north, the proportion of Guineo-Congolian species (GC) decreases while that of Sudanian (S) and Sudano-Zambezian (SZ) increases, if disregarding the PDs Bassila and Atacora Chain, of which the values do not follow the general trend. This variation becomes sharp when moving from Plateau to Zou: 61-26% for GC versus 9-36% for S & SZ. This indicates a major change in species composition, which suggests a shift from one phytochorological zone to another. From the PD Zou northwards the variation of GC and S & SZ becomes more gradual. Along this south-north gradient, the most important change in the species composition occurs when shifting from the PDs Borgou-Sud to Borgou-North: 20-12% for GC and 41-48% for S & SZ. Because of these variations, the 10 PDs can be merged into three higher phytochorological units (Table 2.2 & Figure 2.7):

(1) The Guineo-Congolian region, where the proportion of GC (61-78%) is remarkably high and that of S & SZ (2-9%) is very low. It includes the PDs “Côtier”, “Pobè”, “Plateau”, and “Vallée de l’Ouémé”. The importance of GC clearly decreases from Pobè to Plateau. This can be related to the decrease of the annual rainfall when moving eastwards or northwards within this phytochorological region. The rainfall regime is bimodal with two rainy seasons throughout the area.

(2) The Guineo/Sudanian transition zone, where the proportions of GC and S & SZ are relatively similar. It includes the PDs Zou, Borgou-Sud and Bassila. The climate exhibits a tendency to a unimodal rainfall regime and the two rainfall peaks tend to merge into one peak, which indicates one rainy season. Within this zone, the PD Bassila is relatively richer in GC elements than its southern and eastern neigbouring areas i.e. Zou and Borgou-Sud. This fact seems to be favoured by particular ecological conditions (annual rainfall of 1200-1300 mm and ferrallitic soil) prevailing in this PD. However the proportion of S & SZ (30%) clearly reflects its northern position.

(3) The Sudanian region, where S & SZ (48-53%) prevails. It includes the PDs Borgou-Nord, Atacora Chain, and Mékrou-Pendjari; the rainfall regime there is unimodal. The difference between the importance of GC and S & SZ is remarkably important in Mékrou-Pendjari (GC: 3% and S & SZ: 53%), where the climate is much drier. The proportion of GC in the PD Atacora Chain (18%) is higher than in Borgou-Nord (12%) and Mékrou-Pendjari (3%). This fact can be related to the altitudinal influence on the mountain range, which makes the environment cooler in the Atacora Chain compared to its surroundings.

2.3.9. Floristic and ecological background of the phytogeographical districts

Table 2.3 summarises the chorological, floristic and ecological characteristics of each PD. From this table and Figure 2.7, the climate and soil types appear as the major factors determining the observed phytogeographical patterns.

Table 2.3: Ecological, chorological, and floristic characterisation of the phytogeographical districts

Phytogeographic districts	R	Rainfall (mm)	Major soil types	PChor	Major plant formation	Species exclusive to the phytogeographical district
Côtier	Bi	900-1300	Sandy + Hydromorphic & halomorphic soils	GCR	Coastal forest and derived thickets, Mangrove	*Diospyros tricolor, Chrysobalanus icaco* subsp. *icaco, Syzygium guineense* var. *littorale, Barteria nigritana, Trichoscypha oba, Cassipourea barteri, Smeathmannia pubescens, Dalbergia ecastaphyllum*
Pobè	Bi	1200-1300	Ferrallitic soils without concretions	GCR	Semi-deciduous forest	*Strombosia pustulata, Canarium schweinfurthii, Distemonanthus benthamianus, Chytranthus macrobotrys, Coelocaryon preussii, Amphimas pterocarpoides, Euclinia longiflora, Sherbournia bignoniiflora, Hannoa klaineana, Landolphia incerta*
Plateau	Bi	900-1100	Ferrallitic soils without concretions	GCR	Semi-deciduous forest	*Celtis mildbraedii, Rinorea brachypetala, Dennettia tripetala, Pouchetia africana, Lasiodiscus mannii, Griffonia simplicifolia, Mansonia altissima, Pterygota macrocarpa*
Vallée de l'Ouémé	Bi	1100-1300	Hydromorphic soils	GCR	Swamp and semi-deciduous forest	*Syzygium owariense, Xylopia rubescens, Mitragyna ledermannii, Uapaca paludosa, Rothmannia megalostigma, Nauclea xanthoxylon, Tricalysia reticulata, Harungana madagascariensis, Anthostema aubryanum, Lasiomorpha senegalensis Cynometra vogelii, Grewia malacocarpa, Grewia barombiensis, Zacateza pedicellata, Eremospatha macrocarpa*
Bassila	TUn	1100-1300	Ferrallitic soils with concretions and breastplates	GS	Semi-deciduous forest, woodland, and riparian forest	*Khaya grandifoliola, Aubrevillea kerstingii, Erythrophleum suaveolens*
Zou	TUn	1100-1200	Ferruginous soils on crystalline rocks	GS	Dry forest, woodland, and riparian forest	*Hildegardia barteri, Eugenia nigerina, Aframomum latifolium, Acridocarpus smeathmannii, Millettia warneckei* var. *porphyrocalyx**
Borgou-Sud	TUn	1100-1200	Ferruginous soils on crystalline rocks	GS	Dry forest, woodland, and riparian forest	*Tetrapleura andongensis*
Borgou-Nord	Un	1000-1200	Ferruginous soils on crystalline rocks	SR	Dry forest, woodland, and riparian forest	*Cordyla pinnata, Irvingia smithii*, Trichilia retusa**
Chaîne de l'Atacora	Un	1000-1200	Poorly evolved & mineral soils	SR	Riparian forest, dry forest, and woodland	*Haematostaphys barteri, Erythrophleum africanum, Terminalia brownii, Commiphora pedunculata, Bewsia biflora, Trachypogon spicatus, Eriocoelum kerstingii*, Broenadia salicina*, Uvaria angolensis*, Synsepalum passargei*, Thunbergia atacoriensis*, Chrysobalanus icaco* subsp. *atacorensis*, Garcinia ovalifolia*, Gardenia imperialis**
Mékrou-Pendjari	Un	950-1000	Ferruginous soils with concretions on sedimentary rocks	SR	Tree and Shrub savannahs, dry forest and riparian forest	*Albizia chevalieri, Balanites aegyptiaca, Guiera senegalensis, Sclerocarya birrea, Cadaba farinosa, Lonchocarpus laxiflora, Grewia flavescens, Acacia seyal, Ziziphus spina-christi*, Garcinia livingstonei**

R: Rainfall regime: Bi: Bimodal (2 rainy seasons), TUn: Tendency to unimodal, Un: Unimodal (1 rainy season).
PChor: Phytochorological zones based on the composition in distribution range types: GCR: Guineo-Congolian region, GS: Guineo/Sudanian transition zone, SR: Sudanian region. * Typical riparian forest species.

2.4. DISCUSSION

2.4.1. Interpretation of the phytogeographical units

The previous phytogeographical subdivisions established on the basis of physiognomic units or climatic zonation (Adjanohoun et al. 1989, Wezel et al. 1999, Houinato et al. 2000, Akoègninou 2004) partly (in many instances) fit our floristic subdivisions based on vegetation species composition using TWINSPAN classification and DECORANA ordination. Our floristic units present some relationships with those recognised in Togo (Ern 1979) and Nigeria (Keay 1949 & 1953). However, interesting facts and some modifications of the original vegetation zone map (Adjanohoun et al. 1989) came up:

(1) The PD "Ouémé Valley" and Bassila emerge as separate floristic areas in contrast to Adjanohoun *et al*. (1989). The pristine vegetation of the Ouémé Valley is composed of swampy and periodically-flooded forests on hillocks (Paradis 1975). The presence of plant species such as *Mitragyna ledermannii*, *Uapaca paludosa*, *Syzygium owariense*, *Xylopia rubescens*, *Anthostema aubryanum*, *Rothmannia munsae, Spondianthus preussii*, and *Carapa procera* substantiates its floristic link to the Guineo-Congolian swampy forest (White 1983). Its biogeographical particularity can be illustrated by the fact that the only family hitherto considered endemic for the Guineo-Congolian region found in Benin – i.e. Octoknemataceae (now in Olacaceae) with *Octoknema borealis* (White 1983) – appears to be restricted to this PD. As for the PD Bassila, its floristic particularity had already been pointed out by Adjanohoun *et al*. (1989), Ayichédéhou (2000), Natta (2003), and Akoègninou (2004).

(2) The PD Plateau is revealed as a homogenous area characterised by the species combination *Triplochiton scleroxylon-Celtis zenkeri* while Adjanohoun *et al*. (1989) split it into two units.

(3) Far in the north, the PDs Atacora, Pendjari and "W du Niger" of Adjanohoun *et al*. (1989) are simplified to the PDs Atacora Chain and Mékrou-Pendjari. The Atacora Mountain turns out as an ecologically and floristically distinct unit separating the PD Mékrou-Pendjari into eastern and western parts, which proved to be floristically similar.

In general, the various phytogeographic boundaries are floristically and ecologically better supported. The phytochorological pattern as derived from species distribution ranges coincides with the major climatic zones as suggested by Adjanohoun (1989) and documented by Akoègninou (2004). Using the climatic index of Mangenot (1951), Akoègninou (2004) identified three main climatic zones in Benin, which correspond to the three phytochorological zones identified on the basis of composition in distribution range types: the Guineo-Congolian and Sudanian regions separated by the Guineo/Sudanian transition zone. The northern boundary of the Guineo-Congolian region corresponds to the major change in species composition and ecological factors such as climate (bimodal versus unimodal rainfall regimes), soil (ferrallitic versus ferruginous) and geology (sedimentary plateau versus Precambrian shield). The vegetation consists of semi-deciduous forest patches, farms, and secondary succession to forest when moving southwards of this boundary, while the vegetation includes Sudanian woodlands and savannahs, farms, and secondary succession to savannah when moving northwards (Hopkins 1992).

In fact, the observed phytogeographic pattern could be described as a result of numerous ecological factors (geology, landform, soil and climate) and historical processes (human activity and past climatic changes). The high importance of rainfall seasonality as well as the amount of annual rainfall and soil types is obvious. Considering the high influence of soil on the vegetation of the PDs Coast (sandy soil) and Ouémé-Valley (hydromorphic soil), the basic phytogeographical pattern seems to be the zonal sequence Plateau & Pobè – Zou – Borgou-Sud – Borgou-Nord – Mékrou-Pendjari. The chorological analysis clearly depicts this south-north floristic zonation (Table 2.2, Figure 2.7), which corresponds fairly well with the climatic patterns (Akoègninou 2004). The distinction of the PDs Pobè from Plateau can be interpreted as a response to the southeast-southwest and south-north gradients of decreasing annual rainfall (Paradis 1983). The chorotypic and species compositions of the PDs Bassila (in our Guineo/Sudanian transition zone) and Atacora-Chain (our Sudanian region) seem to be determined by other factors than ecological factors, namely historical processes. The past climatic changes would have had a strong impact on the vegetation of southern Benin (Tossou 2002, Salzmann & Hoelzmann 2005) as well as on the vegetation of the PDs Bassila and Atacora Chain (Aubréville 1937, Akpagana 1989).

2.4.2. The phytochorological position of Southern Benin

The climax vegetation of southern Benin (from the coast up to latitude c. 7°30'N) is described as a semi-deciduous forest of "*Triplochiton-Celtis* type" (Paradis 1983, Sokpon 1995, Akoègninou 1998), which corresponds to the dry peripheral semi-evergreen rain forest of the regional Guineo-Congolian phytochorion (Guillaumet & Adjanohoun 1971, White 1983, Kouamé *et al*. 2004). Among the three endemic plant species of the Sudanian Regional Centre of Endemism (White 1983), only *Vitellaria paradoxa* has been recorded around the latitude 7°N. This fact, added to the dominance of the Guineo-Congolian species as shown by the chorological analysis, leads to the logical conclusion that the southern Benin should belong to the Guineo-Congolian regional centre of endemism (White 1983). This hypothesis is supported by earlier local studies (Adjanohoun *et al*. 1989; Sokpon 1995; Akoègninou 1998 & 2004) and numerical analyses of African plant distribution patterns (Linder 1998). However, it should be stressed that, in Benin, the Guineo-Congolian endemic genera such as *Amphimas*, *Anthonotha*, *Distemonanthus*, *Hymenostegia*, *Anthrocaryon*, *Coelocaryon*, and *Discoglypremna* (White 1983) are restricted to the PD Pobè (south-east Benin). This lends support to White (1983) who described southern Benin as part of the Guinea-Congolia/Sudania regional transition zone, except the PD Pobè that he included in the Guineo-Congolian regional centre of endemism. More explicitly, southern Benin belongs to the Dahomey gap, which is the dry wedge or savannah corridor that separates the West African rain forest belt into the Upper Guinea and Lower Guinea/Congolian Forest Blocks (Aubréville 1937, White 1983, Ern 1988, Jenik 1994, Dupont & Weinelt 1996, Nagel *et al*. 2004). Palynological studies in Benin revealed that the gap was "closed" in early-mid Holocene times and its re-opening was induced by the abrupt climate change of the late Holocene (4000-3000 years BP) (Tossou 2002, Salzmann & Hoelzmann 2005). Nevertheless, the present ecological conditions (bimodal rainfall regime, deep and well-drained ferrallitic soil) are still favourable to the establishment and maintenance of a semi-deciduous forest, which therefore seems to be the climax vegetation of this zone in the absence of anthropogenic influence (Mangenot 1951, Akoègninou 1998 & 2004). Aubréville (1962) underlined soil type and even distribution of the precipitation throughout the year as strong ecological determinants for the establishment of rain forest. West African semi-deciduous forest characteristic species such as *Celtis* spp., *Triplochiton scleroxylon*, *Mansonia altissima*, *Nesogordonia papaverifera*, *Pterygota macrocarpa*, *Milicia excelsa* and moist elements including *Piptadeniastrum africanum* and *Parkia bicolor* (Vooren & Sayers 1992) are still frequent in some semi-deciduous forest islands in southern Benin.

In Benin, the Guineo-Congolian region (as defined here) is climatically (bimodal rainfall regime), pedologically (ferrallitic soil), geologically (sedimentary plateau) and floristically distinct from the Guineo/Sudanian transition zone. The PD Zou, which is the southern part of our Guineo/Sudanian transition zone, falls within the Guinea-Congolia/Sudania regional transition zone of White (1983). The transitional character of its flora is well portrayed by its chorotypic composition (GC: 26% and S & SZ: 36%) and the climate prevailing in this PD. The climatic diagram of Bohicon and Savè shows that the two rainfall peaks (i.e. two rainfall seasons) tend to merge into one peak (i.e. one rainfall season), indicating the transition to the Sudanian climate (Figure 2.7). Characteristic plant communities of the Guineo-Congolia/Sudania regional transition zone have been reported from the PD Zou: the dry semi-deciduous forest dominated by *Hildegardia barteri*, *Diospyros mespiliformis* and *Pouteria alnifolia* (Adjanohoun 1989, Akoègninou 2004) and riparian forest dominated by *Parinari congensis*, *Cynometra megalophylla*, *Cola laurifolia* and *Berlinia grandiflora* (Natta 2003). It should be emphasised that the natural vegetation of the transition zone have been largely destroyed by farming, logging and fire, and thereby converted into savannah (Keay 1959, White 1983). The experiments at Olokemedji in the regional Guinea-Congolia/Sudania transition zone in Nigeria, which showed that secondary wooded grasslands, when protected against farming and fire, can be directly invaded by forest species and revert to close forest dominated by *Hildegardia barteri*, *Diospyros mespiliformis*, and *Pouteria alnifolia* (MacGregor 1937, Clayton 1958, Charter & Keay 1960).

2.4.3. Biogeographical significance of the PDs of Bassila and Atacora Chain

The natural vegetation (in absence of disturbance) of the PD Bassila seems to be a semi-deciduous forest (Akoègninou *et al*. 2002) floristically similar to the dry semi-deciduous forest “fire zone subtype” of Hall & Swaine (1981). Its species composition is similar to the *Khaya grandifoliola* - *Aubrevillea kerstingii* community described in Ivory Coast as a northern type of semi-deciduous forest (Guillaumet & Adjanohoun 1971). Even if this floristic zone is located in the Sudanian regional centre of endemism (White 1983), it appears as floristically and chorologically more similar to the Guineo-Congolian region. This fact is illustrated by the presence of characteristic semi-deciduous forest species such as *Triplochyton scleroxylon*, *Celtis zenkeri*, *Holoptelea grandis*, *Cola gigantea*, *Trilepisium madagascariense*, *Rinorea dentata*, *Trichilia prieureana*, *Pierreodendron kerstingii*, *Albizia ferruginea*, and *Rothmannia longiflora*. At first sight, it is difficult to say that the northern position of these species is either a consequence of the present climatic (annual rainfall of 1200-1300 mm) and pedological (fairly deep ferrallitic soil) conditions or an indication that they survived the dry periods of quaternary climatic changes. But, a thorough analysis of the flora reveals that the populations of many species, including *Khaya grandifoliola*, *Aubrevillea kerstingii*, *Erythrophleum suaveolens* and *Pentadesma butyracea* are restricted to this part of the country. Green & Sayer (1978) pointed out the consistent record of the monotypic Guineo-Congolian endemic genus *Aubrevillea* with *A. kerstingii*, which is often associated with *Holoptelea grandis*, *Celtis zenkeri*, *Ricinodendron heudelotii*, *Cola gigantea*, *Antiaris toxicaria*, and *Englerophytum oblanceolatum*. These facts constitute a floristic justification to the hypothesis that the flora of this PD have originated from the Upper Guinea Forest Block using the Togo Mountains as route of dispersion during the past climatic fluctuations (Aubréville 1937, Guillaumet 1967, Adjanohoun *et al*. 1989, Akpagana 1989). A bridge of rain forest connecting the PD Bassila to the Upper Guinea would have existed during the humid periods of early Holocene to mid-Holocene (8500-4000 years BP) (Tossou 2002, Salzmann & Hoelzmann 2005). The record of a dense population of *Rinorea dentata* provides further evidence for the existence of a true semi-deciduous forest in a recent past, even though currently the area is largely covered by woodlands and savannahs. *Rinorea* species are considered as rainforest bio-indicator species because of their slow seed dispersal ability (Achoundong 1996 & 2000). It is probable that the Atacora Chain has played a major role in the ecological and historical processes leading to the floristic particularities of the PD Bassila.

The Atacora Chain acts as a physical and floristic discontinuity dividing the PD Mékrou-Pendjari into western and eastern parts, which proved to be floristically and ecologically similar. Furthermore, the Chain acts as a refuge for rain forest species such as *Antiaris toxicaria*, *Milicia excelsa*, *Pentadesma butyracea*, *Lecaniodiscus cupanioides*, *Detarium senegalense*, and *Millettia thonningii*, which are abundant in some riparian forests (Wala, 2005). Natta (2003) demonstrated that the species composition of the riparian forest at the foot of the Atacora Mounts is unique in Benin, with many exclusive species such as *Eriocoelum kerstingii*, *Broenadia salicina*, *Synsepalum passargei*, *Chrysobalanus icaco* subsp. *atacorensis,* and *Gardenia imperialis*. The exclusive presence of the Sudanian endemic genus *Haematostaphis* (with *H. barteri*) (White 1983) and Benin's endemic plant species *Thunbergia atacoriensis* (Akoègninou & Lisowski 2004) constitute the major biogeographical particularity of this PD.

2.5. CONCLUSION

This paper shows that meaningful and objective phytogeographical subdivision can be achieved using numerical and chorological analyses, which suggest the partition of Benin into ten phytogeographical districts (PDs) and two major phytochorological regions separated by a transition zone: the Guineo-Congolian region with four PDs, the Guineo/Sudanian transition zone with three PDs, and the Sudanian region with three PDs. The former phytogeographical subdivision on climatic-physiognomic basis partly fits the floristic patterns proposed in this paper. The observed phytogeographical pattern seems to be primarily influenced by climate. Several ecological factors (climate, soil, geology and land form) and historical factors seem to act together to give rise to the patterns described. The PDs Pobè, Bassila and the Atacora Chain turn out to be ecologically and biogeographically outstanding floristic areas. Furthermore, this study reveals that phytosociology and chorology are complementary approaches to quantitative phytogeography. Phytogeographical analysis based on the flora as a whole, and if possible involving environmental information, such as climate, soils, and geomorphology, is likely to be more successful, but has hitherto been scarce due to the lack of adequate data.

Chapter 3

VEGETATION PATTERNS IN BENIN (WEST AFRICA): GRADIENTS IN SPECIES COMPOSITION

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VEGETATION PATTERNS IN BENIN (WEST AFRICA): GRADIENTS IN SPECIES COMPOSITION

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Abstract

Distribution patterns of vascular plants were studied on the basis of floristic data from 598 vegetation relevés of 30 x 30 m plots, taken during an extensive phytosociological survey through latitudinal gradients in Benin. Two-Way Indicator Species Analysis (TWINSPAN) performed on the matrix of these relevés and 1021 plant species resulted in twenty distinct plant communities, which overall floristic relationships were assessed using Jaccard's index of similarity. Chorological and Detrended Correspondence Analyses (DCA) of these plant communities led to the recognition of four main chorological groups patterned along a climatic gradient. The four chorological groups geographically correspond to four different phytochorological zones. This allowed a synthetic view of the relationships between chorological categories, vegetation types, and ecological factors.

Our findings emphasised the overriding importance of water availability and the secondary importance of soil in controlling vegetation patterns at meso-scale. It is not correct to assume that mean annual rainfall alone is the prime water factor underlying plant species distribution in tropical Africa. The climatic index of Mangenot provides a better quantitative assessment of climatic conditions at a site than the annual rainfall.

The distribution of the various chorological categories within the vegetation types is strongly correlated with the main ecological factors, whose influences led to the present vegetation patterns. This demonstrates the highly predictive value of vegetation type with regard to chorological categories, and vice versa. Furthermore, this study clearly reveals that phytosociology and chorology are complementary approaches to phytogeography.

Key words: Phytosociology, Chorology, Vegetation patterns, DCA, TWINSPAN, Water availability, Climatic index of Mangenot, West Africa, Benin.

3.1. INTRODUCTION

Natural regions are best defined by functional relationships between physical factors of the environment and biological components such as plant and animal communities (Rowe & Sheard 1981). The distribution of plant species and communities generally provides the best assessment of environment. Overlap between different species distribution patterns means that species composition at a site may indicate quite particular environmental conditions, a basic premise of using vegetation to predict the environment (Hall & Swaine 1976). In Africa South of the Sahara, the amount of Guineo-Congolian plant species decreases with increasing latitude from south (closed forest zone) to north (savannah zone), where the amount of rainfall becomes low and the drought stress is high. On the contrary, the proportion of Sudanian elements increases along this south-north latitudinal gradient. In the Sudanian region, the Guineo-Congolian elements tend to take refuge in riparian forest, where soil moisture is higher (Medley 1992, Kellman *et al*. 1994, Meave & Kellman 1994, Natta 2003). Therefore, we expect a strong correlation between plant community patterns and the proportion of Guineo-Congolian or Sudanian species.

Understanding plant species distribution patterns and the underlying factors is a crucial step for the conservation and management of plant communities and ecosystems. There is a general agreement that climate is the primary factor explaining the distribution of forest and savannah, at least at a continental scale (Adejuwon 1971, Swaine 1992). In West Africa, there is a strong south-north rainfall gradient from the coastal zone to the Sahelian and the vegetation species composition changes accordingly (van Rompaey 1993, Bongers *et al*. 1999). Wieringa & Poorter (2004) emphasised that the length and intensity of the dry season are likely to be stronger determinants of floristic patterns than the rainfall per se. Aubréville (1962) stressed that the even distribution of the precipitation throughout the year and soil type are strong ecological factors shaping the plant species and community patterns. White (983) pointed out that the distribution of Guineo-Congolian species in relation to moisture conditions is complex and the relative importance of rainfall is imperfectly understood. Furthermore, the distribution patterns of many plant species are poorly correlated to rainfall (Bongers *et al*. 1999). Thus, the effect of water availability – expressed in terms of precipitation, length and intensity of the dry season – on vegetation patterns is expected to be stronger than the influence of rainfall considered alone (Mangenot 1951, Gautier & Spichiger 2004).

In general, studies on the vegetation of Benin are sparse and are only available at local level (Paradis 1983, Adjakidjè 1984, Akoègninou 1984, Sinsin 1993, Sokpon 1995, Houinato 2001, Akoègninou *et al*. 2002, Oumorou 2003). Hardly any general vegetation analysis based on detailed inventories has been done. FAO/PNUD (1980) and Adjanohoun *et al*. (1989) described the major physiognomic units in terms of the most abundant species. Recent study on natural forests has provided details on climatic conditions, but endeavoured to correlate forest types to environmental factors (Akoègninou 2004). Furthermore, the specific aspects of gradients in species composition have not been examined.

This paper aims to identify the major plant communities, to determine their geographical distribution through latitudinal gradients, and to highlight their ecological relationships with hypothesised underlying environmental factors including water availability (as a combination of climatic factors) and rainfall (considered alone). We analysed the chorological differentiation of the flora within various vegetation types described and related these chorological facts both to ecological factors and to historical evidence. The present vegetation-chorology-environment analysis provides a framework for the development of syntaxonomic vegetation units, vegetation mapping, and climatic change studies in a tropical African subhumid region.

3.2. METHODS

3.2.1. Research area

The study was conducted in the Republic of Benin, situated in West Africa between latitudes 6°10'N and 12°25'N and longitudes 0°45'E and 3°55'E (Figure 3.1). It is bordered by the Republics of Togo in the west, Burkina Faso and Niger in the north, and Nigeria in the east. In general, the profile of the country is a plateau with a few scattered hills in the centre and the north. The altitude varies from sea level to 400-650 m in the northwest, where the Atacora chain is the outstanding feature. Geologically the southern part (up to 7°30'N) refers to the West African continental terminal made of sedimentary rock, while the central and northern section refer to the Precambrian shield made of granito-gneissic rock, which can be found as outcrops. Four major groups of soils can be distinguished (Willaine & Volkoff 1967): (1) ferrallitic soils covered by semi-deciduous forest, (2) ferruginous soils covered by dry forest, woodland, and savannah, (3) vertisols soils in the depression of Lama covered by a particular dry type of semi-deciduous forest, and (4) hydromorphic soils covered by swamp and riparian forests.

The mean annual rainfall varies from 900 to 1300 mm. Its lowest values are recorded in the southwest and in the far north (900-950 mm). The highest precipitation (1200-1300 mm) is confined to Southeast Benin as well as the tract Bassila-Djougou. The mean annual temperature ranges from 26 to 28°C and may exceptionally reach 35-40°C in northern localities such as Kandi. The annual temperature amplitude is low in the southern part (5-10°C) while it is high (11-13°C) in the northern part (at least from the latitude 8°N northwards). As in most West-African countries, the climate is primarily determined by the annual cycle of the "Inner Tropical Convergence Zone" (ITCZ). Three climate zones can broadly be distinguished (Adjanohoun et al. 1989, Akoègninou 2004).

(1) The southern zone: From the coast up to the latitude 7°N, the climate is Guinean or subequatorial with two rainy seasons alternating with a longer dry season. The shorter dry season rarely exceeds two months.

(2) The transition zone: Between the latitudes 7° and 9°N, the climate becomes subhumid or subsudanian with a tendency to a pattern of one rainy season and one dry season.

(3) The northern zone is characterised by a truly Sudanian climate with a unimodal rainfall regime.

Southern Benin falls in the so-called Dahomey gap, which is the dry wedge that interrupts the zonal West African rain forest belt dividing it into the Upper Guinea and Lower Guinea/Congolian Forest Blocks (Aubréville 1937, White 1983, Ern 1988, Jenik 1994, Tossou 2002). As a response to low rainfall, this distinctive biogeographical area is devoid of evergreen rain forest and its associated plant and animal species (Martin 1991). The vegetation mainly consists of savannahs, grasslands, farmlands, and fallows intermingled with small islands of closed forest (semi-deciduous forest and swamp forest). From c. 7°30'N to 12°25' N, the vegetation is essentially a patchwork of woodlands and savannahs with belts of riparian forest along rivers.

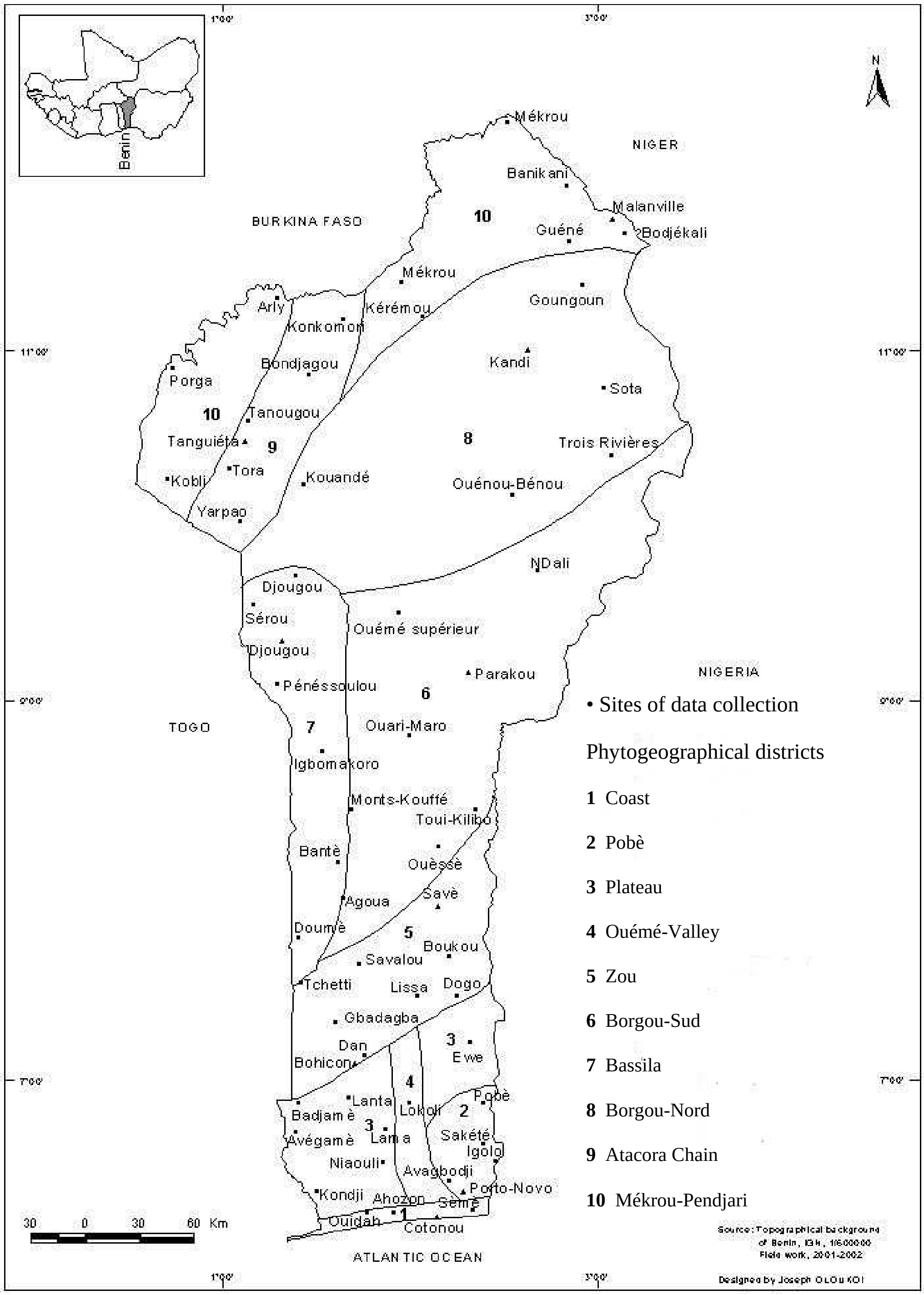

Figure 3.1: Map of Benin showing the 10 phytogeographical districts (Chapter 2) and the study sites.

3.2.2. Data collection

The vegetation map of Benin (FAO/PNUD 1980) was used as the basis for site selection. Aided by field experience of local botanists, we made a checklist of protected areas, sacred forests, and all unprotected areas hosting a tract of relatively undisturbed vegetation. To be certain that all the major vegetation zones were covered, we prepared a map showing the distribution of the localities where “undisturbed vegetation” is likely to be found (Figure 3.1). At each locality, we avoided vegetation plots with strong human interference in the choice of sites and placement of sample plots.

Phytosociological relevés according to Braun-Blanquet’s (1932) approach were carried out at sites hosting the major plant formations such as mangrove, swamp forest, semi-deciduous forest, dry forest, riparian forest, woodland, and savannah (Aubréville 1957). At each site we selected representative and homogeneous sample stands, following the variations in dominant species and the major environmental factors such as soil texture, outcrops, topography etc. The geographical coordinates and altitude were noted using a GPS (Global Positioning System). General information related to soil conditions (texture, flooding, outcrops etc.) and topography (plateau, slope, and valley) was noted. The vegetation structure (number of layers, their cover and height) was described. We visually estimated the cover of each species using the Braun Blanquet cover/abundance scale (Westhoff & van der Maarel 1978): +: rare, less than 1% cover, 1: 1-5% cover, 2: 5-25% cover, 3: 25-50% cover, 4: 50-75% cover, and 5: 75-100% cover. In total 598 floristic relevés were, in most cases, performed within quadrates of 30 x 30 m except in riparian forest, where rectangular plots of 50 x 10 m were laid out. The relevé points were spread over the whole country in such a way that they can be considered as representative of the major vegetation types (Figure 3.1). Botanical nomenclature was according to Keay & Hepper (1954-1972), updated by Lebrun & Stork (1991-1997) and new data acquired in the Project Flora of Benin (Akoègninou & Lisowski 2004).

Climatic data (rainfall, temperature and air humidity) for the period 1956-1996 were obtained from 24 meteorological stations. The dataset, which consists of monthly climate values, is available from the Laboratory of Botany at the University of Abomey-Calavi (Benin). Akoègninou (2004) provided a synthesis (climatic map) of these data. The major soil types were derived from the pedological map of Benin (Willaine & Volkoff 1967).

3.2.3. Data analysis

Classification and ordination of vegetation samples

In the first place, an abundance matrix consisting of 598 phytosociological relevés and 1021 plant species was submitted to Two-Way Indicator Species Analysis (TWINSPAN) (Hill 1979a) available in the program package “Community Analysis Package (CAP)” (PISCES Conservation 2002). Thus, the whole data set was stratified into major plant communities (or vegetation types), each of which was named after the two most differential species as singled out by TWINSPAN output. The species composition of these vegetation types were paired-wise compared using Jaccard’s similarity index (Jaccard 1901). In order to give a synthetic view of the floristic pattern among all plant community types, a dendrogram was constructed from the similarity matrix using the average linkage clustering as supplied in the software CAP (PISCES Conservation 2002). The similarity index of Jaccard is defined as follows:

$$P_j = 100 \times \frac{c}{a + b - c}$$

where P_j is the Jaccard's community coefficient, c is the number of shared species between communities to be compared, A and B are the number of species in each community.

The maximum value of this index (100) indicates that the two compared communities have the same floristic composition. The minimum value (0) indicates that two communities have no species in common.

We used Detrended Correspondence Analysis (DECORANA or DCA) (Hill 1979b) to explore the distribution pattern of the described vegetation types based on species composition. The resulting vegetation type scores were used in the vegetation-environment relationship analyses.

Chorological characterisation of plant communities

We used the publications of Keay & Hepper (1954-1972), White (1983), and Aké Assi (2001 & 2002) to determine the chorotype (i.e. types of distribution range) of each species. The five main chorotypes used are as follows: GC: Guineo-Congolian species, S: Sudanian species, SZ: Sudano-Zambesian species, SG: Guineo-Congolian/Sudanian transition species i.e. linking elements between the Guineo-Congolian and Sudanian Regions, and Wd: Species with wide distribution such as Cosmopolitan, Pantropical, and Paleotropical. The proportions of the various chorotypes were calculated using the species checklist compiled for each community type.

To characterise each plant community chorologically, we defined the phytogeographical index Ip, which is the ratio of the proportion of "Sudanian & Sudano-Zambezian" (S&SZ) species to that of the Guineo-Congolian (GC) species.

$$Ip = \frac{S + SZ}{GC}$$

where S is the frequency of Sudanian species, SZ the frequency of Sudano-Zambezian species, and GC the frequency of Guineo-Congolian species.

When $Ip < 1$, the plant community shows an affinity to the Guineo-Congolian region.
When $Ip > 1$, the plant community shows an affinity to the Sudanian region.

The correlation between the major chorotypes (GC, S, and SZ) was studied using linear regression analysis. The nature and strength of the relationship were assessed by means of correlation analysis using Spearman's rank correlation, which is a non-parametric test. The correlation coefficient (r_S) was computed using the software MINITAB (version 13.32). The significance of r_S was assessed by consulting the tabulated critical values. The critical values for r_S in our case ($n = 20$ plant communities or degree of freedom $n-2 = 18$) are 0.377 at $p < 0.05$ and 0.534 at $p < 0.01$.

Vegetation-environment relationships

The humidity or climatic index of Mangenot (1951) was used as a quantitative summary of the climatic variables such as annual rainfall, length and intensity of the dry season, and relative air humidity of a given geographical area. This index reflects the importance of water availability and is given by the formula:

$$I_M = \frac{P/100 + Ms + \bar{U}x}{nS + 500/\bar{U}n}$$

where I_M: Climatic or humidity index of Mangenot, P: mean annual rainfall (mm), Ms: mean rainfall of dry months i.e. months which rainfall is less than 50 mm, nS: number of dry months, $\bar{U}x$: maximum of annual relative humidity (%), $\bar{U}n$: minimum of annual relative humidity (%).

The highest values ($I_M > 7.5$) of Mangenot's index indicate a hyperhumid climate and the lowest values ($I_M < 1$) suggest a Sahelian (dry) climate (Mangenot 1951). The author specified that this index is only applicable in tropical regions.

The DCA axis that carried the main variation in species composition was related to mean annual rainfall and Climatic index of Mangenot (used here as a water availability index) using linear regressions. The nature and strength of the correlation were assessed using the Spearman's rank correlation coefficient (see detail on page 39).

The relations between the distribution range types and ecological factors were studied taking the main trend revealed by the ordination as an axis on which the proportions of the main chorotypes (GC, S and SZ) were plotted. The strength of the relation was evaluated using the Spearman's rank correlation coefficient.

The major soil types were derived from the pedological map of Benin (Willaine & Volkoff 1967).

3.3. Results

3.3.1. Plant communities and their floristic relationships

The hierarchical clustering of the 598 vegetation samples and 1021 plant species using TWINSPAN (classification) resulted in five (5) major clusters subdivided into 20 sub-clusters, which we considered as plant communities or vegetation types. Figure 3.2 summarises their floristic relationships using the similarity index of Jaccard. The five major clusters can be described as follows:

Cluster I: includes six (6) vegetation types:
    (1) *Chrysobalanus icaco–Barteria nigritana* (Ch-Bar) (semi-deciduous forest),
    (2) *Rhizophora racemosa–Avicennia germinans* (Rh-Av) (mangrove),
    (3) *Terminalia superba–Piptadeniastrum africanum* (Te-Pi) (semi-deciduous forest),
    (4) *Triplochiton scleroxylon–Celtis zenkeri* (Tr-Ce) (semi-deciduous forest),
    (5) *Mimusops andongensis–Cynometra megalophylla* (Mu-Cy) (semi-deciduous forest),
    (6) *Drypetes aframensis–Nesogordonia papaverifera* (Dr-Ne) (semi-deciduous forest).
Cluster II: includes six (6) vegetation types:
    (7) *Khaya grandifoliola–Aubrevillea kerstingii* (Kh-Au) (dry semi-deciduous forest),
    (8) *Cola gigantea–Khaya grandifoliola* (Co-Kh) (riparian forest),
    (9) *Cynometra megalophylla–Parinari congensis* (Cy-Pa) (riparian forest),
    (10) *Anogeissus leiocarpa–Lecaniodiscus cupanioides* (An-Le) (dry forest),
    (11) *Anogeissus leiocarpa–Anchomanes welwitschii* (An-Anch) (dry forest),
    (12) *Hildegardia barteri–Aphania senegalensis* (Hi-Ap) (dry forest),
Cluster III: includes: one (1) vegetation type:
    (13) *Mitragyna ledermannii–Lasiomorpha senegalensis* (Mi-La) (swamp forest),
Cluster IV: includes six (6) vegetation types:
    (14) *Isoberlinia doka–Chromolaena odorata* (Iso-Ch) (woodland to tree savannah),
    (15) *Isoberlinia* spp.–*Bridelia ferruginea* (Iso-Br) (woodland to tree savannah),
    (16) *Isoberlinia* spp.–*Combretum glutinosum* (Iso-Co) (woodland to tree savannah),
    (17) *Albizia chevalieri–Balanites aegyptiaca* (Al-Ba) (shrub savannah),
    (18) *Isoberlinia* spp.–*Haematostaphis barteri* (Iso-Hae) (savannah on hill),

(19) *Synsepalum passargei-Broenadia salicina* (Sy-Br) (riparian forest on hill), and Cluster V: includes one (1) vegetation type:

(20) *Garcinia livingstonei–Vitex chrysocarpa* (Ga-Vi) (riparian forest).

It must be pointed out that *Chromolaena odorata* is an exotic invasive species that is ecologically restricted to the closed forest zone. We used it in the combination *Isoberlinia doka–Chromolaena odorata* because it was singled out as the most differential species by TWINSPAN.

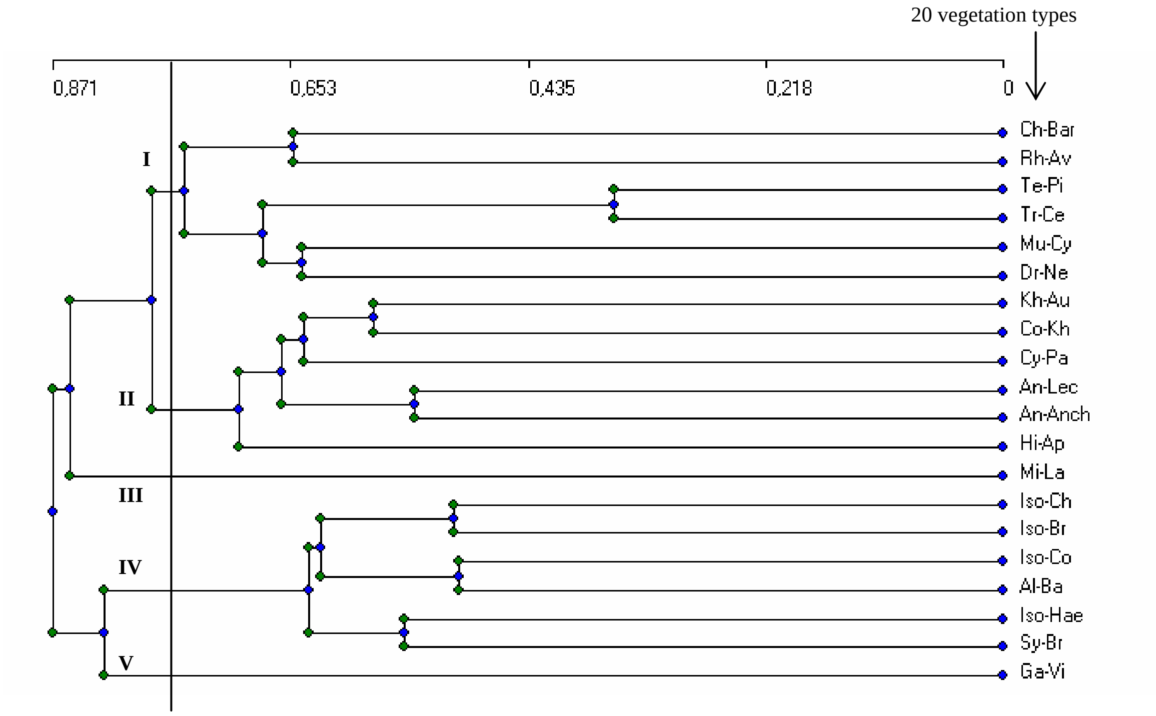

Figure 3.2: Dendrogram based on Jaccard’s similarity index, showing five major clusters subdivided into 20 vegetation types. Major clusters: I: Semi-deciduous forest (and mangrove), II: Dry semi-deciduous forest, dry forest and associated riparian forest, III: Swamp forest, IV: Woodland, savannah woodland, tree & shrub savannah and associated riparian forest, V: Riparian forest in dry savannah zone.

Table 3.1 (at the end of this chapter) summarises the floristic, climatic and soil characteristics of the 20 vegetation types described. In general, the values of the mean annual rainfall and the climatic index of Mangenot decrease from the south (closed forest zone) to the north (savannah zone). Soil type largely varies from one plant community to another.

3.3.2. Chorological spectrum the plant communities

Chorological affinities among plant communities

Table 3.2 depicts the chorological spectrum of the 20 plant communities described. Based on the values of the phytogeographic index I_P – ratio of the proportion of the “Sudanian & Sudano-Zambezian” elements to that of the Guineo-Congolian species – we distinguished two major groups of plant communities:

(i) Plant communities with $I_P < 1$: includes communities showing an affinity to the Guineo-Congolian region; these can be subdivided into two groups:

(1) Communities with $I_P < 0.2$: those expressing a strong affinity to the Guineo-Congolian region.

(2) Communities with $I_P > 0.2$: those expressing affinity to the “Guineo-Sudanian” transition zone, i.e. the transition zone between the Guineo-Congolian and Sudanian regions where the Guineo-Congolian elements prevail.

(ii) Plant communities with $I_P > 1$: includes communities showing affinity to the Sudanian region; these can be subdivided into two groups:

(3) Communities with $I_P < 4$: those showing affinity to the “Sudano-Guinean” transition zone, i.e. the transition zone between the Guineo-Congolian and Sudanian regions where the Sudanian elements prevail.

(4) Communities with $I_P > 4$: those expressing a strong affinity to the Sudanian region.

Table 3.2: Chorological spectrum of plant communities

		%							
Plant communities	N	GC	SG	S	SZ	S+ SZ	Wd	$I_{P=}$	Phytoch. zone
Mitragyna ledermannii-Lasiomorpha senegalensis	121	79	11	0	1	1	10	0.01	GCR
Rhizophora racemosa-Avicennia germinans	85	72	12	1	1	2	14	0.03	GCR
Terminalia superba-Piptadeniastrum africanum	368	80	10	1	3	4	6	0.05	GCR
Chrysobalanus icaco-Barteria nigritana	178	71	14	1	3	4	11	0.06	GCR
Drypetes aframensis-Nesogordonia papaverifera	179	72	13	1	4	5	11	0.07	GCR
Triplochiton scleroxylon-Celtis zenkeri	329	72	14	2	4	6	8	0.08	GCR
Mimusops andongensis-Cynometra megalophylla	151	70	10	5	5	10	10	0.14	GCR
*Cynometra megalophylla-Parinari congensis**	207	56	16	6	11	16	12	0.29	GSTZ
Khaya grandifoliola-Aubrevillea kerstingii	241	55	17	7	11	18	10	0.33	GSTZ
*Cola gigantea- Khaya grandifoliola**	264	47	20	7	11	17	16	0.36	GSTZ
Hildegardia barteri-Aphania senegalensis	135	41	19	10	12	22	18	0.54	GSTZ
Anogeissus leiocarpa-Lecaniodiscus cupanioides	203	43	17	9	16	26	14	0.6	GSTZ
Anogeissus leiocarpa-Anchomanes welwitschii	197	28	25	16	15	31	16	1.11	SGTZ
*Synsepalum passargei-Broenadia salicina**	341	26	21	16	26	42	11	1.62	SGTZ
*Garcinia livingstonei-Vitex chrysocarpa**	93	22	23	18	22	40	16	1.82	SGTZ
Isoberlinia doka-Chromolaena odorata	213	15	24	17	29	46	15	3.07	SGTZ
Isoberlinia spp.-*Bridelia ferruginea*	231	14	23	20	30	50	13	3.57	SGTZ
Isoberlinia spp.-*Combretum glutinosum*	232	6	22	25	31	56	16	9.33	SR
Isoberlinia spp.-*Haematostaphis barteri*	157	7	18	29	38	66	9	9.43	SR
Albizia chevalieri-Balanites aegyptiaca	238	5	24	22	31	53	18	10.60	SR

N: Total number of species recorded in each vegetation type, GC: Guineo-Congolian species, SG: Guineo/Sudanian transition species, S: Sudanian species, SZ: Sudano-Zambezian species, Wd: widespread species, I_P (phytogeographical index): Ratio of (S + SZ) to GC.
Phytoch. zone: phytochorological zone corresponding to each chorological group: GCR: Guineo-Congolian region, GSTZ: “Guineo-Sudanian” transition zone (i.e. richer in GC than S + SZ), SGTZ: “Sudano-Guinean” transition zone (i.e. richer in S + SZ than GC), SR: Sudanian region; *: Riparian forest communities.

The four chorological sets (or groups) of vegetation types described are geographically separated and correspond to four different phytochorological zones (Figure 3.3).

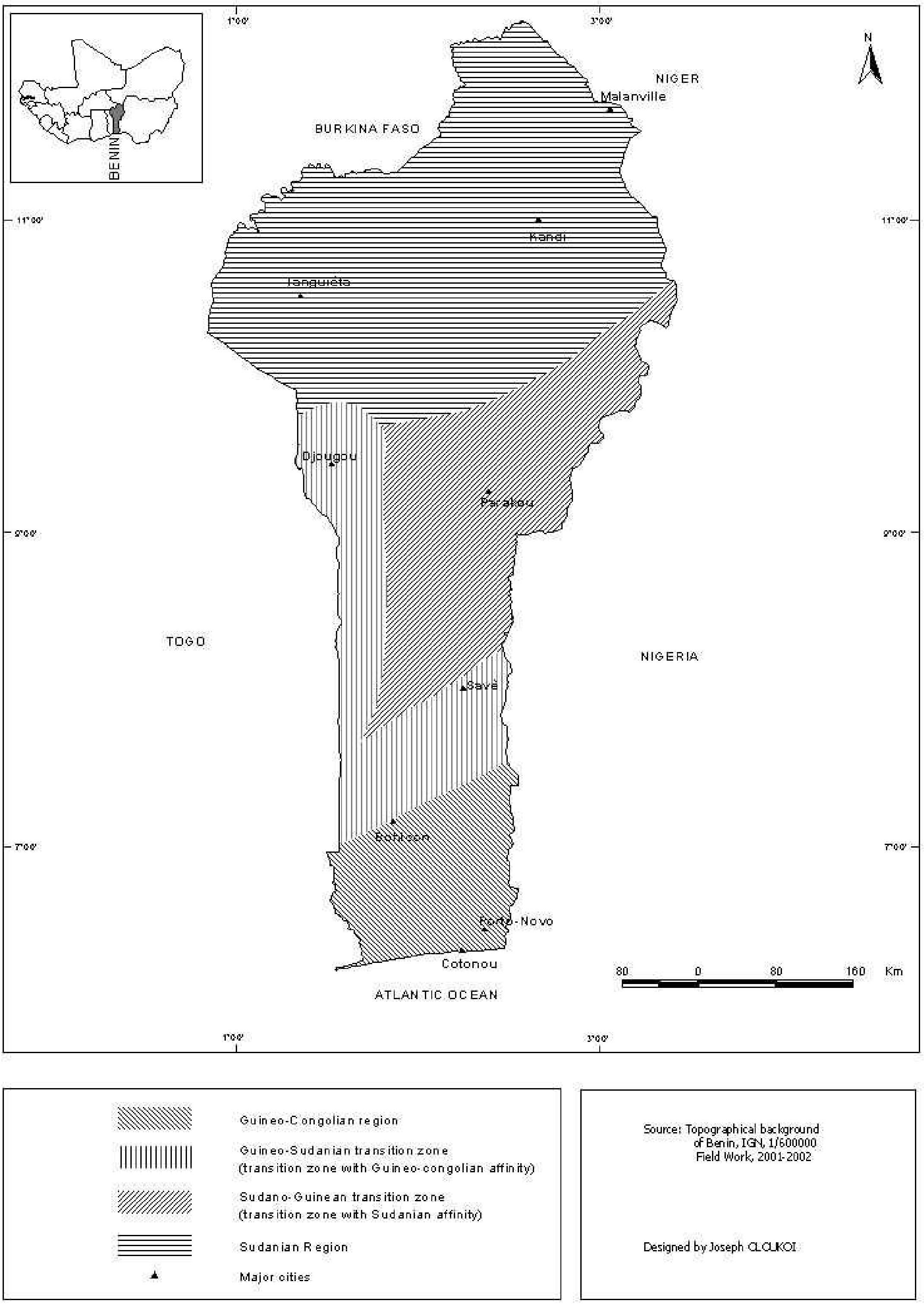

Figure 3.3: Phytogeographical map of Benin showing the main chorological zones based on composition in distribution range types.

The transition zone is subdivided into two sub-zones, which do not strictly follow the latitudinal zonation:

* The “Guineo-Sudanian” transition zone: Part of the transition zone where the Guineo-Congolian elements prevail. It is characterised by the *Khaya grandifoliola–Aubrevillea kerstingii* (GC: 55, S + SZ: 18) and *Hildegardia barteri–Aphania senegalensis* (GC: 41, S + SZ: 22) communities.

* The “Sudano-Guinean” transition zone: Part of the transition zone where the Sudanian elements prevail. It is characterised by the absence of the two plant communities mentioned above. It must be pointed out that the riparian forest communities such as *Garcinia livingstonei-Vitex chrysocarpa* and *Synsepalum passargei-Broenadia salicina* are actually situated in the Sudanian zone, but express a chorological affinity to the “Sudano-Guinean” transition zone. This can be explained by the presence of water, which allows some Guineo-Congolian species to extend their ecological amplitude far inland.

Correlation between chorotypes

Figure 3.4 pictures a highly significant negative linear relationship between the proportions of Guineo-Congolian species (GC) and Sudanian (S) or Sudano-Zambezian (SZ) elements. Inversely, the proportions of S and SZ are highly positively correlated. This indicates that the regression equations are good predictors of the variations observed. These strong relationships seem to be linked to a gradient in species composition, which is expected to be a response to environmental factors such as climate.

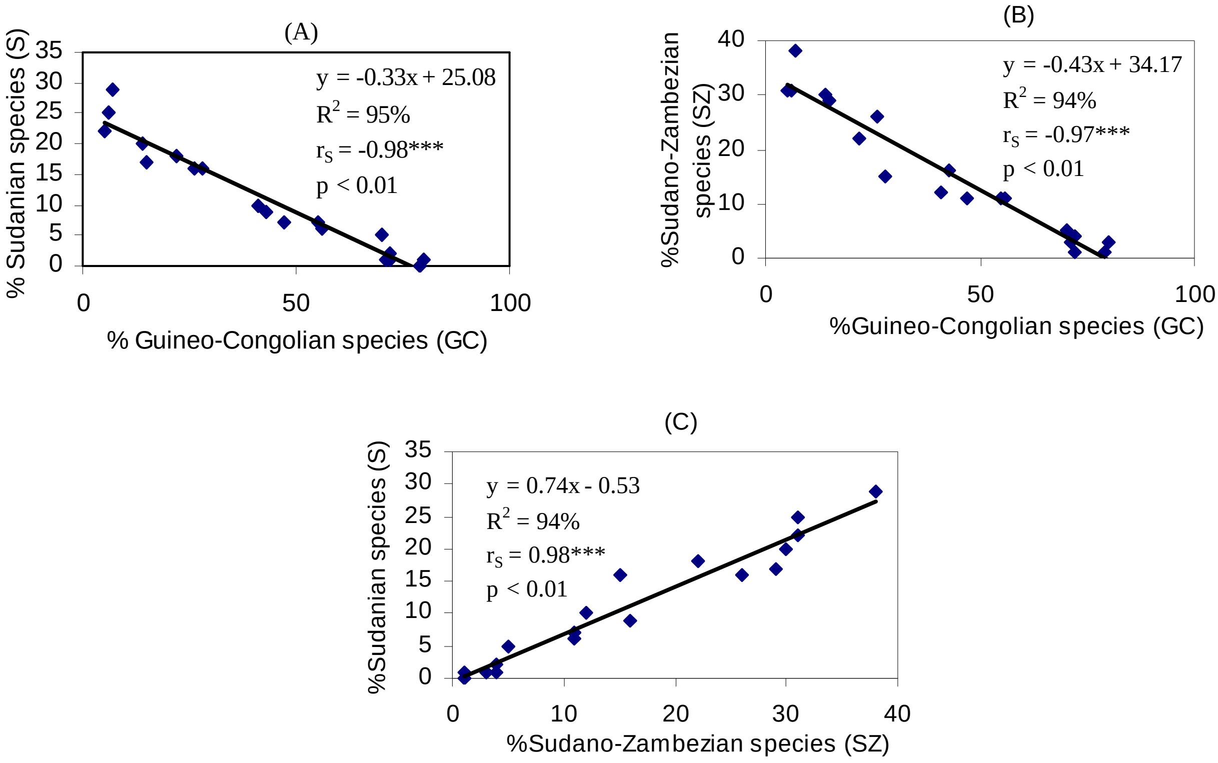

Figure 3.4: Relationships among proportions of the major chorotypes.
A & B) Highly significant negative relationship between GC and S or SZ. C) Highly significant positive relationship between S and SZ. The best-fit regression line, equation, coefficient of determination (R^2), Spearman’s rank correlation coefficient (r_S), and significance level are given.

3.3.3. Vegetation gradient and underlying factors

The Detrended Correspondence Analysis (DCA) of 20 plant communities and 1021 plant species shows a major indirect floristic factor (axis 1), which seems to be correlated to climate (Figure 3.5). The axis scores (0.61 for axis 1 and 0.29 for axis 2) clearly indicate that axis 1 explains the major variation in species composition of the vegetation types described. Along this axis, we distinguish four clusters of vegetation types, which geographically correspond to the four phytochorological areas described using the phytogeographical index (I_P) (Table 3.2). Thus, the DCA strengthens our results obtained in Table 3.2. The position (outlier) of the *Rhizophora racemosa-Avicennia germinans* (Rh-Av, mangrove) and *Mitragyna ledermannii-Lasiomorpha senegalensis* (Mi-La, swamp forest) communities in the ordination space reflects their strong azonal behaviour.

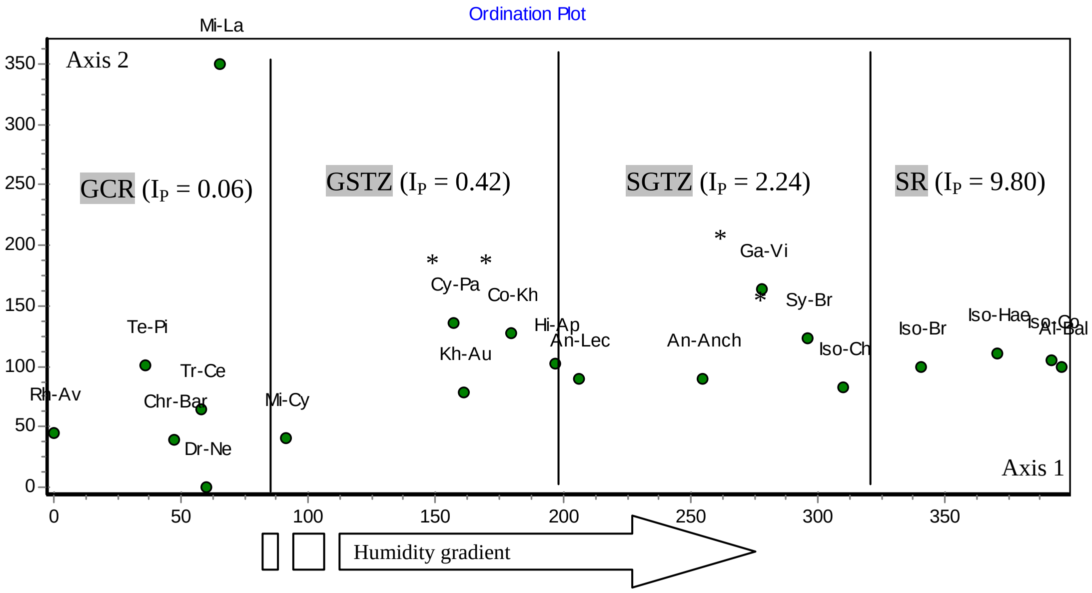

Figure 3.5: DCA ordination of 20 vegetation types and 1021 plant species in Benin, showing 4 clusters of vegetation types, which correspond to the 4 phytochorological areas established using the phytogeographical index I_P (see Table 3.2 & Figure 3.3).
GCR: Vegetation types showing affinity to the Guineo-Congolian region, GSTZ: Vegetation types showing affinity to the "Guineo-Sudanian" transition zone, SGTZ: Vegetation types showing affinity to the "Sudano-Guinean" transition zone, and SR: Vegetation types showing affinity to the Sudanian region; *: Riparian forest communities. The average value of I_P for each cluster is indicated between brackets.

The floristic change along the axis 1 is better elucidated by the highly significant relationship between this axis and the proportion of Guineo-Congolian (GC) species or Sudanian species (S & SZ) (Figure 3.6 a & b). More explicitly, from the left hand side to the right hand side of this axis (Figure 3.5), the importance of the Guineo-Congolian species decreases (negative correlation), while the proportion of "Sudanian and Sudano-Zambezian" elements increases (positive correlation). This fact seems to support the hypothesis that this axis reflects a humidity gradient with decreasing humidity from the left to the right. We therefore expect straight line correlations between vegetation type scores along this axis and climatic variables.

We examined the relation between the axis 1 scores and climate using two climatic variables: mean annual rainfall and water availability (in terms of climatic or humidity index of Mangenot). The values of these variables for each community type are provided in Table

3.1 (at the end of this chapter). Regression analyses show that rainfall significantly correlated with axis 1 ($p < 0.05$), even though it accounts for only 30% of the variation in species composition (Figure 3.6c). The axis 1 was found to be highly significantly correlated with the climatic index of Mangenot (used as water availability index) ($P < 0.01$), which explains 80% of the variation in species composition (Figure 3.6d). Therefore, water availability – expressed as a function of rainfall, length and intensity of the dry season, and relative air humidity – appears to be the major factor controlling the plant species and community distribution patterns, which in their turn, determine the main phytochorological groups (Figure 3.5). In other words, the axis 1 can be considered as carrying a phytogeographical gradient determined by a climatic gradient. It is noteworthy that the riparian forest communities are well separated along the floristic gradient suggesting the influence of climate on their distribution. Two groups can be distinguished:

(1) The *Cola gigantea-Khaya grandifoliola* (Co-Kh) and *Cynometra megalophylla-Parinari congensis* (Cy-Pa) communities showing chorological affinity to the "Guineo-Sudanian" transition zone.

(2) The *Synsepalum passargei-Broenadia salicina* (Sy-Br) and *Garcinia livingstonei-Vitex chrysocarpa* (Ga-Vi) communities expressing chorological affinity to the "Sudano-Guinean" transition zone.

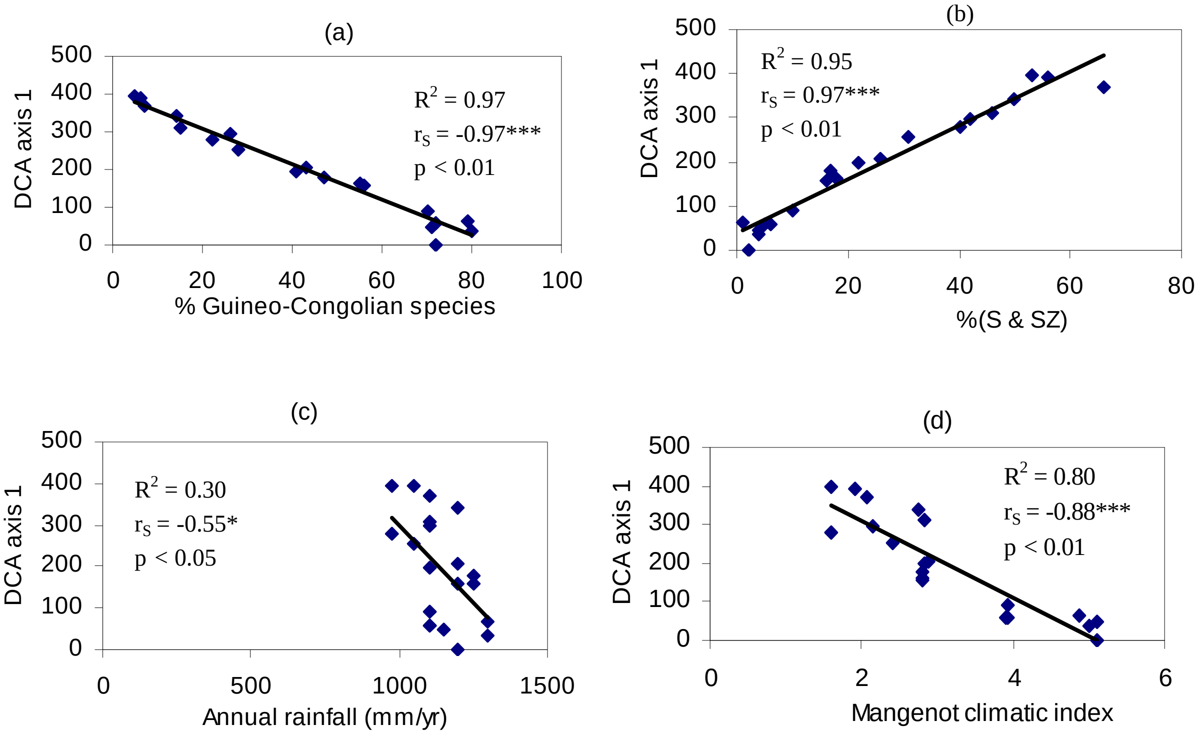

Figure 3.6: Relationship between the first DCA axis scores (indicating the largest variability in species composition) and various environmental variables. a) Proportion of Guineo-Congolian species, b) Proportion of Sudanian & Sudano-Zambezian species, c) Mean annual rainfall, d) Mangenot's climatic index (used as a water availability index). The best-fit regression line, coefficient of determination (R^2), Spearman's rank correlation coefficient (r_S), and significance level are given.

3.4. DISCUSSION

3.4.1. Water availability as the driving force of the vegetation gradient

Our results reveal that water availability – expressed as a function of rainfall, length and severity of the dry season, and air humidity – is the major factor determining the vegetation gradient in Benin, and explains 80% of the variation in species composition. This seems to be consistent with the actual distribution of vegetation types in the country. Rainfall, considered alone, only accounts for 30% of the variation in species composition along the vegetation gradient (Figure 3.6 c & d). Thus, is not correct to assume that mean annual rainfall alone is the prime water factor underlying the distribution of plant species in West Africa (Hall & Swaine 1976, 1981; van Rompaey 1993, van Rompaey & Oldeman 1997, Bongers *et al*. 2004, Tchouto 2004). Bongers *et al*. (1999) attempted to generate ecological explanations for the effect of three climatic factors (annual rainfall, dry period length, and cumulative water deficit due to evapotranspiration exceeding rainfall) on the distribution of tree species in West Africa. They came to the conclusion that each of the climatic factors could explain just a part of the variation encountered in species abundance. They assumed that the three climatic variables together, indicating three different additional aspects of water availability, would be able to explain a larger part of the variation observed. Veenendaal *et al*. (1996) showed that length and intensity of the dry period determined soil water potential, which is the actual factor indicating water availability for plants. Recent studies on West African vegetation put emphasis on the length and severity of the dry season as stronger determinants of floristic patterns than the rainfall per se (Wieringa & Poorter 2004). Thus, the strength of the humidity index of Mangenot (1951) is likely that it clearly takes into account the climatic variables (rainfall amount, length of dry period and its severity) that strongly influence water availability. Moreover, this index includes the air humidity whose influence on transpiration rates of plants (i.e. plant water loss) is well known. This paper demonstrates that this index provides a better quantitative assessment of climatic conditions at a site than any single climatic variable. This index has been successfully applied in the establishment of the climatic map of Benin (Akoègninou 2004), which fits with our phytochorological map established on the basis of the composition in distribution range types. This paper provides its validation against genuine floristic data, as independent variables.

Despite the strong dependence of riparian forest communities on soil moisture, their position along the floristic gradient clearly specifies the influence of the general climatic on their distribution patterns. This highlights the assumption of Natta (2003) who stressed latitude as an important factor controlling riparian forest types in Benin.

The second factor influencing the distribution of plant communities in Benin is soil type. Even though we have not statistically tested its influence on vegetation, it greatly varies from one vegetation type to another. It should be emphasised that the major change in vegetation species composition ─ which occurs at latitudes 7^{o}-$7^{o}30'$─ coincides with the major change in climate (bimodal versus unimodal rainfall regime), soil (ferrallitic versus ferruginous soils) and geology (sedimentary plateau versus Precambrian shield).

Soil moisture – which is governed by climate and soil properties (soil texture and depth) – seems to be the best discriminating factor of plant communities (Markham & Babbedge 1979, Hall & Swaine 1981, van Rompaey 1993, Swaine 1996, Gautier & Spichiger 2004). This could be because the processes by which key nutrients such as nitrogen are made available to the plant are strongly controlled by soil moisture (Scholes 1993, Fairbanks 2000). However, Garlan *et al*. (1986) and Newbery & Garlan (1996) argued that rainfall and seasonality are likely to lead to stronger floristic gradients than soil nutrients in West Africa. Actually, many factors such as climate, soil features, past climatic fluctuations, and human disturbance appear to act in concert to give rise to the current floristic patterns, both on regional and local scales (Emberger 1971, Cornet & Guillaumet 1976, Holmgren *et al*. 2004).

3.4.2. Biogeographical implications

The strong dependence of plant species and community distribution on water availability implies that they are sensitive to climate change, which induces a change in species composition. Climate fluctuations require plants to be able to shift the placement of their populations to areas of varying moisture. Thus, the forest has migrated over considerable distance to adapt to the dry periods in Pleistocene time (Maley 1987, Hamilton 1982 & 1992, Sosef 1996, Achoundong 2000). The high sensitivity of plant species to water availability indicates that rivers would have undoubtedly played a vital role during past climatic changes, since they are known for their potential to maintain a great number of species, and to act as safe sites for tropical rain forest species when the regional climate becomes drier (Medley 1992, Kellman et al. 1994, Meave & Kellman 1994, Porembski 2001, Puth & Wilson 2001, Natta 2003, Holmgren et al. 2004). Wild (1968) considered that the dominance of Guineo-Congolian species in patches of relic forest may be due to a formerly greater extent of lowland rain forest during the humid phases of past climatic fluctuations. The high proportion of Guineo-Congolian species in riparian forest communities such as Cynometra megalophylla-Parinari congensis (56%) and Cola gigantea-Khaya grandifoliola (47%) respectively in the phytogeographical districts (PDs) of Zou and Bassila (Figure 3.1) can be an indication of a former floristic connection with the Guineo-Congolian region during the humid phases of quaternary climatic changes (Aubréville 1937). The best evidence is the common presence of characteristic semi-deciduous forest species including Khaya grandifoliola, Trilepisium madagascariense, Albizia ferruginea, Cola gigantea and the evergreen forest species Pentadesma butyracea in riparian forest of the PD Bassila (Natta 2003). The outpost role of riparian forest is even felt further north on the Atacora Chain, where semi-deciduous forest species such as Detarium senegalense, Antiaris toxicaria, Milicia excelsa, Lecaniodiscus cupanioides, and Alchornea cordifolia have been regularly recorded in the Synsepalum passargei-Broenadia salicina community (Natta 2003, Wala 2005). This substantiates the hypothesis of Akpagana (1989) who assumed that semi-deciduous forest would have extended far to the north and covered all of the Atacora Mountains (up to latitude 10°30'N at least) in a recent past, presumably the humid phase of early-mid Holocene (8500-4000 years BP) (Salzmann & Hoelzmann 2005). Palynological data from the Nigerian Sudanian region (Salzmann et al. 2002) support the assumption that increasing humidity during the early-mid Holocene period led to a northwards migration of numerous plants from a more humid southern vegetation zone (Dupont & Agwu 1992). Lake sediment records from southern Benin showed that during this period, the lowland rain forest was represented by a continuous semi-deciduous or semi-evergreen forest dominated by Triplochiton scleroxylon and Celtis spp. (Tossou 2002, Salzmann & Hoelzmann 2005), which would have expanded farther north over the “Guineo-Sudanian” transition zone (Figure 3.3). The current semi-deciduous forest islands can be considered as relics from the subsequent dry period of late Holocene (4000-3000 years BP), during which the semi-evergreen forest would have contracted to just a few suitable areas such as river banks.

Our results highlight the highly predictive value of vegetation type with regard to chorological categories and climate (Lausi & Nimis 1985). This is illustrated by the strongly significant relation between the first DCA-axis scores, the chorological category proportions and the index of Mangenot. Furthermore, the results underline the strength of the criteria set in the use of the phytogeographical index (I_P), which is simply coined on purpose to have a single value expressing the variation in the proportions of Guineo-Congolian, Sudanian and

Sudano-Zambesian elements. The four chorological groups of vegetation types distinguished on the basis of I_P turn out to be similar to the four clusters of vegetation types derived from the DCA ordination. Thus, the proposed phytochorological map (Figure 3.3) can be regarded as a synthesis reflecting the plant community, chorological, and climatic patterns in Benin. Therefore, it should be taken into account along with the 20 associated plant communities described in vegetation and flora management plans. When responses of plant species and community to environment are understood, their occurrence can be predicted based on environmental data only (Hall & Swaine 1976).

The transition between the Guineo-Conglian and Sudanian regions as established in Benin seems to be in agreement with what has been observed at regional scale, where the forest-savannah transition zone occurs at latitudes 8-9°N (Gautier & Spichiger 2004). It also fulfils the basic criterion of the forest-savannah boundary in West Africa, which is interpreted as a transitional belt of varying width, where Guineo-Congolian and Sudanian floras coexist and compete (Spichiger 1975). The distinction between the "Guineo-Sudanian" transition zone (as chorologically showing affinity to the Guineo-Congolian region) and the "Sudano-Guinean" transition zone (as chorologically showing affinity to the Sudanian region) has already been made in the phytogeographical subdivision of Cameroon (Letouzey 1985, van der Zon 1992). However, our delimitation does not strictly coincide with the latitudinal belt because of the "aberrant" latitudinal position" of the PD of Bassila within the Guineo/Sudanian transition zone (Chapter 2). This can be interpreted as a result of past climatic fluctuations, which favoured the irradiations of Guineo-Congolian elements from the Upper Guinea (Poorter et al. 2004) creating a distinctive biogeographical area in this centre-western part of Benin (Aubréville 1937).

3.5. CONCLUSION

The driving force of the floristic gradient in Benin is found to be water availability in terms of humidity index of Mangenot, which is a function of rainfall, length and severity of the dry season, and air humidity. Mean annual rainfall should not be the only climatic factor taken into account in vegetation studies in West Africa. The Mangenot's humidity index provides a better quantitative assessment of climatic conditions at a site than any single climatic variable.

The strong correlation between the first DCA-axis (carrying on the vegetation type's scores) and chorological categories (GC, S and SZ) highlights the highly predictive value of vegetation type with regard to chorological categories and climate, and vice versa. The influence of past climatic changes on the distribution of plant species and community was elucidated. Therefore, the proposed phytochorological map should be regarded as a synthesis reflecting the plant community, chorological and climatic patterns in Benin. It should be taken into account along with the 20 associated plant communities described in vegetation and flora management plans.

Table 3.1: Floristic and ecological characteristics of the 20 major plant communities defined on the basis of TWINSPAN classification of 598 vegetation samples and 1021 plant species in Benin.

Plant Communities	Differential species	Most frequent species (> 80%)	Plant formation	PD	N/ha	I_M & Rainfall	Soil types
Terminalia superba-Piptadeniastrum africanum (Te-Pi) (40 relevés)	*Strombosia pustulata Piptandeniastrum africanum, Parkia bicolor, Terminalia superba, Distemonanthus benthamianus, Amphimas pterocarpoides, Euclinia longiflora etc.*	*Triplochiton scleroxylon, Antiaris toxicaria, Celtis zenkeri, Cola millenii, Terminalia superba, Rothmannia urcelliformis, Ceiba pentandra*	Semi-deciduous forest	PO* & PL	234	4.17-5.75 (1300 mm/yr)	Ferrallitic without concretions on sedimentary rock (temporarily flooded)
Mitragyna ledermannii-Lasiomorpha senegalensis (Mi-La) (29 relevés*)*	*Mitragyna ledermannii, Lasiomorpha senegalensis, Syzygium owariense, Xylopia rubescens, Anthostema aubryanum, Rothmannia megalostigma, Uapaca paludosa etc.*	*Syzygium owariense, Xylopia rubescens, Mitragyna ledermannii, Spondianthus preussii, Lasiomorpha senegalensis*	Swamp forest	VO	106	4-5.75 (1300 mm/yr)	Hydromorphic on sedimentary rock
Rhizophora racemosa-Avicennia germinans (Rh-Av) (02 relevés*)*	*Rhizophora racemosa, Avicennia germinans, Dalbergia ecastaphyllum, Machaerium lunatum, Sesuvium portulacastrum etc.*	*Rhizophora racemosa, Avicennia germinans*	Mangrove	CO	85	4.61-5.63 (1200 mm/yr)	Halomorphic (saline) on sedimentary rock
Triplochiton scleroxylon-Celtis zenkeri (Tr-Ce) (30 relevés)	*Griffonia simplicifolia*	*Celtis zenkeri, Cola gigantea, Triplochiton Scleroxylon, Ceiba pentandra, Milicia excelsa, Antiaris toxicaria, Millettia thonningii, Holoptelea grandis*	Semi-deciduous forest	PO*, PL*, OV & BA	205	3-5.75 (1100 mm/yr)	Ferrallitic without concretions on sedimentary rock
Drypetes aframensis-Nesogordonia papaverifera (Dr-Ne) (25 relevés)	*Drypetes aframensis, Drypetes gilgiana, Nesogordonia papaverifera, Pterygota macrocarpa, Mansonia altissima, Celtis mildbraedii, Rinorea ilicifolia etc.*	*Drypetes aframensis, Ceiba pentandra, Triplochiton scleroxylon, Antiaris toxicaria, Celtis zenkeri, Celtis mildbraedii, Nesogordonia papaverifera, Drypetes floribunda*	Semi-deciduous forest	PL	149	3.90 (1100 mm/yr)	Ferrallitic with concretions on sedimentary rock
Chrysobalanus icaco-Barteria nigritana (Chr-Bar) (29 relevés)	*Barteria nigritana, Diospyros tricolor, Chrysobalanus icaco* subsp. *icaco, Syzygium guineense* var. *littorale, Trichoscypha oba etc.*	*Dialium guineense, Lecaniodiscus cupanioides, Chrysobalanus icaco, Cleistopholis patens, Barteria nigritana, Celtis prantlii*	Semi-deciduous forest	CO	143	4.61-5.63 (1150 mm/yr)	Coastal sand
Mimusops andongensis-Cynometra megalophylla (Mi-Cy) (12 relevés)	*Mumusops andongensis*	*Dialium guineense, Diopyros mespiliformis, Mimusops andongensis, Celtis prantlii, Afzelia africana, Ceiba pentandra, Anogeissus leiocarpa, Drypetes floribunda*	Semi-deciduous forest	PL	149	3.93 (1100 mm/yr)	Vertisols
Cynometra megalophylla-Parinari congensis (Cy-Pa) (35 relevés)	*Parinari congensis, Millettia warneckei*	*Cynometra megalophylla, Pterocarpus santalinoides, Cola laurifolia, Diospyros mespiliformis, Morelia senegalensis, Parinari congensis*	Riparian forest	ZO*, BA* & BS	124	2.67-2.94 (1200 mm/yr)	Hydromorphic on crystalline rock (riparian)
Khaya grandifoliola-Aubrevillea kerstingii (Kh-Au) (40 relevés)	*Aubrevillea kerstingii*	*Cola gigantea, Celtis zenkeri, Holoptelea grandis, Celtis toka, Pouteria alnifolia, Cola millenii, Diospyros mespiliformis*	Semi-deciduous forest	BA	147	2.80 (1250 mm/yr)	Ferrallitic with concretions on crystalline rock
Cola gigantea-Khaya grandifoliola (Co-Kh) (40 relevés*)*	*Pseudospondias microcarpa*	*Pterocarpus santalinoides, Cola gigantea, Lecaniodiscus cupanioides, Antiaris toxicaria*	Riparian forest	BA	169	2.80 (1250 mm/yr)	Ferrallitic on crystalline rock (hydromorphic)

Anogeissus leiocarpa-Lecaniodiscus cupanioides (An-Lec) (28 relevés)	*Erythrophleum suaveolens*	*Anogeissus leiocarpa, Diospyros mespiliformis, Pouteria alnifolia, Manilkara multinervis, Mallotus oppositifolius*	Dry forest	ZO* & BA*	127	2.80-2.94 (1200 mm/yr)	Ferruginous with concretions on crystalline rock
Hildegardia barteri- Aphania senegalensis (Hi-Ap) (9 relevés)	*Hildegardia barteri, Eugenia nigerina, Acridocarpus smeathmannii*	*Hildegardia barteri, Ceiba pentandra, Millettia thonningii, Aphania senegalensis, Cola millenii*	Dry forest	ZO	88	2.73-2.94 (1100 mm/yr)	Ferruginous with concretions on crystalline rock (rock outcrop and boulder meanders)
Anogeissus leiocarpa-Anchomanes welwitschii (An-Anch) (35 relevés)	*Anchomanes welwitchii*	*Anogeissus leiocarpa, Diospyros mespiliformis, Khaya senegalensis, Antiaris toxicaria, Milicia excelsa*	Dry forest	BA*, BS*, BN*, AT* & M-P*	133	1.88-2.94 (1050 mm/yr)	Ferruginous with concretions on crystalline rock
Synsepalum passargei-Broenadia salicina (Sy-Br) (38 relevés)	*Synsepalum passargei, Broenadia salicina, Eriocoelum kerstingii, Chrysobalanus icaco* subsp. *atacorensis, Thunbergia atacoriensis, Gardenia imperialis etc.*	*Khaya senegalensis, Rourea coccinea, Syzigium guineense, Diospyros mespiliformis, Lannea acida, Afzelia africana*	Riparian forest	BN & AT*	149	1.96-2.37 (1100 mm/yr)	Poorly evolved soil with raw minerals (hydromorphic)
Garcinia livingstonei- Vitex chrysocarpa (Ga-Vi) (20 relevés)	*Garcinia livingstonei, Combretum acutum*	*Mitragyna inermis, Cola laurifolia, Vitex chrysocarpa, Pterocarpus santalinoides*	Riparian forest	M-P	60	1.42-1.80 (975 mm/yr)	Ferruginous with concretions on sedimentary rock (hydromorphic)
Isoberlinia doka-Chromolaena odorata (Iso-Ch) (29 relevés)	*Aframomum latifolium*	*Pterocarpus erinaceus, Isoberlinia doka, Vitellaria paradoxa, Anogeissus leiocarpa, Burkea africana, Daniellia oliveri*	Woodland & savannah woodland	ZO* & BA*	151	2.73-2.94 (1100 mm/yr)	Ferruginous with concretions on crystalline rock
Isoberlinia spp.-*Bridelia ferruginea* (Iso-Br) (27 relevés)	*Combination Isoberlinia spp.-Hexalobus monopetalus-Bridelia ferruginea*	*Isoberlinia doka, Pterocarpus erinaceus, Siphonochilus aethiopicus, Anogeissus leiocarpa, Burkea africana*	Woodland & savannah woodland	BA* & BS*	154	2.67-2.82 (1200 mm/yr)	Ferruginous with concretions on crystalline rock
Isoberlinia spp.-*Haematostaphis barteri* (Iso-Hae) (26 relevés)	*Haematostaphys barteri, Erythrophleum africanum, Terminalia brownii, Commiphora pedunculata*	*Pterocarpus erinaceus, Lannea acida, Isoberlinia doka, Burkea africana, Rourea coccinea, Khaya senegalensis*	Woodland & savannah woodland	AT	115	1.80-2.37 (1100 mm/yr)	Poorly evolved soil with raw minerals
Isoberlinia spp.-*Combretum glutinosum* (Iso-Co) (40 relevés)	*Combination Isoberlinia spp.-Hexalobus monopetalus-Combretum glutinosum*	*Isoberlinia doka, Burkea africana, Lannea acida, Vitellaria paradoxa, Pterocarpus erinaceus, Detarium microcarpum*	Woodland & savannah woodland	BN*, AT* & M-P	159	1.88-1.96 (1050 mm/yr)	Ferruginous with concretions on crystalline rock
Albizia chevalieri-Balanites aegyptiaca (Al-Bal) (64 relevés)	*Albizia chevalieri, Balanites aegyptiaca, Sclerocarya birrea, Cadaba farinosa, Guiera senegalensis, Lonchocarpus laxiflora*	*Combretum nigricans, Combretum glutinosum, Combretum collinum, Anogeissus leiocarpa, Vitellaria paradoxa*	Shrub savannah	M-P	110	1.42-1.80 (975 mm/yr)	Ferruginous with concretions on sedimentary rock

PD: Phytogeographic districts (Figure 3.1): CO: Côtier, PO: Pobè, PL: Plateaux, VO: Vallée de l'Ouémé, BA: Bassila, ZO: Zou, BS: Borgou-Sud, BN: Borgou-Nord, AT: Atacora Chain, M-P: Mékrou-Pendjari; N/ha: Species richness per ha; I_M: Climatic Index of Mangenot (1951), values of mean annual rainfall are put between brackets beside I_M; *Isoberlinia* spp. includes *I. doka* and *I. tomentosa*; *: PDs in which the plant community is frequent.

Chapter 4

Plant community patterns of semi-deciduous forest islands in Benin with emphasis on the Dahomey Gap

Chapter 4

Plant community patterns of semi-deciduous forest islands in Benin with emphasis on the Dahomey Gap

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Abstract

Patterns in semi-deciduous forest islands are investigated in Benin by means of phytosociological relevés, forest inventories and multivariate analyses. The TWINSPAN classification and DCA ordination of 176 semi-deciduous forest relevés and 559 plant species result in six plant communities, which are patterned along climatic and edaphic gradients. The semi-deciduous forest types described and their floristic composition (both at species and family levels) are comparable to those recognised in other parts of West Africa where the semi-deciduous forest is more continuous. The ecologically dominant families include Sterculiaceae, Celtidaceae, Leguminosae, Moraceae, Ebenaceae, Rubiaceae and Euphorbiaceae. The *Drypetes aframensis-Nesogordonia papaverifera* community appeared to be the type in which the Celtidaceae (ex Ulmaceae), Sterculiaceae, Euphorbiaceae, and Violaceae are best represented. The record of many Upper Guinean endemic species in Benin's semi-deciduous forest islands provides strong evidence for past floristic connections of the Dahomey Gap with the West African rain forest zone. The restriction of the *Khaya grandifoliola-Aubrevillea kerstingii* community to the centre-northern section is interpreted as being a result of past floristic connections between this area and the Upper Guinean forest block.

The overall species composition of the semi-deciduous forest islands situated in southern Benin is in good agreement with the pollen assemblage of the humid period of early-mid Holocene (8500-4000 years BP), a period during which the gap was shown to be covered by a continuous semi-deciduous forest. The *Terminalia superba-Piptadeniastrum africanum* community, which corresponds to the West African moist semi-deciduous forest, is assumed to dominate the vegetation of the Dahomey Gap during this period. Its subsequent retreat to forest stream bank is interpreted as an ecological response to the general dry climate of the late Holocene, which induced the fragmentation of West African rain forest. The agreement between the pollen assemblage and the species composition of the semi-deciduous forest types points to the existence of a latitudinal floristic gradient associated with a climatic gradient during the early-mid Holocene. Furthermore, the results show that knowledge of modern plant community structure, species composition and distribution is vital for the in-depth interpretation of pollen data in the process of palaeo-vegetation reconstruction.

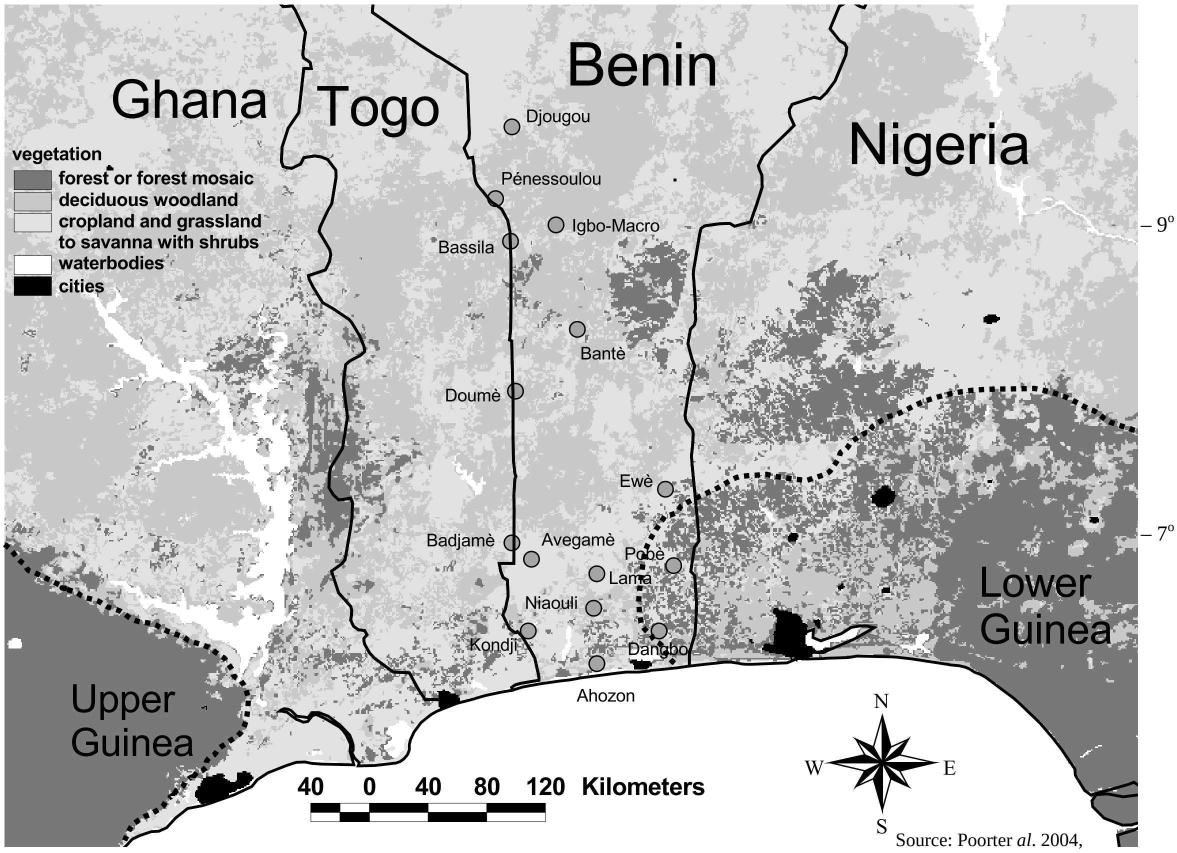
4.1. INTRODUCTION

The analysis of the West African palaeo-environment reveals that during the Last Glacial Maximum (18 000 years BP) the once continuous rain forest belt became fragmented and reduced to few refugia (Diamond & Hamilton 1980, Hamilton 1981, van Zinderen Bakker 1982, Dupont & Weinelt 1996, Maley 1996). The Dahomey Gap – the present dry corridor in the zonal West African rain forest – remains one of the major imprints of the Pleistocene hyper-arid period. More specifically, the Dahomey Gap (or interval) is often defined as the savannah region between southern-eastern Ghana and southern-western Benin through southern Togo, splitting the West African rain forest into the Upper Guinean and Lower Guinean forest blocks (White 1983) (Figure 4.1). It is considered as an important ecogeographical barrier to species exchange between the two forest blocks and is, as such, of a crucial significance for their distribution patterns in West Africa (van Bruggen 1989, Martin 1991, Jenik 1994). It is ecologically characterised by a decline in annual rainfall from more than 2000 mm in the Upper and Lower Guineas to about 1300 to 900 mm in the dry corridor. Consequently, the Gap is almost completely devoid of evergreen rain forest and its associated plant and animal species. It should be emphasised that the African lowland rain forest consists of two floristically and climatically different components: (i) the evergreen forest belt with annual rainfall > 2000 mm/year, dry season period < 3 months, tree layer rich in evergreen species belonging to the Leguminosae-Caesalpinoideae; and (ii) the semi-evergreen or semi-deciduous forest belt with annual rainfall < 1600-2000 mm/year, dry season period > 3 months, tree layer rich in deciduous species belonging to the Celtidaceae, Malvaceae, Sterculiaceae and Moraceae (White 1983, Vooren & Sayers 1992).

After the end of the last ice age (10 000 years BP), the climate became warmer and wetter, the African rain forest expanded, and during the early Holocene it even bridged the Dahomey Gap (Dupont & Weinelt 1996). Pollen records from southern Benin indicated that the gap was closed and covered with a semi-evergreen rain forest during the early-mid Holocene (8500-4000 years BP) (Tossou 2002, Salzmann & Hoelzmann 2005). More explicitly, the Upper and Lower Guineas were connected by a band of semi-deciduous forest during this period. At the onset of late Holocene (4000-3000 years BP) an abrupt climatic change towards drier environmental conditions caused the sudden re-opening of the Dahomey Gap with the establishment of the savannah vegetation. Palaeo-records from southern Benin and from other parts of West Africa indicated wetter climatic conditions after 3000 years BP and the subsequent spread of semi-evergreen forest into the open savannah leading to a forest-savannah mosaic in the gap. A return to drier climatic conditions after 2500 years BP resulted in the renewed establishment of an open savannah, which persists until the present (Maley 1989, 1991 & 1992, Tossou 2002). Talbot *et al.* (1984) and Salzmann & Hoelzmann (2005) set the beginning of this dry period after 1100 years BP.

The present vegetation of southern Benin is a forest-savannah mosaic consisting of fallows, fields, oil palm plantations, and intermittent semi-evergreen/deciduous forest islands. These forest islands even extend to the centre-western part of the country. They have probably survived the dry climate of late Holocene, which led to the abrupt deterioration of the continuous semi-deciduous forest belt that existed in early-mid Holocene. Thus, the species composition and the plant community structure of these forest islands are expected to be similar to the semi-deciduous forest situated in Upper and Lower Guineas. We also assume that understanding of the present plant community structure is vital for the in-depth interpretation of pollen assemblage of early-mid Holocene, period during which the gap was covered with a continuous semi-deciduous forest. The present paper represents an attempt (1) to make a comprehensive analysis of the plant community structure and species composition of the semi-deciduous forest islands in Benin, (2) to establish their floristic links with the

West African rain forest, and (3) to elucidate the species composition and the nature of the semi-deciduous forest that covered the gap in early-mid Holocene times.



Source: Poorter *al*. 2004, pp. 482-483

Figure 4.1: Vegetation map of West Africa showing the rain forest zone and Benin indicating the semi-deciduous forest sites where data were collected. *The Dahomey Gap is the light grey area between the Lower and Upper Guinea Forest Blocks.*

4.2. METHODS

4.2.1. Study area

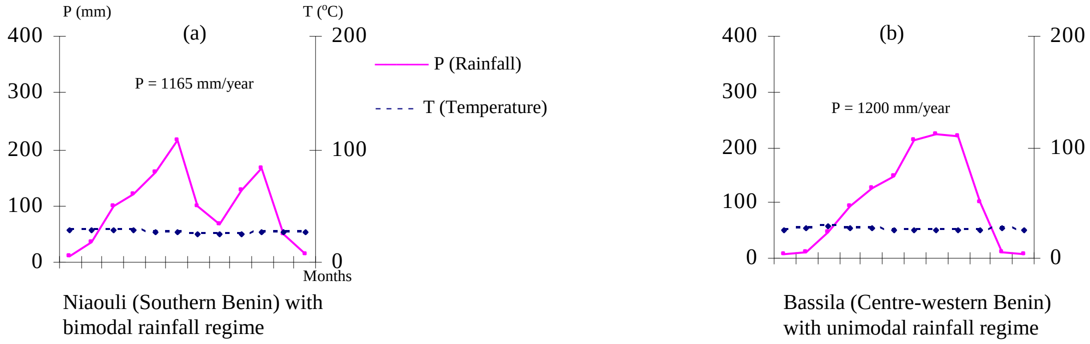
The study area involves the semi-deciduous forest islands of Benin (Figure 4.1), most of which are located in southern and centre-western parts of the country. Southern Benin falls in the core area of the Dahomey Gap.

Southern Benin has a Guinean climate with a bimodal rainfall regime i.e. two rainy seasons and two dry seasons (Adjanohoun 1989, Akoègninou 2004) (Figure 4.2a). The area is characterised by two rainfall gradients (Paradis 1983): a strong east-west gradient of decreasing annual rainfall (1200-1300 mm in the east and 900 mm in the west) and a weak south-north gradient with a trend towards a unimodal rainfall regime i.e. north of latitude 7^{o} North the two rainfall peaks tend to merge into one peak. The coastal area is characterised by high air humidity (80%). Much of the area is dominated by a plateau (with ferrallitic soil) bisected by the depression of Lama (with vertisol) into the southern and northern sections.

The dominant soil is ferrallitic without concretions on sedimentary rock. Forest sites such as Pobè, Dangbo and Niaouli are dissected by streams.

The centre-western part of the country has a tropical climate with a unimodal rainfall regime (Figure 4.2b). The annual rainfall ranges from 1200 to 1300 mm. The climate of the area seems to be positively influenced by the vicinity of the Atacora Mountains, which makes it a distinctive ecological region (Akoègninou 2004, Chapter 2). The dominant soil is ferrallitic with concretions on crystalline rock.

The prevailing wind throughout the year is a breeze from the south-west, but from January to February the Harmattan, a northerly dry wind from the Sahara, reaches the coast.



Niaouli (Southern Benin) with bimodal rainfall regime

Bassila (Centre-western Benin) with unimodal rainfall regime

Figure 4.2: Ombrothermograms showing the climate (rainfall & temperature) of southern and centre-western Benin, where semi-deciduous forest islands occur.

4.2.2. Data collecting

Vegetation sampling

The existing semi-deciduous forest relics were gazetted with the help of locally experienced botanists and ecologists. Site selection was based on the existence of forest reserves and sacred forests, which are protected by the local population. At each site, we carried out phytosociological relevés within quadrates of 30 x 30 m according to Braun-Blanquet's (1932) approach. We visually estimated the cover of each species using the Braun Blanquet's cover/abundance scale (Westhoff & van der Maarel 1978): +: rare or less than 1% cover, 1: 1-5% cover, 2: 5-25% cover, 3: 25-50% cover, 4: 50-75% cover, and 5: 75-100% cover. The vegetation structure (number of layers, their cover and height) was visually described. Moreover, all trees and lianas of a diameter at breast height (dbh) > 10 cm were tagged, their number counted and dbh measured. General information related to soil conditions (texture and flooding) and topography (plateau, slope, and valley) was noted. A total of 176 vegetation relevés with 559 plant species were made.

Holocene pollen data

Based on Holocene pollen diagrams from Tossou (2002) and Salzmann & Hoelzmann (2005), we selected the pollen-types that dominated (with a representation of more than 20%) the entire early-mid Holocene period. These authors showed that during this period the Dahomey Gap (to which southern Benin belongs) was covered with a continuous semi-deciduous forest. In total, we selected 30 pollen-types, which correspond to at least 30 plant species. The pollen-types related to a-zonal vegetations (mangrove and swamp forest) were not included.

4.2.3. Data processing

Semi-deciduous forest patterns

The 176 semi-deciduous forest relevés and 559 plant species were classified into clusters (groups of relevés) using Two Way Indicator Species Analysis (TWINSPAN) (Hill 1979a). We used the Detrended Correspondence Analysis (DECORANA or DCA) (Hill 1979b) to ordinate the forest relevés and to detect the underlying ecological gradients/factors within the data structure. The delineation of plant community types within the ordination space was guided by the clusters generated by TWINSPAN classification. Plant communities were characterised using the most differential species (as derived from TWINSPAN output) with high ecological importance value.

Species and family Importance Values (I.V.)

We used Importance Values (I.V.) to characterise the different vegetation types and reveal dominance. They were calculated both for species and families using the following formulas:

(1) The plant Species Importance Value (S.I.V.) is defined as the sum of its relative density, relative dominance, and relative frequency (Cottam & Curtis 1956).

$$\text{Relative density} = \frac{\text{Number of individuals of a species} \quad \text{X } 100}{\text{Total number of individuals}}$$

$$\text{Relative dominance} = \frac{\text{Total basal area of a species} \quad \text{X } 100}{\text{Total basal area of all species}}$$

Basal area = $(1/2 \text{ x dbh})^2 \text{ x } \pi$, where dbh is the diameter at breast height

$$\text{Relative frequency} = \frac{\text{Frequency of a species} \quad \text{X } 100}{\text{Sum frequency of all species}}$$

(2) The plant Family Importance Value (F.I.V.) is defined as the sum of its relative density, relative dominance, and relative diversity (Mori et al. 1983).

$$\text{Relative diversity} = \frac{\text{Number of species in a family X } 100}{\text{Total number of species}}$$

The relative density and relative dominance of a family were obtained by summing up the values of its specific (species) components.

The values of S.I.V. and F.I.V. range from 0 (absence of dominance) to 300 (mono-dominance). They allow identifying the leading dominant entities, i.e. those species and families having the highest ecological value. Reitsma (1988) considered as ecological dominant species or families those having S.I.V. or F.I.V. > 10.

Similarity among semi-deciduous forest types

The species lists of the described forest types were pairwise compared using the Jaccard's (1901) similarity index, which is given by the formula:

$$P_j = 100 \times \frac{c}{a + b - c}$$

where P_j is the Jaccard's community coefficient, a is the number of species present in the community A, b is the number of species in the community B, and c is the number of species shared by A and B.

The values of P_j range from 0 for an absence of similarity to 100 for a complete similarity.

Comparison between the species composition of semi-deciduous forest types and the pollen assemblage of early-mid Holocene

We used the plant species lists of the semi-deciduous forest types described by means of TWINSPAN and DCA as references to assign each pollen-type to semi-deciduous forest types. The resulted matrix was used to elucidate the relationships between the early-mid Holocene pollen assemblage and the species composition of the current forest types.

4.3. RESULTS

4.3.1. Semi-deciduous plant community patterns in Benin

The TWINSPAN classification of the 176 semi-deciduous forest relevés and 559 plant species resulted in six main clusters, which correspond to six forest types. The DCA ordination of the same matrix shows that these plant communities are patterned along two ecological gradients (Figure 4.3):

* The axis 1 can be interpreted as an edaphic gradient from the *Chrysobalanus ellipticus-Barteria nigritana* community on coastal sandy soil (Ahozon forest) to the *Drypetes aframensis-Nesogordonia papaverifera* on ferrallitic soil (Ewè forest) through the *Mimusops andongensis-Cynometra megalophylla* community on vertisol (Lama forest).

* The axis 2 can be interpreted as a climatic gradient with the *Terminalia superba-Piptadeniastrum africanum* and *Triplochiton scleroxylon-Celtis zenkeri* communities in the Guineo-Congolian region with a bimodal rainfall regime and the *Khaya grandifoliola-Aubrevillea kerstingii* community in the Guineo-Sudanian transition zone with a unimodal rainfall regime. The *Terminalia superba-Piptadeniastrum africanum* community – the most humid type in Benin – always occurs under a bimodal rainfall regime of 1100-1300 mm/year on the lower slope, a few strides from the river crossing the forest site. Reported from the forest islands of Pobè, Dangbo and Niaouli (Figure 4.1), it is characterised by the exclusive presence of species such as *Piptadeniastrum africanum*, *Parkia bicolor*, *Pentaclethra macrophylla*, *Canarium schweinfurthii*, *Distemonanthus benthamianus*, and *Strombosia pustulata*. The *Triplochiton scleroxylon-Celtis zenkeri* community generally occurs on plateau in southern Benin, under a bimodal rainfall regime of 900-1300 mm/year, but has been also reported in the centre-western part of the country (in the tract Doumè-Bantè) under a unimodal rainfall regime with an annual rainfall of 1200 mm. It can be better described by the absence of the characteristic tree species of the former forest type and thus, can be considered as a relatively dry type of the *Terminalia superba-Piptadeniastrum africanum* community.

Similarly, the *Khaya grandifoliola-Aubrevillea kerstingii* community is best described by the absence of *Triplochiton scleroxylon,* and can be regarded as a climatically dry type of the *Triplochiton scleroxylon-Celtis zenkeri* community. The presence of *Triplochiton scleroxylon* always implies the presence of *Celtis zenkeri,* but the inverse situation is not always true. *Celtis zenkeri* is among those semi-deciduous forest plant species (including *Trilepisium madagascariense*, *Holoptelea grandis* and *Cola gigantea*) that reach the latitude 9°40' North in the locality of Djougou (Figure 4.1), where the climate is of Sudanian type (unimodal rainfall regime). The establishment and maintenance of semi-deciduous forest at this latitude seem to be favoured by the importance of rainfall (1300 mm/year) – certainly induced by the vicinity of the Atacora Mountains – and the soil type (fairly ferrallitic).

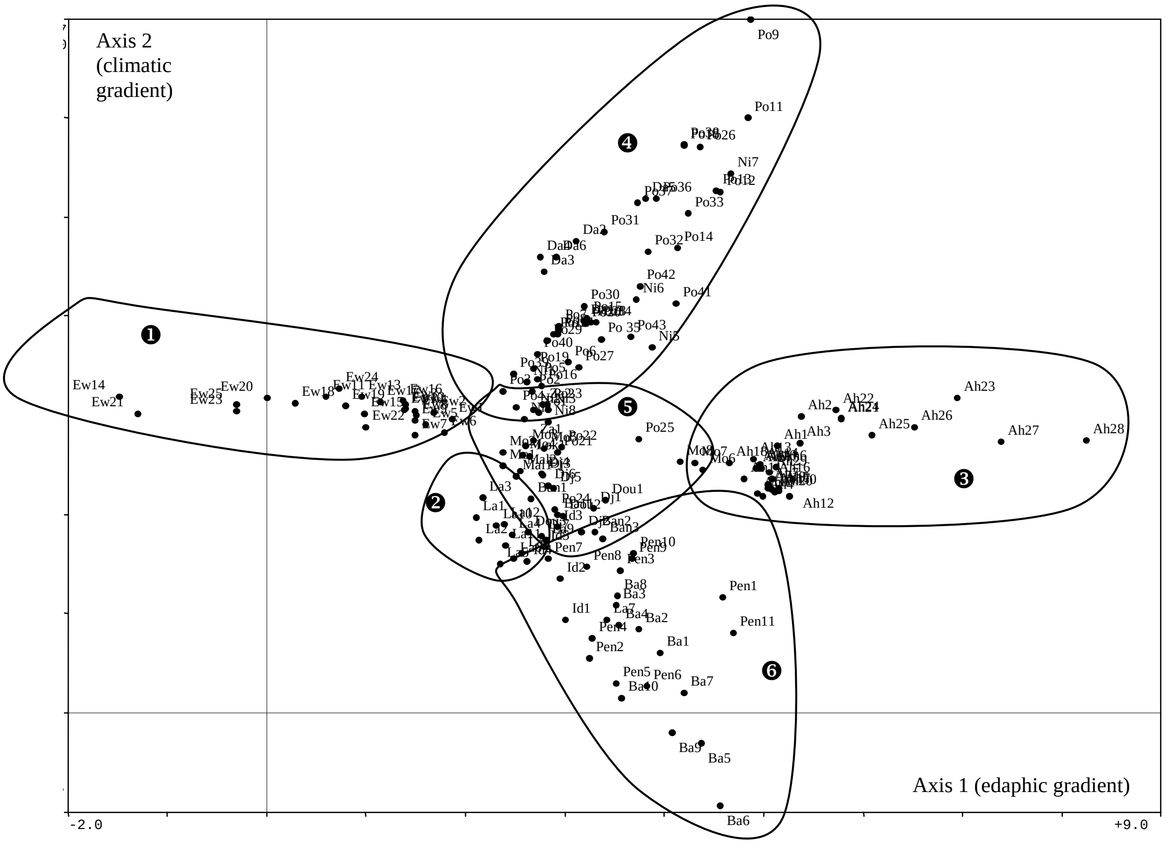


Figure 4.3: DCA ordination of 176 semi-deciduous forest samples and 559 plant species in Benin, showing six plant community types.

Plant community types: ❶ *Drypetes aframensis-Nesogordonia papaverifera* community, ❷ M*imusops andongensis-Cynometra megalophylla* community, ❸ *Chrysobalanus ellipticus-Barteria nigritana* community, ❹ *Terminalia superba-Piptadeniastrum africanum* community, ❺ *Triplochiton scleroxylon-Celtis zenkeri* community, and ❻ *Khaya grandifoliola-Aubrevillea kerstingii* community.

Table 4.1 gives an overview of the floristic and ecological characteristics of the six semi-deciduous forest types described. It shows that the most dominant families of the plant communities on ferrallitic soil are: Leguminosae, Sterculiaceae, Celtidaceae, Moraceae, and Euphorbiaceae.

Table 4.1: Floristic and ecological characteristics of the six major semi-deciduous forest types described in Benin.

Plant community	Differential species	Dominant species (S.I.V. > 10) in decreasing order of importance	Dominant families (F.I.V. > 10) in decreasing order of importance	Rainfall	**Soil**
Terminalia superba-Piptadeniastrum africanum (4 layers, tree layer is 15-25 m tall) (40 relevés)	Strombosia pustulata Piptadeniastrum africanum, Parkia bicolor, Terminalia superba, Distemonanthus benthamianus, Anthonotha macrophylla, Canarium scheinfurthii	Triplochiton scleroxylon, Antiaris toxicaria, Celtis zenkeri, Cola millenii, Terminalia superba, Rothmannia urcelliformis, Ceiba pentandra	Leguminosae, Sterculiaceae, Moraceae, Rubiaceae, Ulmaceae, Combretaceae, Bombacaceae, Annonaceae, Euphorbiacae	Bimodal rainfall regime, with 1100-1300 mm/year	Ferrallitic soils on sedimentary rock (deep and temporary flooding)
Triplochiton scleroxylon-Celtis zenkeri (4 layers, tree layer is 15-25 m tall) (30 relevés)	Characterised by the absence the differential species of the Terminalia superba-Piptadeniastrum africanum community	Celtis zenkeri, Cola gigantea, Triplochiton scleroxylon, Ceiba pentandra, Milicia excelsa, Antiaris toxicaria, Millettia thonningii, Holoptelea grandis, Diospyros mespiliformis, Pouteria alnifolia	Sterculiaceae, Ulmaceae, Leguminosae, Ebenaceae, Sapotaceae, Moraceae, Bombacaceae, Annonaceae	- Bimodal rainfall regime, with 900-1300 mm/year - Unimodal rainfall regime with 1200 mm/year	- Mainly on ferrallitic soils on sedimentary rock (deep) - rare on ferrallitic soil s on crystalline rock (shallow)
Khaya grandifoliola-Aubrevillea kerstingii (3 layers, tree layer is 10-20 m tall) (40 relevés)	Khaya grandifoliola and Aubrevillea kerstingii	Cola gigantea, Anogeissus leiocarpa, Pouteria alnifolia, Cola millenii, Diospyros mespiliformis	Moraceae, Leguminosae, Ulmaceae, Sterculiaceae, Sapotaceae, Combretaceae, Sapindaceae, Anacardiaceae, Ebenaceae, Euphorbiaceae	Unimodal rainfall regime with 1200-1300 mm/year	Ferrallitic soils on crystalline rock (shallow)
Chrysobalanus ellipticus-Barteria nigritana (3 layers, tree layer is 10-20 m tall) (29 relevés)	Chrysobalanus ellipticus, Barteria nigritana, Syzygium guineense var. littorale, Trichocypha oba, Tricalysia faranahensis, Spatandra blackeoides, Leptoderris cyclocarpa, Cassipourea barteri	Dialium guineense, Lecaniodiscus cupanioides, Chrysobalanus ellipticus, Cleistopholis patens, Barteria nigritana, Olax subscorpioidea	Leguminosae, Chrysobalanaceae, Annonaceae, Sapindaceae, Euphorbiaceae, Passifloraceae, Moraceae, Sterculiaceae	Bimodal rainfall regime, with 900-1200 mm/year	Coastal sand
Mimusops andongensis-Cynometra megalophylla (3 layers, tree layer is 10-20 m tall) (12 relevés)	Mimusops andongensis and Cynometra megalophylla	Dialium guineense, Diopyros mespiliformis, Mimusops andongensis, Celtis prantlii, Afzelia africana, Ceiba pentandra, Anogeissus leiocarpa, Cynometra megalophylla, Drypetes floribunda	Leguminosae, Ebenaceae, Sapotaceae, Combretaceae, Ulmaceae, Bombacaceae, Sapindaceae, Moraceae, Euphorbiaceae	Bimodal rainfall regime with 1100 mm/year	Vertisols (temporary flooding)
Drypetes aframensis-Nesogordonia papaverifera (4 layers, tree layer is 15-25 m tall) (25 relevés)	Drypetes aframensis, Drypetes gilgiana, Rinorea ilicifolia, Rinorea kibbiensis, Nesogordonia papaverifera, Octobolus spectabilis, Mansonia altissima, Pterygota macrocarpa, Hymenodicton pachyantha, Vitex micrantha, , Zanthoxylum rubescens	Drypetes aframensis, Ceiba pentandra, Triplochiton scleroxylon, Antiaris toxicaria, Celtis zenkeri, Celtis mildbraedii, Nesogordonia papaverifera, Drypetes floribunda, Octolobus spectabilis	Euphorbiaceae, Sterculiaceae, Ulmaceae, Bombacaceae, Moraceae, Leguminosae	Bimodal rainfall regime with 1100-1200 mm/year	Ferrallitic soils on sedimentary rock (deep)

S.I.V.: Species Importance values, F.I.V.: Family importance values.

The plant families such as Sterculiaceae, Celtidaceae and Euphorbiaceae are best represented in the *Drypetes aframensis-Nesogordonia papaverifera* community which is restricted to the forest island of Ewè (Figure 4.1). This forest type corresponds to the richest in *Rinorea* with four species recorded: *R. brachypetala*, *R. kibbiensis*, *R. dentata*, and *R. ilicifolia*, which dominate the underwood in several stands with a cover sometimes reaching 70%.

The *Chrysobalanus ellipticus-Barteria nigritana* community on coastal sand (Ahozon's forest) is largely dominated by Leguminosae and Chrysobalanaceae while Leguminosae, Sapotaceae, and Ebenaceae are the leading families of the *Mimusops andongensis-Cynometra megalophylla* forest type on vertisol (Lama's forest).

4.3.2. Floristic similarity among semi-deciduous forest types

Table 4.2 summarises the floristic relationships among the six forest types described. The highest similarity value was between the *Terminalia superba- Piptadeniastrum africanum* (on the lower slope) and *Triplochiton scleroxylon-Celtis zenkeri* (on plateau) communities, which share 64% of their species. The similarity values among all other pairs of communities are low and range from 28-38; this is due to the fact that the forest types share a common floristic background, which includes forest plant species with large ecological amplitude such as *Antiaris toxicaria*, *Milicia excelsa*, *Ceiba pentandra*, *Dialium guineense*, *Celtis prantlii*, *Oxyanthus racemosus*, and *Rothmannia longiflora*.

Table 4.2: Matrix of similarity between semi-deciduous forest types based on the distribution of 559 plant species using Jaccard's similarity index.

Forest types	Chr-Bar	Te-Pi	Tr-Ce	Mi-Cy	Dr-Ne
Te-Pi	34				
Tr-Ce	34	64			
Mi-Cy	33	28	33		
Dr-Ne	31	32	34	36	
Kh-Au	30	33	38	33	33

Semi-deciduous forest types: Chr-Bar: *Chrysobalanus ellipticus-Barteria nigritana* community, Te-Pi: *Terminalia superba-Piptadeniastrum*, *africanum* community, Tr-Ce: *Triplochiton scleroxylon-Celtis zenkeri* community, Mi-Cy : *Mimusops andongensis-Cynometra megalophylla* community, Dr-Ne: *Drypetes aframensis-Nesogordonia papaverifera* community, Kh-Au: *Khaya grandifoliola-Aubrevillea kerstingii* community.

4.3.3. Relationships between the species composition of semi-deciduous forest types and the early-mid Holocene pollen assemblage from Southern Benin

Table 4.3 shows the relationships between the early-mid Holocene pollen assemblage reflecting the species composition of past forest vegetation and the present forest types. Each of the 30 selected pollen-types is assigned to at least one semi-deciduous forest type. The pollen type *Cola* spp. certainly includes *Cola gigantea* and *Cola millenii*, which are still frequent in most of the semi-deciduous islands. The *Celtis* spp. pollen type probably includes *C. zenkeri*, *C. mildbraedii* and *C. prantlii*. There seems to be a strong agreement between the early-mid Holocene pollen assemblage and the overall plant species composition of the semi-deciduous forest relics.

Table 4.3: Assignment of early-mid Holocene pollen types from southern Benin to the major semi-deciduous forest types.

		Current semi-deciduous forest types based on species composition of forest islands					
Dominant pollen-types during early-mid Holocene in southern Benin	Plant family	Te-Pi	Tr-Ce	Dr-Ne	Chr-Bar	Mi-Cy	Kh-Au
Alstonia congensis Engl.	Apocynaceae	1	0	0	1	0	0
Anthonotha macrophylla (Te-Pi)*	Leg.-Caes.	1	0	0	0	0	0
Canarium schweinfurthii (Te-Pi)*	Burseraceae	1	0	0	0	0	0
Ceiba pentandra	Celtidaceae	1	1	1	1	1	1
Celtis spp.	Celtidaceae	1	1	1	1	1	1
Chaetacme aristata	Celtidaceae	0	1	1	0	0	0
Cola spp.	Sterculiaceae	1	1	1	1	0	1
Diospyros mespiliformis	Ebenaceae	0	1	1	0	1	1
Distemonanthus benthamianus (Te-Pi)*	Leg.-Caes.	1	0	0	0	0	0
Englerophytum oblanceolatum	Sapotaceae	1	1	1	0	0	1
Holoptelea grandis	Celtidaceae	1	1	1	0	0	1
Lannea nigritana	Anacardiaceae	1	1	1	1	1	1
Macaranga barteri	Euphorbiaceae	1	0	0	1	0	0
Mansonia altissima (Dr-Ne)*	Sterculiaceae	0	0	1	0	0	0
Maranthes robusta	Chrysobalanaceae	1	0	0	1	0	0
Milicia excelsa	Moraceae	1	1	1	1	1	1
Mimusops andogensis (Mi-Cy)*	Sapotaceae	0	0	0	0	1	0
Nesogordonia papaverifera (Dr-Ne)*	Sterculiaceae	0	0	1	0	0	0
Pancovia bijuga	Sapindaceae	1	1	0	0	1	0
Parkia bicolor (Te-Pi)*	Leg.-Mim.	1	0	0	0	0	0
Pentaclethra macrophylla	Leg.-Mim.	1	1	0	0	0	0
Piptadeniastrum africanum (Te-Pi)*	Leg.-Mim.	1	0	0	0	0	0
Psydrax subcordata	Rubiaceae	1	0	0	0	0	0
Pycnanthus angolensis	Myristicaceae	1	0	0	1	0	0
Spathodea campanulata	Bignoniaceae	1	1	1	0	1	1
Sterculia tragacantha	Sterculiaceae	1	1	1	1	1	1
Syzygium guineense var. littorale (Chr-Ba)*	Myrtaceae	0	0	0	1	0	0
Terminalia superba (Te-Pi)*	Combretaceae	1	0	0	0	0	0
Trilepisium madagascariense	Moraceae	1	1	0	0	0	1
Triplochiton scleroxylon	Sterculiaceae	1	1	1	0	0	0
Number of pollen types in each forest types		24	15	14	11	09	11

Described semi-deciduous forest types: Ch-Bar: *Chrysobalanus icaco-Barteria nigritana*, Te-Pi: *Terminalia superba-Piptadeniastrum africanum*, Tr-Ce: *Triplochiton scleroxylon-Celtis zenkeri*, Dr-Ne : *Drypetes aframensis-Nesogordonia papaverifera*, Mu-Cy: *Mimusops andongensis-Cynometra megalophylla*, and Kh-Au: *Khaya grandifoliola-Aubrevillea kerstingii*.

Leg.-Caes.: Leg.-Caesalpinioideae, Leg.-Mim.: Leguminosae-Mimosoideae.

Pollen type assignment to forest types is based on the presence (record) or absence of the corresponding plant species in a given forest type; 0: Pollen-type absent from the forest type; 1: Pollen-type present in the forest type. *: Pollen types corresponding to characteristic species, related semi-deciduous forest types are indicated in parentheses.

The pollen-type composition includes 10 plant species, which have proved to be characteristic species (differential species) of the four semi-deciduous forest types which are geographically confined to southern Benin (up to the latitude 7°30'N):

* The *Terminalia superba-Piptadeniastrum africanum* community with 7 characteristic pollen taxa: *Anthonotha macrophylla*, *Canarium schweinfurthii*, *Distemonanthus benthamianus, Parkia bicolor, Piptadeniastrum africanum,* and *Terminalia superba*.

* The *Drypetes aframensis-Nesogordonia papaverifera* community with 2 characteristic pollen taxa: *Mansonia altissima* and *Nesogordonia papaverifera*.

* The *Mimusops andongensis-Cynometra megalophylla* community includes *Mimusops andogensis* as characteristic pollen taxon.

* The *Chrysobalanus ellipticus-Barteria nigritana* community with *Syzygium guineense* var. *littorale* as characteristic pollen taxon.

The early-mid Holocene pollen assemblage from southern Benin reflects the species composition of these four forest types, which were probably the main semi-deciduous forest types that dominated this period. Out of the 30 dominant pollen-types selected, 24 (80%) are related to the *Terminalia superba-Piptadeniastrum africanum* community. This suggests that this plant community was likely the most dominant forest type during the early-mid Holocene humid period. The *Triplochiton scleroxylon-Celtis zenkeri* community, which is considered as a relatively dry type of the former one, would have colonised relatively dry areas during this period. 15 pollen types (50% of the selected pollen types) are related to this forest type.

The absence of pollen types corresponding to the characteristic species *Khaya grandifoliola* and *Aubrevillea kerstingii* from the pollen assemblage indicates that the *Khaya grandifoliola-Aubrevillea kerstingii* community was not part of the vegetation of southern Benin in the early-mid Holocene period. As mentioned before, this forest type is restricted to the centre-western part of the country, which is climatically drier compared to the south.

We can conclude that the pollen assemblage of the early-mid Holocene humid period from southern Benin fits with the species composition and community pattern of the present semi-deciduous forest remnants. Therefore, these forest islands can be considered as relics from the late Holocene dry period that triggered the fragmentation of the continuous semi-deciduous forest belt, which bridged the Upper and Lower rain forest blocks (Figure 4.1) in early-mid Holocene time.

4.4. DISCUSSION

4.4.1. Semi-deciduous forest in Benin versus West African semi-deciduous forest

(1) The *Terminalia superba-Piptadeniastrum africanum* community belongs to the phytosociological order of *Piptadenio-Celtidetalia* (Lebrun & Gilbert 1954), which corresponds to the West African moist semi-deciduous forest (Letouzey 1968, Hall & Swaine 1981, Vooren & Sayers 1992). It corresponds to the *Triplochiton-Strombosia* community of Sokpon & Lejoly (1994), which was described from the forest of Pobè in south-east Benin. This plant community is fundamentally typified by the presence of moist tree species such as *Piptadeniastrum africanum, Parkia bicolor, Pentaclethra macrophylla, Canarium schweinfurthii, Distemonanthus benthamianus, Celtis mildbraedii, Terminalia superba, Strombosia pustulata,* and *Anthonotha macrophylla*. The Guineo-Congolian endemic genera such as *Amphimas*, *Anthonotha*, *Distemonanthus*, *Anthrocaryon*, *Coelocaryon* and *Discoglypremna* (White 1983, Swaine 1996) are restricted to this forest type in Benin.

(2) The *Drypetes aframensis-Nesogordonia papaverifera* community, which is restricted to the Ewè's forest relic (Figure 4.1), is floristically comparable to the moist semi-deciduous

forest of Richards (1939) in Nigeria and corresponds to the *Celtis* spp.-*Mansonia altissima* community of Guillaumet & Adjanohoun (1971) in Ivory Coast. These authors considered this forest type as the climatic climax of the West African semi-deciduous forest because of the dominance of Celtidaceae and Sterculiaceae. The floristic link of the *Drypetes aframensis-Nesogordonia papaverifera* forest type to the West African semi-deciduous forest can be illustrated by the best representation of species belonging to the families of Celtidaceae (*Celtis mildbraedii*, *Celtis zenkeri* and *Celtis prantlii*), Sterculiaceae (*Nesogordonia papaverifera*, *Mansonia altissima*, *Pterygota macrophylla*, *Octobolus spectabilis* and *Sterculia tragacantha*), and Euphorbiaceae (*Drypetes floribunda*, *Drypetes gilgiana* and *Drypetes aframensis*) (Vooren & Sayers 1992, Swaine 1996). Furthermore, its richness in *Rinorea* species (with *R. brachypetala*, *R. dentata*, *R. kibbiensis* and *R. ilicifolia*) and their abundance in the forest floor are unique in the country and good indicators of its climax state (Achoundong *et al*. 2000). *R. ilicifolia* – characteristic of semi-deciduous forest in Cameroon (Achoundong 1996) – appears to be restricted to this forest type in Benin.

(3) The *Triplochiton scleroxylon-Celtis zenkeri* community is floristically similar to the *Triplochiton scleroxylon-Afzelia africana* of Schnell (1952) in West Africa, the *Celtis-Triplochiton* of Guillaumet & Adjanohoun (1971) in Ivory Coast, the dry semi-deciduous forest of Hall & Swaine (1981) in Ghana, and the *Triplochiton scleroxylon-Dialium guineense* community of Sokpon (1995) in south-eastern Benin.

(4) The *Chrysobalanus ellipticus-Barteria nigritana* community, the coastal semi-deciduous forest type, is similar to the south-east outlier forest type in Ghana where the most important species is *Dialium guineense* (Hall & Swaine 1981). In Benin, this species also appears to be the leading element in this forest type. The frequent occurrence of species such as *Baphia nitida*, *Xylopia aethiopica*, *Barteria nigritana*, *Pycnanthus angolensis*, *Alstonia congensis*, and *Symphonia globulifera* suggests that this forest type can be regarded as the dry type of the West African coastal evergreen forest (Letouzey 1968, Tchouto 2004).

(5) The *Mimusops andongensis-Cynometra megalophylla* community corresponds to the *Diopyros mespiliformis* community of Kokou (1998) in South Togo and seems to represent the pedo-climax semi-deciduous forest on vertisol. The abundance of *Dialium guineense*, *Diopyros mespiliformis*, and *Cynometra megalophylla* illustrates its floristic link to the dry semi-deciduous forest in Upper Guinea (Hall & Swaine 1981, Hovestadt *et al*. 1998).

(6) The *Khaya grandifoliola-Aubrevillea kerstingii* community is floristically similar to the forest dominated by Sterculiaceae and Sapotaceae of Akpagana (1989) in Togo and the dry semi-deciduous forest "fire zone subtype" of Hall & Swaine (1981) in Ghana. Recognised as such in Ivory Coast by Guillaumet & Adjanohoun (1971), these authors regarded it as the northernmost type of semi-deciduous forest characteristic of the fire-prone forest-savannah boundary. The two characteristic species *Aubrevillea kerstingii* and *Khaya grandifoliola*, which are Guineo-Congolian and Upper Guinean endemics respectively (White 1983, Bongers *et al*. 2004), are found to be restricted to centre-western Benin. In Ivory Coast the northern limit of the semi-deciduous forest is marked by the distribution limit of *Aubrevillea kerstingii* (Bongers *et al*. 2004).

To summarise, the semi-deciduous forest of Benin exhibits strong affinities to the West African semi-deciduous forest in terms of overall species composition and forest types. It corresponds to the dry peripheral semi-evergreen rain forest of the regional Guineo-Congolian phytochorion (White 1983). The occurrence of the Dahomey Gap seems to have little influence on the plant community structure and the spectrum of families with high ecological value such as Sterculiaceae, Celtidaceae, Leguminosae, Moraceae, Ebenaceae, Rubiaceae and Euphorbiaceae (Bakayoko *et al*. 2001). Records of Upper Guinean endemics including *Zanthoxylum gilletii*, *Turraea heterophylla*, *Tricalysia reticulata*, *Tricalysia faranahensis*, *Urera obovata*, *Dennetia tripetala*, *Khaya grandifoliola* and *Pierreodendron kerstingii*

(Poorter *et al*. 2004) in these forest islands strongly support the past floristic connection of southern and centre-western Benin with the Upper Guinean region.

4.4.2. Present semi-deciduous forest versus Holocene semi-deciduous forest

Palynogical work conducted in southern Benin showed that the Dahomey-Gap was covered by a semi-deciduous forest during the humid period of early-mid Holocene (8500-4000 years BP) (Tossou 2002, Salzmann & Hoelzmann 2005). The pollen assemblage of this period is in agreement with the overall species composition of the present semi-deciduous forest islands in southern Benin. The dominant pollen-types indicate that the *Terminalia superba-Piptadeniastrum africanum* community, which is the moist type of the West African semi-deciduous forest (Letouzey 1968, Hall & Swaine 1981, Vooren & Sayers 1992), probably dominated the zonal vegetation of the Dahomey Gap during this period. It seems not to have crossed the latitude 7^{o} North, since the pollen assemblage from a site situated at the latitude 7^{o}09'North (Salzmann & Hoelzmann 2005) suggests the exclusive presence of the *Triplochyton-Celtis* forest type, which we have described as the dry type of the former community. This implies that a latitudinal floristic gradient associated with a climatic gradient similar to the present situation would have prevailed in early-mid Holocene times. During the dry-out period of late Holocene (4000-3000 years BP), the *Terminalia superba-Piptadeniastrum africanum* community probably contracted and persisted in some forest sites along stream banks, which offered the humid conditions for its maintenance when the general climate became too dry. This is well in accordance with the present distribution and ecology of this semi-deciduous forest type in Benin, where it is restricted to those forest sites which are crossed and irrigated by streams with marshy places providing refuge conditions. The reserve forests of Pobè, Dangbo and Niaouli in southern Benin (Figure 4.1) can be cited as examples. The subsequent semi-deciduous forest expansion induced by the short humid period after 3000 years BP (Salzmann & Hoelzmann 2005) probably started in the Dahomey Gap from those isolated humid pockets, which can be regarded as areas of medium refugium probability. Similar situations have recently been described for Cameroon (Tchouto 2004) and Gabon (Leal 2004).

The *Khaya grandifoliola-Aubrevillea kerstingii* community is characteristic of the centre-western part of Benin, which corresponds to the phytogeographical district of Bassila (Chapter 2). The restriction of these two plant species to this area provides evidence for its past floristic connection with the Upper Guinea Forest Block (Aubréville 1937, Adjanohoun *et al*. 1989). It should be stressed that *Aubrevillea* is a monotypic Guineo-Congolian genus while *Khaya grandifoliola* (Meliaceae) is an Upper Guinean endemic species (Poorter *et al*. 2004). The absence of these two characteristic species from the pollen assemblage from southern Benin suggests that this semi-deciduous forest type had not probably extended further southwards during the early-mid Holocene humid period. Kouamé *et al*. (2004) reported *Khaya grandifoliola* as the most characteristic species of moist semi-deciduous forest in Ivory Coast. The record of populations of *Rinorea dentata* (Violaceae) – a typical under-storey species of mature secondary rain forest (Achoundong 1996 & 2000, Achoundong *et al*. 2000) – from this area indicates that this forest type might be a relict of a formerly more humid forest type. The occurrence of typical semi-deciduous forest dominated by Celtidaceae, Sterculiaceae and Moaceae at latitude the 9^{o}40' North in the region of Djougou (Figure 4.1) located in the Sudanian regional centre of endemism (White 1983) seems to be an unusual event in West Africa and can partly be interpreted as a result of Holocene climatic fluctuations. The savannah vegetation that surrounds the semi-deciduous forest in this area would have been derived from the former continuous semi-deciduous forest that had experienced the dry spells of late Holocene aggravated by recent human activities such as shifting cultivation, logging, and fire) (Hopkins 1992, Maley 2002).

4.5. CONCLUSION

The major semi-deciduous forest types described in Benin are floristically comparable to those recognised in other parts of West Africa. The combined effect of climate and soil types turns out to be the strong determinant of the forest species composition and community patterns. The species composition and plant community structure of the forest islands situated in southern Benin (in the Dahomey Gap) reflect the pollen assemblage of early-mid Holocene's humid period, which corresponds to the last full expansion of West African rain forest. The pollen assemblage from southern Benin indicates that the current south-north climatic gradient has existed since early-mid Holocene times and would have limited the northwards expansion of some rain forest species. The results show that knowledge of modern plant community structure, species composition and distribution is vital for the in-depth interpretation of pollen data in the process of palaeo-vegetation reconstruction. The investigated semi-deciduous forest islands can be considered as relics from late Holocene forest fragmentation. Comprehensive palynological data from many sites are still needed to conclusively establish the palaeo-vegetation of the Dahomey Gap and its response to climate change.

Chapter 5

Plant species and ecosystems with high conservation priority in Benin

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Chapter 5

Plant species and ecosystems with high conservation priority in Benin

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Abstract

Increasing human impact on vegetation urgently necessitates the identification of the most endangered sectors to be conserved. To achieve this goal, an extensive phytosociological survey conducted in Benin, herbarium records, flora database and rarity index assessment led to the identification of 280 threatened plants species in Benin. Their conservation status was assessed following IUCN-criteria. The categories "critically endangered" and "endangered" scored respectively 34% and 56% of the threatened plant species recorded. An analysis of their phytogeographical spectrum shows that 60% of the threatened plant species recorded are Guineo-Congolian. The list of 280 threatened species represents c. 10% of the total flora and constitutes the first comprehensive Plant Red List for Benin. It provides baseline information to guide biodiversity conservation actions.

Areas of conservation value were targeted on the basis of threatened species concentration, presence of endemic plant species and presence of rare vegetation types. To maximise plant diversity conservation in Benin, priority must be given to natural close forest remnants that include about 20% of the total flora. We have argued that the distribution of threatened plant species and communities provides a substantial basis for improving the existing reserve network in Benin. The conservation of maximum plant diversity can simply be achieved by attempting to capture all vegetation types into the reserve network.

Key words: Benin, threatened plant species, rare vegetation types, rarity index, IUCN categories, plant diversity, conservation, reserve network.

5.1. INTRODUCTION

Loss of biodiversity is currently a problem raising much concern globally. In Africa, the process of deforestation, which is mainly due to shifting cultivation and timber exploitation, is proceeding at an alarming rate. Since time immemorial, vegetation has been vanishing at the rate of 92 000 km^2 per year (Myers 1980). The last estimation of the forest cover change showed that humid part of West Africa is the most affected by the deforestation (annual rate of 2.0%) in Africa South of the Sahara (FAO 2001b). While the forest cover is no more than 3 349 000 ha, Benin loses about 70 000 ha of forest cover every year, which corresponds to a deforestation rate of 2.3% (*Ibid*.).

For all the changes that man inflicts upon the earth, none is more permanent or more wasteful than the extinction of a species. It has been estimated that as many as 60 000 plant species could become extinct by 2050 if present trends continue (Davis *et al*. 1986). Furthermore, some 15-20% of species is likely to become extinct even before they are known to science (Davis *et al*. 1994). Early-warning systems to monitor the status and trends of biodiversity loss would play a pivotal role in minimizing and preventing species extinctions.

Assessment of the status and trends of the biological diversity and identification of areas under particular threat constitute the two foremost goals of the Convention on Biological Diversity in dry and sub-humid lands (CBD 2001). In this respect, three attributes of biodiversity have nowadays attracted particular attention from the international conservation community: species richness, rare or threatened species richness, and endemism (Caldecott *et al*. 1996). Species that are rare or those that are threatened with extinction are indicator of the state of ecosystem functioning, and may signal the impending degeneration of biodiversity (Golding 2002). A Red Data List (RDL), which is a catalogue of species whose future survival in nature is questionable, is a fundamental tool for biodiversity conservation planning. It provides guidelines for why and where conservation efforts should be concentrated, and operates as an early-warning system at the level of species and their habitats. Thus, the listing of threatened plant species is a step toward plant species and vegetation conservation. More specifically, the assessment of the conservation status of species and ecosystems is a basic step towards assigning priorities for biodiversity conservation. The IUCN (2000) Red List provides the conservation state of species at global level. In West Africa, the most recent and comprehensive assessments of threatened, rare and endemic plant species are provided by Hawthorne (1996) and Poorter *et al*. (2004). Species listed in such assessments, however, can be globally or regionally threatened but are not necessarily threatened locally at the country level. On the other hand, species that are threatened or experiencing local extinction may be common elsewhere or globally, but would need to be included in the national red data list. To achieve the goal of national plant diversity conservation and maintenance of maximum plant species diversity, assessment of floral elements that are threatened with the risk of extinction is very crucial.

Threatened plants have so far been incompletely documented in Benin. Few scattering papers on threatened plant species and their conservation status are available, but the listing seems to be based on piecemeal approach and conjecture and does not meet the IUCN requirements (Hedberg 1979, Akpagana *et al*. 1998, Agbahungba *et al*. 2001). It becomes necessary to use the bulk of existing floristic information to prepare a meaningful and comprehensive Red Plant List for the country. So, in this study we aim to identify threatened plant species, assess their conservation status, and work out the vegetation sites of high conservation priority.

5.2. METHODS

5.2.1. Study area

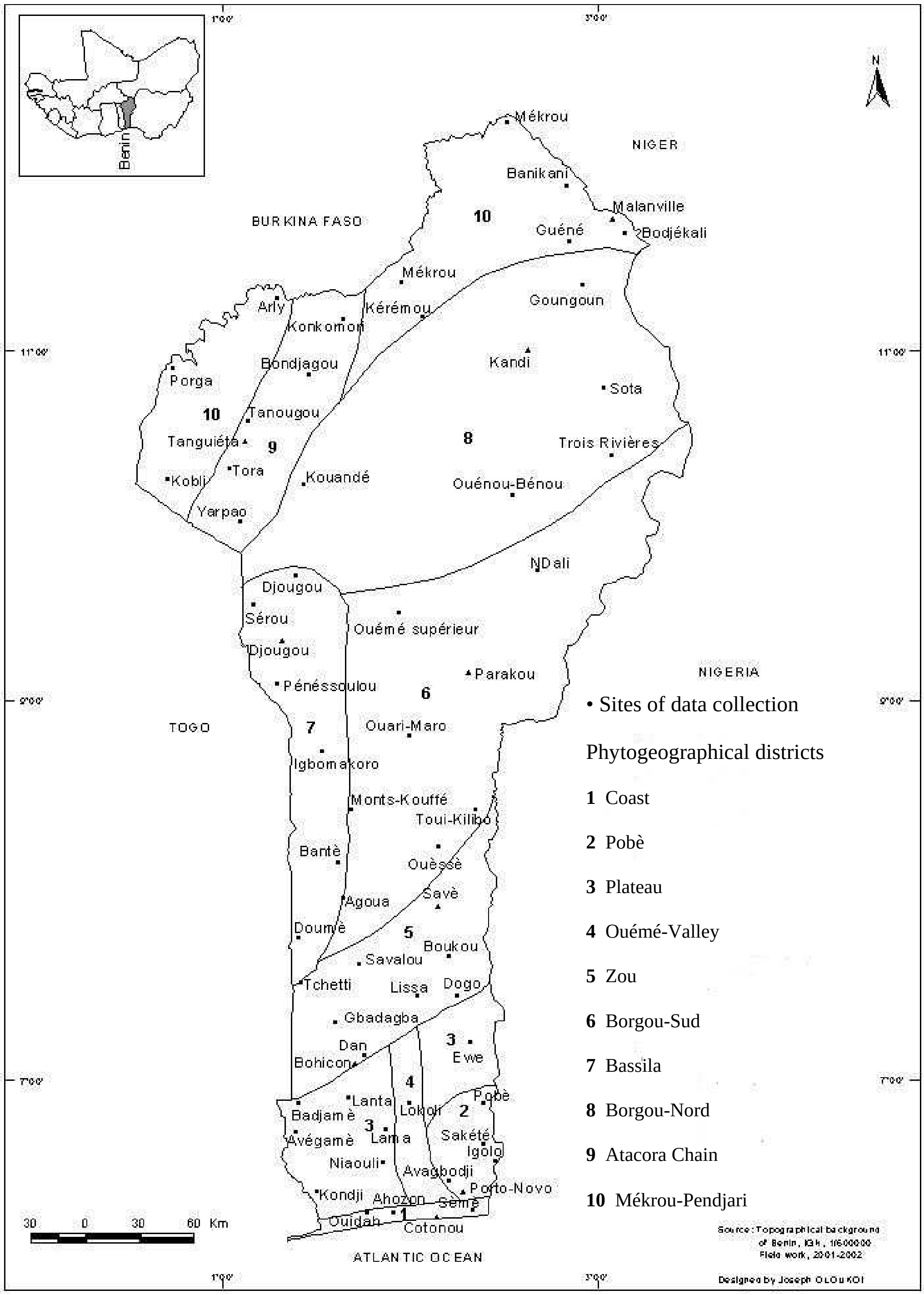


Figure 5.1: Map of Benin showing the 10 phytogeographical districts as distinguished in Chapter 2 and the sites of data collection.

The Republic of Benin is situated between latitudes 6°10’N and 12°25’N and longitudes 0°45’E and 3°55’E. It covers a land area of 112 622 km^2, of which 22.7% is legally protected (CENATEL 1992, FAO 2001b). The population has been estimated at 6 752 569 inhabitants with an average density of 57 inhabitants/km^2 (INSAE 2002). In general, the profile of the country is an undulating plateau except for a few scattered hills in the centre and north. The altitude varies from sea level to 400-650 m in the northwest, where the Atacora chain is the outstanding feature. The mean annual rainfall varies from 900 to 1300 mm. Its lowest values are recorded in the southwest and in the far north (900 mm/year). The highest precipitation (1200-1300 mm) is confined to Southeast Benin and the tract Bassila-Djougou. The mean annual temperature ranges from 26 to 28°C.

Southern Benin (up to 7°30’ N latitude) belongs to the Dahomey Gap, which is the dry corridor that separates the West African rain forest belt into the Upper Guinea and Lower Guinea/Congolian Forest Blocks (White 1983). As a result, this part of the country mainly consists of savannah, grassland, farm, and fallow intermingled with islands of close forest such as semi-deciduous and swamp forests. Human pressure on these forest islands has been so severe that the estimated rate of deforestation for close forest is 12 km^2/year out of a forest cover of 470 km^2 (FAO/UNEP 1981). From 7°30’N to 12°25’ N, the vegetation is essentially made of a patchwork of woodlands and savannahs. The flora of Benin has been estimated at about 3000 plant species (Adjanohoun et al. 1989, Project Flora of Benin 2001). The existing forest reserves are mostly concentrated in the centre and northern sections of the country.

5.2.2. Data collecting

Field data

The vegetation map of Benin (FAO/PNUD 1980) was used as the basis for site selection. The site selection was based on the existence of forest reserves, sacred forests, and all unprotected areas hosting a tract of relatively undisturbed vegetation (Figure 5.1). At each site, we avoided vegetation stands with strong human interference in the placement of sample plots.

Phytosociological relevés according to Braun-Blanquet’s (1932) approach were carried out at sites hosting the major plant formations such as mangrove, swamp forest, semi-deciduous forest, dry forest, riparian forest, woodland, and savannah (Aubréville 1957). At each site we selected representative and homogeneous sample stands, following the variations in dominant species and the major environmental factors such as soil texture, outcrops, topography etc. The geographical coordinates and altitude were noted using a GPS (Global Positioning System). General information related to soil conditions (texture, flooding, outcrops etc.) and topography (plateau, slope, and valley) was noted. The vegetation structure (number of layers, their cover and height) was described. We visually estimated the cover of each species using the Braun Blanquet cover/abundance scale (Westhoff & van der Maarel 1978): +: rare or less than 1% cover, 1: 1-5% cover, 2: 5-25% cover, 3: 25-50% cover, 4: 50-75% cover, and 5: 75-100% cover. A total of 598 floristic relevés were, in most cases, performed within quadrates of 30 x 30 m except in riparian forest, where species samples were taken from 50 x 10 m strips. The vegetation survey was conducted during the years 2001-2002 and the floristic relevés cover the whole country in such a way that they can be considered as representative of the major vegetation types.

Herbarium data

To be effective, the field data were complemented by information on species distribution using botanical collections, the flora database of the Project Flora of Benin, and field observations made by professional botanists and ecologists familiar with Benin's flora. While going through herbarium sheets and the electronic database, we reported every plant species suspected to have a restricted distribution i.e. confined to a particular vegetation type or occurring at no more than five sites.

5.2.3. Data processing

The Rarity Index

This index was applied to the phytosociological data resulted from the fieldwork. A matrix of 598 vegetation samples and 1021 plant species were elaborated. For each species the Rarity index (RI) was evaluated following Géhu & Géhu (1980):

$$RI = [1 - (n/N)] \times 100,$$

where RI is the Rarity index, n is the number of quadrates of 30 x 30 m where the taxon was recorded, and N = 598 was the total number of quadrates.

Ferrari *et al*. (2000), who dealt with quadrates (sample units) of a grid system, considered taxa with RI > 0.20 as uncommon. Gómez-Hinostrosa & Hernández (2000) analysing the geographical distribution of Cactaceae in Mexico, considered as uncommon those species occurring in no more than 17 grid squares out of a total of 40 (i.e. RI > 57.5). In the present case, since we worked with loose and irregular quadrates set out in the major vegetation types, it is safer to consider the highest values of this index to minimise the assessment bias. Thus, the non-ruderal or non-invasive plant species with RI > 80 — i.e. occurring in less than 20% of the total number of quadrats — were qualified as uncommon as opposed to common/frequent. Accordingly, the remaining plant species with RI < 80 were categorised as common, not inviting concern from a conservation perspective.

The geographic distribution of the uncommon plant species in the country was assessed using phytosociological data, records from herbarium sheets, the database of the Project Flora of Benin, and field experience. Uncommon plant species were regarded as being endangered of extinction or threatened (i.e. being at risk of becoming endangered) due to their restricted distribution range over the country.

Species only known from herbarium

The list of uncommon species as defined above was completed by some plant species not encountered during the phytosociological survey, but known from botanical collections. We selected plant species restricted to at most five (5) sites. Species were ranked as uncommon if the consultation with experienced field botanists revealed that these do not effectively occur in any more sites.

Red Data List (RDL) compilation

The IUCN-threatened-status criteria (IUCN 1994 & 2001) were used to assign conservation status to plant species categorised as uncommon. The system used consists of nine (9) categories (Figure 5.2): Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Lower Risk (LR) or Least Concern (LC), Data Deficient (DD), Near Threatened (NT), and Not Evaluated (NE). Rating plant species as CR, EN or VU requires using specific criteria defined by IUCN (1994 & 2001). Given the kind of data gathered, we have opted to use the criterion "b" defined by the extent of the area of occurrence, population size, and population fragmentation. It involves the number of locations (Nl) in which the species occurs. The taxon (species) was qualified as: CR when Nl = 1, EN when 2 ≤ Nl ≤ 5, VU when 6 ≤ Nl ≤ 10, and LR when Nl > 10. It should be emphasised that species of high commercial value (Agbahungba *et al*. 2001) may be assigned higher rank than they deserve following the criteria defined above because of overexploitation (timber, fruit or seed). We define "rare" plant species as those belonging to the threatened-categories CR, EN, and VU (Willis *et al.* 1996). So, the number of rare plant species is given by the following sum: CR + EN + VU.

A taxon is extinct (EX) when there is no reasonable doubt that the last individual has died. A taxon is extinct in the wild (EW) when it is known only to survive in cultivation or as a naturalised population well outside its past range. A taxon is "data deficient" (DD) when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution and/or population status. A taxon is not evaluated (NE) when it has not yet been assessed against IUCN criteria.

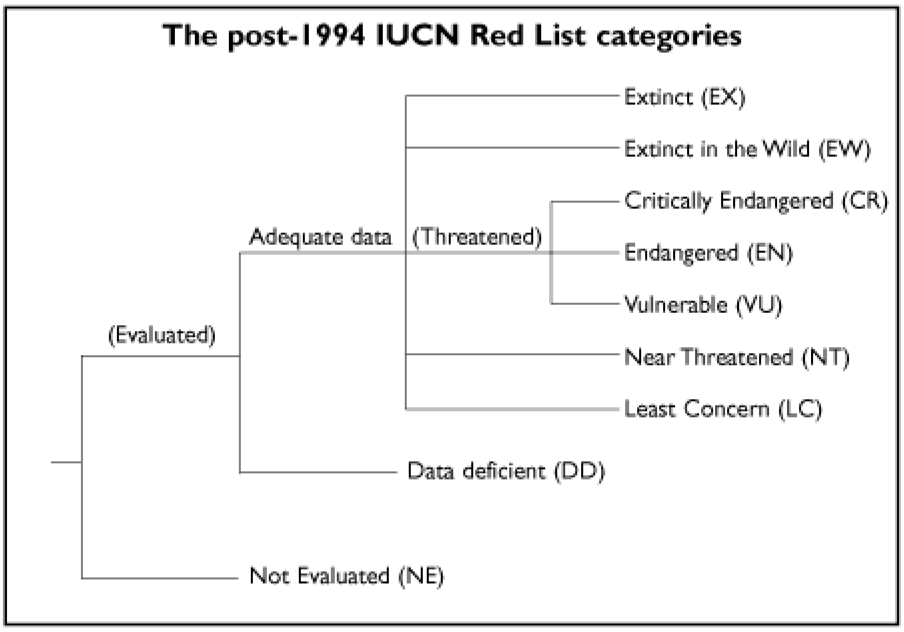


Figure 5.2: Dendrogram showing the IUCN Red List categories (IUCN 2001).

Biogeographical analysis of threatened plant species

We used the publications of Keay & Hepper (1954-1972), White (1983), and Aké Assi (2001 & 2002) to assess the entire geographic range of each threatened plant species recorded. The following chorological types (i.e. distribution range types) were used: GC: Guineo-Congolian, GE: Lower Guinean, GO: Upper Guinean, S: Sudanian, SG: Guineo/Sudanian transition, SZ: Sudano-Zambezian, At: Tropical Africa, Pt: Pantropical, and PAL: Paleotropical. The proportion of each chorological type in the threatened plant list was calculated.

Identification of vegetation sites/types with high conservation priority

The 20 major vegetation types defined in *Chapter 3* served as the basis for the selection of plant communities of conservation concern. Rare or threatened vegetation types were selected on the basis of their distribution range over the country. The highest priority was given to vegetation types that are "unique" and confined to only one site or landscape unit.

The selection of priority sites for plant diversity conservation was based on plant species richness, threatened species concentration, occurrence of endemic plant or/and rare/threatened vegetation types. Species richness and rare/threatened species concentration are the most frequently cited criteria for site selection by conservationists (Prendergast *et al.*, 1993). Threatened species richness or concentration (TSR) is defined as the number of threatened species recorded in a given area or site.

5.3. Results

5.3.1. The Benin's Plant Red List

A total of 280 threatened plant species (c. 10% of the total flora) representing 212 genera and 67 families received IUCN categories: CR = 96, EN = 157, VU = 17, LR = 2, EW = 3, EX = 1, DD = 4, NE = 0 (Table 5.1, at the end of the chapter). The categories CR and EN scored respectively 34.4% and 56.1% of the total number of the threatened plant species recorded. *Dodonaea viscosa* (Sapindaceae) collected in 1975 on the shore was the only plant species reported to be extinct. This species would have been frequent in the coastal thicket, most of which has been replaced by grass savannah. It seems not to have been well-known from the Benin's scientific community. As for *Caesalpinia bonduc* (Caesalpinioideae), it was categorised as "Extinct in the Wild (EW) and was known to have colonised the coastal thicket. Its extinction in the wild is certainly due to the exploitation of its seeds and roots for medicinal purposes. The number of "rare" plant species (CR + EN + VU) was estimated at 270, which corresponds to 96.4% of the threatened plant species recorded. Of these rare species, 96 were restricted to only one site, 25 of which were restricted to unprotected sites i.e. vegetation sites which are neither legally classified nor protected by local population (Table 5.2).

The families scoring highest in threatened plant species are respectively Leguminosae (14%), Rubiaceae (10%), Euphorbiaceae (5%), Apocynaceae (5%), Meliaceae (3%), and Annonaceae (3%).

Table 5.2: Unprotected sites harbouring locally range-restricted species

Sites	Geographic coordinates	Plant formation	Species	(sub-)Family
Lac Azili	07°15'N 02°27'E	Thicket	*Aeschynomene uniflora*	Leguminosae
Sèmè	06°23'N 02°37'E	Coastal savannah	*Ancistrocladus barteri*	Ancistrocladaceae
Yarpao	10°18'N 01°28'E	Riparian forest	*Chrysobalanus icaco L.* subsp. *atacorensis*	Chrysobalanaceae
Sakété	06°43'N 02°39'E	Riparian forest	*Chrysophyllum pruniforme*	Sapotaceae
Atacora Mts	10°42'N 01°29'E	Woodland	*Commiphora pedunculata*	Burseraceae
Dassa	07°49'N 02°20'E	Dry forest (Hill)	*Cordia millenii*	Boraginaceae
Bonou	06°55'N 02°28'E	Swamp forest	*Croton nigritanus*	Euphorbiaceae
Perma	10°01'N 01°32'E	Riparian forest	*Diplolophium africanum*	Apiaceae
Dassa	07°49'N 02°20'E	Savannah (Hill)	*Ensete gillettii*	Musaceae
Dassa	07°49'N 02°20'E	Hill dry forest	*Eugenia nigerina*	Myrtaceae
Yarpao	10°18'N 01°28'E	Riparian forest	*Gardenia imperialis*	Rubiaceae
Sakété	06°43'N 02°39'E	Riparian forest	*Landolphia incerta*	Apocynaceae
Igolo	06°39'N 02°42'E	Swamp forest	*Macaranga schweinfurthii*	Euphorbiaceae
Adijèmè (Comè)	06°26'N 01°52'E	Swamp forest	*Macaranga staudtii*	Euphorbiaceae
Mondo-Tokpa	06°35'N 02°32'E	Swamp forest	*Martretia quadricornis*	Euphorbiaceae
Bétékoukou	07°49'N 02°20'E	Riparian forest	*Millettia warneckei*	Papilionoideae
Sèmè	06°29'N 02°41'E	Swamp forest	*Mussaenda isertiana*	Rubiaceae
Igolo	06°39'N 02°42'E	Swamp forest	*Neostenanthera myristifolia*	Annonaceae
Sèmè	06°23'N 02°37'E	Swamp forest	*Pauridiantha hirtella*	Rubiaceae
Avrankou	06°34'N 02°40'E	Swamp forest	*Raphia vinifera*	Arecaceae
Avrankou	06°34'N 02°40'E	Swamp forest	*Rinorea subintegrifolia*	Violaceae
Yarpao	10°18'N 01°28'E	Riparian forest	*Synsepalum passargei*	Sapotaceae
Atacora Mts	10°42'N 01°29'E	Woodland	*Terminalia brownii*	Combretaceae
Yarpao	10°18'N 01°28'E	Riparian forest	*Thunbergia atacorensis*	Acanthaceae
Houéyogbé	06°33'N 01°50'E	Thicket	*Uvaria ovata*	Annonaceae

5.3.2. Phytogeographic spectrum of threatened plant species in Benin

Out of 280 threathened species identified, 59.67% were Guineo-Congolian (GC), 12.1% Upper Guinean (GO), 6.78% Sudano-Zambezian (SZ), 5.7% Lower Guinean (GE) and 2.14% Sudanian (S) (Table 5.3). Thus, the Guinean species (i.e. GC + GO + GE) are the dominant elements and represent 77% of the threatened species reported compared to the Sudanian elements. 89.3% of GC, 97.1% of GO, and 100% of GE species were listed as CR and EN.

Table 5.3: Phytogeographic spectrum of threatened plant species in Benin

Chorotypes	**EX**	**EW**	**CR**	**EN**	**VU**	**LR**	**DD**	**NE**	**Total**	**%**
GC	-	3	50	99	11	-	4	-	167	59.65
GO	-	-	17	16	1	-	-	-	34	12.14
At	1	-	6	11	1	-	-	-	19	6.79
SZ	-	-	6	8	3	2	-	-	19	6.78
GE	-	-	10	6	-	-	-	-	16	5.71
PAL	-	-	3	5	-	-	-	-	8	2.86
SG	-	-	2	4	1	-	-	-	7	2.5
S	-	-	-	6	-	-	-	-	6	2.14
Pt	-	-	2	2	-	-	-	-	4	1.43
Total	1	3	96	157	17	2	4	-	280	100

IUCN threatened categories: EX: Extinct, EW: Extinct in the wild, CR: Critically Endangered, EN: Endangered, VU: Vulnerable, LR: Lower Risk, DD: Data Deficient, NE: Not Evaluated. Chorological types: At: Tropical African, GC: Guineo-Congolian, GE: Lower Guinean, GO: Upper Guinean, Pt: Pantropical, PAL: Paleotropical SG: Sudano/Guinean transition, S: Sudanian, SZ: Sudano-Zambezian.

5.3.3. Priority vegetation sites for plant conservation

Table 5.4 gives the vegetation sites of conservation concern, based on overall species richness, threatened species concentration, presence of endemic plant species and threatened plant communities.

Table 5.4: Inventory of vegetation sites of conservation priority in Benin

Vegetation sites	Geographical co-ordinates	Plant formation & threatened community	Phyto. distr.	SR	TSR	%TSR
Protected sites						
Pobè (Botanical reserve) ☺	6°59' N 2°37' E	Semi-deciduous forest: Te-Pi community	Pobè	403	101	36.07
Niaouli (Botanical reserve) ☺	6°43'N 2°08'E	Semi-deciduous forest: Te-Pi community	Plateau	210	41	14.64
Lama ☺	9°14'N 1°32'E	Semi-deciduous forest: Mu-Cy community	Plateau	353	28	10
Pénéssoulou ☺	9°14'N 1°32'E	Riparian forest: Co-Kh community	Bassila	450	21	7.50
Bassila ☺	8°58'N 1°37'E	Semi-deciduous forest: Kh-Au community	Bassila	201	17	6.07
Dogo-Kétou ☺	07°23'N 02°22'E	Woodland + riparian forest	Plateau	210	13	4.64
Monts Kouffé ☺	08°55'N 1°50'E	Woodland + Riparian forest	Bassila	584	10	3.57
Dan-Dassa	7°21'N 02°06'E	Dry forest (Hill): Hi-Ap community	Zou	71	7	2.5
Pendjari Park ☺	11°09'N 02°44'E	Riparian forest: Ga-Vi community	Mékrou-Pendjari	270	6	2.14
Ndali* ☺	9°50'N 2°41'E	Woodland	Borgou-Sud	153	3	1.07
Park W ☺	11°43'N 02°33'E	Riparian forest: Ga-Vi community	Mékrou-Pendjari	232	2	0.71
Culturally protected sites/sacred forests						
Dangbo ☺	6°35' N 2°32' E	Semi-deciduous forest: Te-Pi community	Pobè	101	51	18.21
Ewè ☺	7°27'N 2°34'E	Semi-deciduous forest: Dr-Ne community	Plateau	200	43	15.36

Lokoli☺	07°03'N 02°15'E	Swamp forest: Mi-La community	Ouémé-Valley	121	30	10.71
Avagbodji☺	06°32’N 02°32'E	Riparian forest	Coast	65	21	7.50
Badjamè	7°07'N 1°38'E	Semi-deciduous forest	Plateau	53	8	2.86
Avégamey	7°01'N 1°45'E	Semi-deciduous forest	Plateau	60	8	2.86
Djougou	9°40'N 1°38'E	Semi-deciduous forest: Kh-Au community	Bassila	74	6	2.14
Malomi	8°11'N 1°55’E	Semi-deciduous forest	Bassila	60	5	1.78
Unprotected sites						
Ahozon☺	6°23 N 2°09 E	Semi-deciduous forest: Ch-Bar community	Coast	191	33	11.78
Mondo-Tokpa	6°35' N 2°32' E	Swamp forest: Mi-La community	Ouémé-Valley	68	14	5
Sèmè	06°23'N 02°37'E	Savannah/thicket	Coast	52	9	3.21
Djagbalo	8°23'N 02°04'E	Semi-deciduous forest	Bassila	112	8	2.86
Igolo	06°39'N 02°42'E	Swamp forest: Mi-La community	Pobè	46	8	2.86
Sakété	06°43'N 02°39'E	Riparian forest	Pobè	53	7	2.5
Yarpao (Atacora Mounts)*☺	10°42'N 01°29'E	Riparian forest: Sy-Br community	Atacora Chain	467	6	2.14
Ouidah	06°31'N 02°00'E	Mangrove: Rh-Av community	Coast	85	5	1.78
Mitogbodji	06°26'N 01°52'E	Mangrove : Rh-Av community	Coast	64	3	1.07

Threatened plant communities: Te-Pi: *Terminalia superba-Piptadeniastrum africanum*, Dr-Ne: *Drypetes aframensis-Nesogordonia papaverifera*, Ch-Bar: *Chrysobalanus icaco-Barteria nigritana*, Mi-La: *Mitragyna ledermannii-Lasiomorpha senegalensis*, Mu-Cy: *Mimusops andongensis-Cynometra megalophylla*, Co-Kh: *Cola gigantea-Khaya grandifoliola*, Kh-Au: *Khaya grandifoliola-Aubrevillea kerstingii*, Sy-Br: *Synsepalum passargei-Broenadia salicina*, Rh-Av: *Rhizophora racemosa-Avicennia germinans*, Ga-Vi: *Garcinia livingstonei-Vitex chrysocarpa*, Hi-Ap: *Hildegardia barteri-Aphania senegalensis*.

Phyto. distr.: phytogeographical district; SR: species richness based on vegetation inventory and botanical collection; TSR: Threatened Species Richness; %TSR: Percentage of threatened species out of a total of 280.

☺: Sites hosting at least 20 threatened species or SR ≥ 200 or an endemic plant species, *: Sites hosting Benin’s endemic plant species *Thunbergia atacorensis* (Acanthaceae) or *Ipomoea beninensis* (Convolvulaceae).

Four categories of vegetation sites can be identified as botanical biodiversity conservation priorities for Benin (Table 5.4):

(1) Sites with high concentration of threatened plant species regardless of their overall species richness: include closed forest islands of southern Benin. Examples are Pobè (36.1% of threatened plant species reported), Dangbo (18.2%), Ewè (15.4%), Niaouli (14.6%),

Ahozon (11.8%), Lokoli (10.7%) and Lama (10%) (Figure 5.1). The richest sites in range-restricted species (i.e. species confined to one site) appear to be those harbouring a semi-deciduous forest such as Pobè (17 range-restricted species), Dangbo (11 species), Ewè (9 species), and Ahozon (8 species). Those sites have witnessed significant habitat loss except the Lama forest, which is one of the rare well protected areas in southern Benin.

(2) Sites with the largest numbers of plant species and few threatened species include the Mounts Kouffé (584 species), the Atacora Mountains (with Yarpao) (467 species) and Dogo- Kétou (210 species).

(3) Sites harbouring at least one endemic plant species include Yarpao with *Thunbergia atacorensis* (Acanthaceae) reported from riparian forest and Ndali with *Ipomoea beninensis* (Convolvulaceae) reported from woodland and savannah.

(4) Sites with rare/threatened vegetation types include Pobè and Niaouli with the *Terminalia superba-Piptadeniastrum africanum* community, Ewè with the *Drypetes aframensis-Nesogordonia papaverifera* community, Ahozon with the *Chrysobalanus icaco-Barteria nigritana* community, Lama with the *Mimusops andongensis-Cynometra megalophylla* community, Lokoli (Ouémé valley) with the *Mitragyna ledermannii-Lasiomorpha senegalensis* community, Atacora Chain with the *Synsepalum passargei-Broenadia salicina* community, and the Pendjari Park with the *Garcinia livingstonii* community. The *Rhizophora racemosa-Avicennia germinans* community is one the most threatened vegetation types because it represents the unique and immediate source of firewood for domestic use and traditional salt exploitation (by boiling) in mangrove sites such as Ouidah.

Most of these areas of high conservation priority correspond to sites where the threatened species concentration is high. Some of them are either partially protected (e.g. Dangbo, Ewè, and Lokoli) or entirely unprotected (e.g. Ouidah, Ahozon, Sèmè and Yarpao). The partially protected forests are either communal forest or sacred groves managed by local populations themselves. Protected areas include national parks or legally classified forests.

5.4. DISCUSSION

5.4.1. Plant species under threat in Benin

The relatively high amount of threatened plants (280 species) in Benin is largely due to the highly fragmented landscape and peripheral geographic distribution caused by the Dahomey Gap phenomenon, which is the remarkable dry corridor –covering the southern parts of Benin, Togo, and south-east Ghana – in the West African rain forest belt (White 1983, Jenik 1994). As a result, rain forest only survived in the form of small patches of semi-deciduous forest, which has been further threatened by human activities (shifting agriculture, logging and oil palm plantation). It is evident that species extinction risk is imminent in such a highly fragmented area (MacArthur & Wilson 1967). This is clearly indicated by the importance of the categories "Endangered (EN)" and "Critically Endangered (CR)" species, which represent c. 90% of the threatened species recorded. This is consistent with the high representation of close forest plant species (c. 77% of threatened species recorded), which have survived in the imperiled natural forest vegetation. This interpretation is supported by the high representation of the plant families Leguminosae (14%), Rubiaceae (10%), and Euphorbiaceae (5%) among threatened species, since most of the threatened species of these families appear to occur in the extant forest islands.

Plant species such as *Afzelia africana*, *Milicia excelsa*, *Pterocarpus erinaceus*, *Hallea ledermannii*, and *Rauvolfia vomitoria* occur at more than 10 localities and should be listed as

VU but they were categorised as EN instead. The pressure on the valuable timber species such as *Afzelia africana*, *Milicia excelsa* and *Pterocarpus erinaceus* is so acute that they constitute national priorities in genetic resource conservation in Benin (Agbahungba *et al*. 2001, Sinsin *et al*. 2004). Viable populations of the swamp-specialist *Hallea ledermannii* occur only in Lokoli, and was recorded as EN; at other swampy sites this species included no more than a few sprouting individuals. As to *Rauvolfia vomitoria*, it is much sought after worldwide for its medicinal roots, which are used in the treatment of psychiatric disorders. Futhermore, it should be acknowledged that the collection of seeds of valuable tree species (such as *Pentadesma butyracea* and *Xylopia aethiopica*) for various purposes constitutes a serious threat to the survival of their population (Natta *et al*. 2002).

As more complete floristic data have become available with the Project Flora of Benin, our Red Data List is also more comprehensive with 280 threatened plants compared to Adjanohoun's with 48 threatened species (Hedberg 1979), Akpagana *et al*.'s figures of 39 threatened species (Akpagana *et al*. 1998), and those of Agbahungba *et al*. (2001) who listed 8 threatened plant species. Even though the three lists are to some extent complementary, it must be acknowledged that the list proposed by Adjanohoun in Hedberg (1979) was already more elaborate than the one compiled by Akpagana *et al*. (1998) 19 years later. Many species such as *Petiveria alliacea*, *Cleistopholis patens*, *Sclerocarya birrea* etc. from Adjanohoun's threatened list, are not assigned an IUCN category here, because they are fairly frequent. With respect to *Sarcocephalus pobeguinii* (Rubiaceae), its existence in Benin is still to be confirmed. As far as Akpagana's threatened list is concerned, *Diospyros ferra* and *Dopatrium senegalense* seem to have been wrongly identified and should be *Diospyros soubreana* and *Dopatrium longidens* respectively.

Among the 280 threatened plant species reported, 19 are listed as internationally rare i.e. plant species occupying 1-14 degree squares on a world map (Hawthorne 1996) (Table 5.1). Furthermore, 10 of them are of globally conservation concern and are on the IUCN Red List of threatened species (IUCN 2000) (Table 5.5). All of them rank higher on our list than on the IUCN Red List because of the difference in the scale of assessment (global versus national). In contrast to IUCN assessment, which ranked *Albizia ferruginea* and *Vitellaria paradoxa* as vulnerable species, our distribution data revealed them as common species in Benin. Although depletion in the *Vitellaria paradoxa* population (due to vegetation clearing and seed harvesting) is indicated at national level(Agbahungba *et al*. 2001) this species seems to be a

Table 5.5: Benin's plant species reported on the IUCN Red List (2000)

N°	Plant species	Family	Status on IUCN red list	**Status according to this paper**
1	*Afzelia africana*	Leg. Caesalpinoideae	VU	EN
2	*Albizia ferruginea*	Leg. Mimosoideae	VU	common
3	*Encephalartos barteri*	Cycadaceae	VU	EN
4	*Hallea ledermanni*	Rubiaceae	VU	EN
5	*Khaya grandifoliola*	Meliaceae	VU	EN
6	*Khaya senegalensis*	Meliaceae	VU	EN
7	*Mansonia altissima*	Sterculiaceae	EN	CR
8	*Milicia excelsa*	Moraceae	VU	EN
9	*Nesogordonia papaverifera*	Sterculiaceae	VU	CR
10	*Pierreodendron kerstingii*	Simaroubaceae	VU	EN
11	*Triplochiton scleroxylon*	Sterculiaceae	LR	EN
12	*Vitellaria paradoxa*	Sapotaceae	VU	common

Leg.: Leguminosae; IUCN categories: CR: critically endangered, EN: endangered, VU: vulnerable species, and LR: lower risk.

good colonizer with high potential for vegetative propagation in savannah region where it gets protected by farmers (Yidana 1994, Fobil 2003, Nikiema 2005). As for *Albizia ferruginea*, it is a pioneer forest species that populates a wide range of habitats, including semi-deciduous, dry forest, fallow, and riparian forest (Natta 2003, Akoègninou 2004).

It should be stressed that, the "rare species" category includes a wide array of spatial and temporal patterns of abundance; from sparsely populated species with wide geographic ranges to "point endemics" with localised populations (Kunin & Gaston 1993). It is usually assumed that rare species i.e. those with very limited geographical ranges, are more vulnerable than widely distributed ones (Hernández & Bárcenas 1996). Thus, rare species have a greater likelihood of extinction, and consequently invite stricter conservation measures, especially the protection of their habitats (Gaston 1994).

5.4.2. Using threatened plant species and communities to set conservation priorities

The application of the principle of vegetation representativeness in reserve design ensures that a reserve network includes the full spectrum of the environmental variability of the area, as expressed by the different vegetation types (Margules & Usher 1981, Franklin 1993, Kati *et al.* 2004). The conservation of maximum plant diversity can simply be achieved by including all vegetation types into the reserve network. Information provided herein on threatened plant species and communities can serve as basis to improve the existing reserve network in Benin. Complementarity, a term invented by Vane-Wright *et al*. (1991), is considered as a key-principle in reserve designing (Pressey *et al*. 1993, Reid 1998). Its application in site selection for biodiversity conservation ensures that as much as possible new attributes will added to an existing reserve system. These attributes can be threatened or endemic species, vegetation types or landscapes units. Particular attention must be given to sites with high plant species richness, threatened plant species concentration, endemic plant species, and sites hosting a particular vegetation type (Table 5.4). A special mention has to be made of the Atacora Mountains which provide habitat for the two Beninese endemic plant species, *Thunbergia atacorensis* (Acanthaceae) and *Ipomoea beninensis* (Convolvulaceae) (Akoègninou & Lisowski 2004). The species density in the riparian forest of Yarpao situated at the foot of these mountains was estimated at 358 species/ha (Natta 2003). In Benin, there is no protected domain incorporating swampy forest and mangrove, which are key wildlife habitats in tropical wetlands. These a-zonal plant formations are therefore in serious danger along with their range-restricted plant species such as *Rhizophora racemosa*, *Avicennia germinans*, *Conocarpus erectus* and *Laguncularia racemosa* growing in mangroves, and *Hallea ledermannii*, *Uapaca paludosa*, *Xylopia rubescens*, *Syzygium owariense*, *Rothmannia megalostigma*, and *Alstonia congensis* in swamp forests. The Lokoli's forest (400-500 ha) remains one the rare natural Guineo-Congolian swamp forest (White 1983) in Benin and should be regarded as of high conservation priority. Rare and endangered mammals were reported from this forest, especially the Red-bellied monkey (*Cercopithecus erythrogaster* subsp. *erythrogaster*), which is endemic to Benin (Sinsin & Assogbadjo 2002).

It seems that semi-deciduous forest islands have gained little attention from local conservationists, since most of them remain legally unclassified. Although they are mostly small, they represent the last lowland rain forest remnants in the area. Their contribution to the overall plant diversity can be estimated at 500-600 plant species (c. 20% of the total flora) (Sokpon 1995, Akoègninou 2004, Chapiter 4). The forest of Pobè deserves the highest conservation priority, since it includes c. 36% of the threatened species recorded and 17 range-restricted species. Furthermore, the Guineo-Congolian endemic genera such as *Amphimas*, *Anthonotha*, *Distemonanthus*, *Hymenostegia*, *Anthrocaryon*, *Coelocaryon*, and *Discoglypremna* (White 1983) are restricted to the phytogeographical district of Pobè

(Chapter 2). It is important to underline the case of Ewè's semi-deciduous forest relic (Figure 5.1), which is under severe threat and deserves urgent conservation needs in order to rescue its biological resources. It includes as many as nine (9) range-restricted species including *Mansonia altissima* and *Nesogordonia papaverifera*, which are reported as globally endangered and vulnerable species respectively (IUCN 2000). The population of *Mansonia altissima* is almost completely depleted, since it is used as roofing poles in the locality. It is the richest forest site in *Rinorea* species (with *R. brachypetala*, *R. dentata*, *R. kibbiensis* and *R. ilicifolia*), which are considered as rain forest bio-indicators in West Africa (Achoundong 1996, 2000). Its species richness is estimated at 200 plant species, of which 43 are threatened. All these make it a strategic site meriting full protection in a conservation plan. Furthermore, it is urgent to protect the coastal flora, since some species have disappeared (*Dodonaea viscosa*) or are severely threatened (*Scaevola plumieri* and *Diospyros tricolor*). The forest of Ahozon appears to be the only one natural coastal forest relic left in the country.

In addition, of primary importance are those sites harbouring globally rare plant species (Hawthorne 1996, IUCN 2000) reported in Benin (Tables 5.1 & 5.5). Some of these species are confined to only one site: *Gardenia imperialis* in Yarpao, *Placodiscus boya* in Lama, *Trichilia martineaui* in Niaouli, *Uapaca paludosa* in Lokoli, *Mansonia altissima* and *Nesogordonia papaverifera* in Ewè. In general, geographically or ecologically restricted taxa tend to occur in small local populations, making them extra vulnerable to outside threats, especially to deforestation (Lawton 1993). Their preservation will require establishing reserves – not necessarily the large ones – in just the right places (Terborgh & Winter 1983).

5. CONCLUSION

A total of 280 threatened plant species were recorded, of which 34.3 % were categorised as Critically Endangered (CR) and 56.1 as Endangered (EN); 60% of them are Guineo-Congolian and c. 36% are restricted to the phytogeographical district of Pobè. The high score of the categories "endangered and critically endangered", which represent 90% of the threatened species recorded, indicates a high risk of extinction facing these species. Several areas are crucially important for plant species conservation, in particular the close forest islands (Table 5.4).

Distribution data of threatened plant and community species can be used to improve the existing protected area network and to guide plant diversity conservation in Benin. Particular habitat types with special floristic make-up, sites harbouring range-restricted plant species or globally threatened plant species deserve particular interest. An efficient conservation of botanical resources in Benin requires that an information database for plant species based on thorough phytosociological surveys and botanical collections be created, as a further basis for the improvement of the Plant Red List presented herewith (Table 5.1). Computer databases on endangered plants are needed to back specific monitoring and conservation recommendations.

Table 5.1: List of threatened plant species and their conservation status in Benin

Species + Authors	Family	LF	CT	Hab.	**Distribution in Benin**	RI(%)	TC
Acridocarpus alternifolius (Schum. & Thonn.)Nied.	Malpighiaceae	Lmph	GC	SDF	Ahozon-Pobè	95.71	EN
Acridocarpus smeathmannii (DC.)Guill. & Perr.	Malpighiaceae	mph	GC	DF	Dan-Dassa	99.82	EN
Acroceras gabunense (Hack.)Clayton	Poaceae	Th	GC	SDF	Ewè	98.92	CR
Aechynomene uniflora E.Mey.	Leg.-Pap.	Ch	At	Sav	Lac Azili		CR
Afraegle paniculata (Schum.)Engl.	Rutaceae	mph	At	SDF-SD-Habitation	Lama-Madoro (Dassa)-Tipeti (Natitingou)-Tagayé (Atacora Mountains)	97.67	EN
Afzelia africana Smith ex Pers.	Leg.-Caes.	mPh	S	SDF-DF-Sav	Lama-Dogo-Tui Kilibo-Tchaourou-Ndali-3Rivières-Sota-Goungoun-Savalou-Bantè-Monts Kouffè-Ouémé Supérieur-Alibori Supérieur-Kouandé-Pendjari-Parc W	84.46	EN
Aidia genipiflora (DC.)Dandy	Rubiaceae	mph	GC	SDF	Ahozon-Pobè-Niaouli-Ewè	90.71	EN
Alafia benthamii (Baill. ex Stapf)Stapf	Apocynaceae	Lmph	GC	RF	Avagbodji-Bembè-Sagon (Zou)	99.82	EN
Albizia chevalieri Harms	Leg.-Mim.	mPh	S	Sav	Guéné-Bodjèkali	98.92	EN
Albizia malacophylla (A.Rich.)Walp.	Leg.-Mim.	mPh	SZ	Flooded Sav	Kpédjélé-Ouémé Supérieur	99.82	EN
Alstonia congensis Engl.	Apocynaceae	MPh	GC	Sw	Pobè-Mondo Tokpa-Lokoli-Sèmè-Igolo-Tchi Ahomadégbé	97.5	VU
Amphimas pterocarpoides Harms	Leg.-Pap.	MPh	GC	Sw	Pobè-Kpédjélé	97.67	EN
Ancistrocladus barteri Sc.Elliot	Ancistrocladaceae	Lmph	GO	For	Sèmè		CR
Ancistrocarpus densispinosus Oliv.	Tiliaceae	mph	GE	SDF	Pobè	97.5	CR
Andira inermis (Wright)DC.	Leg.-Pap.	mph	SZ	RF	Doumè-Bantè-Bassila-Koussoukouangou-Pouya-Atacora Mounts-Tui Kilibo-Pehonco	99.46	VU
Angylocalyx oligophyllus (Baker)Baker f.	Leg.-Pap.	nph	GC	SDF	Pobè-Niaouli-Avagbodji-Bembè-Calavi	91.42	EN
Anthonotha macrophylla Pal.Beauv.	Leg.-Caes.	mph	GC	SDF	Pobè-Itchèdè	97.67	EN
Anthostema aubryanum Baill.	Euphorbiaceae	mPh	GC	Sw-RF	Igolo-Sakété-Lokoli-Allada-Kodjiota (Ouémé)	99.64	EN
Antidesma laciniatum Müll.Arg.	Euphorbiaceae	mph	GC	SDF	Pobè	98.92	CR
Antrocaryon micraster A.Chev. & Guillaumet	Anacardiaceae	MPh	GC	SDF	Pobè-Missérété		EN
Asparagus warneckei* (Engl.)Hutch.	Araceae	Lnph	GO	SDF	Niaouli-Lama-Ewè-Bantè	96.25	EN
Aubrevillea kerstingii (Harms)Pellegr.	Leg.-Mim.	mPh	GC	SDF	Bassila	99.28	CR
Avicennia germinans (L.)L.	Avicenniaceae	mPh	GC	Mgr	Ouidah-Grand Popo-Mitogbodji	99.46	EN
Baphia nitida Lodd.	Leg.-Pap.	mph	GC	SDF	Ahozon-Pobè-Niaouli	96.78	EN
Baphia pubescens Hook.f.	Leg.-Pap.	mph	GC	SDF	Dangbo		CR
Barteria nigritiana Hook.f.	Passifloraceae	mph	GE	SDF	Ahozon	96.07	CR
Beilschmiedia mannii (Meissn.)Benth. & Hook.f.	Lauraceae	mph	GC	Sw	Dangbo		DD
Belonophora hypoglauca (Welw.ex Hiern)A. Chev.	Rubiaceae	mph	GC	SDF-DF	Pobè-Igbo-macro	98.92	EN
Borassus aethiopum Mart.	Arecaceae	mPh	SZ	Sav	Ouidah-Sè (Mono)-Monts Kouffè-Savè-Pendjari-Parc W - Spread over the country	96.96	VU
Buxus acutata* Friis	Buxaceae	mph	GC	RF	Kétou-Sèhouè-Zagnanado		EN
Caesalpinia bonduc (L.)Roxb.	Leg.-Caes.	Lnph	GC	Hab	Up to latitude N 7°30’		EW
Calamus deërratus Mann & Wendl.	Arecaceae	Lmph	At	Sw	Sèmè-Lac Azili-Dja-Adjara- Avagbodji-Bembè		VU
Caloncoba echinata (Oliv.)Gilg	Flacourtiaceae	nph	GO	SDF	Niaouli	99.64	CR
Campylospermum glaberrimum* (P. Beauv.)Farron	Ochnaceae	nph	GO	Sw-RF	Avagbodji-Bembè-Lokoli-Lama-Djrègbé-Perma		EN
Canarium schweinfurthii Engl.	Burseraceae	mPh	GC	SDF	Pobè	99.82	CR
Carapa procera DC.	Meliaceae	mPh	GC	Sw	Niaouli-Lokoli	99.46	EN
Carissa edulis (Forssk.)Vahl	Apocynaceae	nph	PAL	Thic	Coast-Calavi	99.28	EN
Casearia calodendron* Gilg	Flacourtiaceae	mPh	GO	SDF	Ahozon-Pobè	97.67	EN
Cassipourea barteri (Hook.f.)N.E. Br.	Rhizophoraceae	mPh	GC	For	Ahozon-Ouidah-Mondo Tokpa	99.1	EN
Cassipourea congoensis DC.	Rhizophoraceae	mPh	GC	For	Lama-Pobè-Ewè	96.6	EN
Cathormion altissimum (Hook.f.)Hutch. & Dandy	Leg.-Mim.	mPh	GC	Sw	Tohouè-Ouémé		EN

Celtis mildbraedii Engl.	Celtidaceae	mPh	GC	SDF	Dangbo-Niaouli-Ewè	94.1	EN
Chasmanthera dependens Hochst.	Menispermaceae	Lnph	GC	SDF	Pobè	99.28	CR
Chionanthus mannii (Solereder)Stearn	Oleaceae	mph	GC	SDF	Dangbo-Lama-Gnaouizoumè	99.46	EN
Chlorophytum inornatum Ker-Gawl	Liliaceae	G	GO	SDF	Dangbo	99.82	CR
Christiana africana DC.	Tiliaceae	mPh	Pt	SDF	Lama-Idadjo	99.64	EN
Chrysobalanus ellipticus Soland. ex Sabine	Chrysobalanaceae	mPh	GC	SDF	Ahozon	98.75	CR
Chrysobalanus icaco L. subsp. atacorensis (A.Chev.)F.White	Chrysobalanaceae	mPh	SZ	RF	Yarpao	99.46	CR
Chrysobalanus icaco L. subsp. icaco	Chrysobalanaceae	nph	GC	Coastal Thic	Coast		CR
Chrysophyllum albidum G. Don	Sapotaceae	mPh	GC	For	Allada-Dangbo-Pobè-Ahozon-Adjara-Bantè-Pira-Ouèssè	96.42	VU
Chrysophyllum pruniforme Pierre ex Engl.	Sapotaceae	mPh	GC	RF	Sakété		CR
Chrysophyllum welwitschii Engl.	Sapotaceae	Lnph	GC	SDF	Ewè		CR
Chytranthus macrobotrys (Gilg.)Exell & Mendonça	Sapindaceae	mph	GC	SDF	Dangbo-Pobè	99.1	EN
Coelocaryon preussii Warb.	Myristicaceae	mPh	GC	SDF	Pobè	99.1	CR
Cola lateritia K. Schum.	Sterculiaceae	mph	GC	RF	Avagbodji-Bembè	99.82	CR
Cola nitida (Vent.)Schott. & Endl.	Sterculiaceae	mph	GC	Sw-SDF	Pobè-Niaouli-Dangbo-Ahouéglé (N 6°40’56.4", E 1°41'26.4")	99.46	EW
Combretum grandiflorum G.Don	Combretaceae	Lmph	GO	Sw-SDF	Pobè-Lama-Lokoli	98.75	CR
Commiphora pedunculata (Kotschy & Peyr.)Engl.	Burseraceae	nph	SZ	Sav (Hill)	Atacora Mountains		CR
Connarus africanus Lam.	Connaraceae	mph	GC	Sw-RF	Dangbo-Pobè-Lokoli-Avagbodji-Bembè	98.21	EN
Conocarpus erectus L.	Combretaceae	mph	PAL	Mgr	Ouidah-Grand Popo	99.82	EN
Cordia millenii Baker	Boraginaceae	mPh	At	DF (hill)	Dassa		CR
Cordia platythyrsa Baker	Boraginaceae	mph	At	SDF	Pobè	98.03	CR
Cordia senegalensis Juss.	Boraginaceae	nph	GC	SDF	Pobè		CR
Cordyla pinnata (Lepr. ex A. Rich.)Milne-Redhead	Leg.-Caes.	mph	SZ	Sav	Ouémé Supérieur-Alibori Supérieur	99.28	EN
Croton nigritanus Scott-Elliot	Euphorbiaceae	Nph	GO	RF	Gnaouizoumè		CR
Crudia klainei Pierre ex Harms	Leg.-Caes.	mph	GC	Sw	Adjara		CR
Crudia senegalensis Planch. ex Benth.	Leg.-Caes.	mPh	GC	Sw	Pobè-Lokoli	98.75	EN
Culcasia barombensis N.E.Br.	Araceae	Lmph	GO	Sw	Dangbo-Pobè	99.1	EN
Cuviera acutiflora DC.	Rubiaceae	mph	GC	SDF	Dangbo-Pobè	99.82	EN
Cuviera macroura K.Schum.	Rubiaceae	mph	GC	RF-Sw	Avagbodji-Bembè-Lokoli-Badjamè-Tchakou-Kraké	99.1	EN
Dalbergia ecastaphyllum (L.)Taub.	Leg.-Pap.	mph	PAL	Mgr	Coast	99.64	EN
Dalbergia setifera* Hutch. & Dalziel	Leg.-Pap.	nph	GO	Sav-Thic-Fallow	Coast	95.71	VU
Dennettia tripetala* Baker f.	Annonaceae	mph	GE	SDF	Lama-Ewè-Monts Kouffè	96.42	EN
Detarium senegalense J.F.Gmel.	Leg.-Caes.	mPh	GC	SDF-RF	Pobè-Dogo-Doumè-Bantè-Bassila-Djougou	98.75	VU
Dichapetalum crassifolium Chodat var. crassifolium	Dichapetalaceae	Lmph	GC	SDF	Ahozon	99.28	CR
Dichapetalum oblongum (Hook.f. ex Benth.)Engl	Dichapetalaceae	nph	GC	SDF-Sw	Lama-Gnaouizoumè	99.28	EN
Dichapetalum pallidum (Oliv.)Engl.	Dichapetalaceae	mph	GC	SDF	Dangbo-Pobè-Ewè	99.82	EN
Dictyandra arborescens Hook.f.	Rubiaceae	mph	GE	SDF	Ahozon-Pobè-Niaouli	90.53	EN
Dictyandra involucrata* (Hook.f.)Hiern	Rubiaceae	Lnph	GC	SDF	Pobè-Ewè-Dja	97.5	EN
Diodia vaginalis Benth.	Rubiaceae	Th	GC	Sandy shores	Cotonou (coast)		CR
Dioscoreophyllum cumminsii (Stapf)Diels	Mennispermaceae	Lnph	At	SDF	Pobè-Ewè		EN
Diospyros abyssinica (Hiern)F.White	Ebenaceae	mPh	GC	SDF	Lama-Ewè-Bantè-Djougou	94.1	EN
Diospyros soubreana F.White	Ebenaceae	nph	GC	SDF	Dangbo-Pobè-Niaouli-Ewè	93.03	EN
Diospyros tricolor (Schum. & Thonn.)Hiern	Ebenaceae	nph	GC	SDF-Sav-Thic	Coast	95	CR
Diplolophium africanum Turcz.	Apiaceae	th	SZ	RF	Perma		CR
Discoglypremna caloneura (Pax)Prain	Euphorbiaceae	mph	GC	SDF	Pobè		CR

Dissotis grandiflora (Sm.)Benth. var. lambii (Hutch.)Keay	Melastomataceae	G	SZ	Sav	Ewè-Tchaourou-Koussoukouangou		EN
Distemonanthus benthamianus Baill.	Leg.-Caes.	MPh	GC	SDF	Pobè	99.46	CR
Dodonaea viscosa Jacq.	Sapindaceae	mph	At	Sandy shores	Cotonou (coast)		EX
Dorstenia walleri Hemsl.	Moraceae	G	SZ	Sav	Tchaourou-3Rivières-Koussoukouangou-Pendjari-Pehonco		EN
Dovyalis afzelii Gilg	Flacourtiaceae	nph	GO	SDF	Ewè		CR
Dracaena fragrans (L.)Ker-Gawl	Agavaceae	nph	GC	SDF	Pobè	99.82	CR
Dracaena mannii Bakker	Agavaceae	nph	GC	SDF	Pobè	99.46	CR
Drypetes aframensis Hutch.	Euphorbiaceae	mph	GO	SDF	Ewè	95.71	CR
Drypetes gilgiana (Pax)Pax & Hoffm.	Euphorbiaceae	nph	GC	SDF	Ewè	95.71	CR
Ekebergia capensis Sparrm.	Meliaceae	mPh	SZ	DF-Sav.	Bassila-Pendjari-Birni	96.96	EN
Embelia guineensis Baker	Myrsinaceae	Lnph	GO	SDF	Lama-Bassila-Pénéssoulou	98.92	EN
Encephalartos barteri Carruth.	Cycadaceae	Ch	SG	Sav	Savalou-Doumè-Wari Maro-Manigri-Bassila	99.82	EN
Ensete gillettii (De Wild.)E.E. Cheesman	Musaceae	G	SG	Sav (hill)	Dassa		CR
Eremospatha macrocarpa (Mann & Wendl.)Wendl.	Arecaceae	LmPh	GC	Sw	Mondo Tokpa-Zinvié-Kraké-Tohouè-Djassin (N 06°28' E 02°36')	99.82	EN
Eriocoelum kerstingii Gilg. ex Engl. var. kerstingii	Sapindaceae	mPh	GC	RF	Yarpao-Kota-Koussoukouangou-Kotiacou-Kandi	98.21	EN
Erythrina excelsa Baker	Leg.-Pap.	mPh	GE	SDF	Pobè		CR
Erythrina vogelii Hook.f.	Leg.-Pap.	mPh	GC	SDF	Dangbo	99.82	CR
Erythrophleum suaveolens (Guill. & Perr.)Brenan	Leg.-Caes.	mPh	GC	DF-RF	Pobè-Doumè-Dan-Bassila-Djougou	98.03	EN
Erythroxylum emarginatum Thonn.	Erythroxylaceae	mph	At	DF-RF	Dassa-Bantè-Avégamey	98.39	EN
Euadenia trifoliata (Schum. & Thonn.)Oliv.	Capparaceae	nph	GC	SDF	Avagbodji-Bembè-Dangbo-Pobè		EN
Euclinia longiflora Salisb.	Rubiaceae	Lmph	GC	SDF	Dangbo-Pobè	97.67	EN
Eugenia nigerina A.Chev. ex Hutch. & Dalziel	Myrtaceae	nph	GC	DF (hill)	Dan-Dassa	99.46	CR
Eugenia salacioides Laws. ex Hutch. & Dalziel	Myrtaceae	nph	GO	RF-SDF	Avagbodji-Bembè-Dangbo-Gnaouizoumè	99.82	EN
Ficus leprieuri Miq.	Moraceae	mph-Ep	GC	Sw	Lokoli	99.28	DD
Ficus lyrata Warb.	Moraceae	nph-Ep	GC	Sw-RF	Lokoli-Igolo-Bassila-Pénéssoulou	98.75	EN
Ficus mucuso Ficalho	Moraceae	mPh	GC	Sw-SDF	Dangbo-Pobè-Niaouli-Lokoli	98.39	EN
Funtumia africana (Benth.)Stapf	Apocynaceae	mPh	GC	SDF-Sw	Pobè-Lokoli	98.92	EN
Funtumia elastica (Preuss)Stapf	Apocynaceae	mPh	GC	SDF	Niaouli	99.64	CR
Gaertnera paniculata Benth.	Rubiaceae	mph	GC	SDF-Sw	Mondo Tokpa-Ahozon-Kraké-Meridjonou (N 06°29' E 02°41')-Cocotomey-Cococodji	99.64	EN
Garcinia kola Heckel	Clusiaceae	mph	GC	Hab	Adjara-Sota-Pahou		EW
Garcinia livingstonei T.Anders.	Clusiaceae	mPh	SZ	RF	Pendjari	99.82	CR
Garcinia mannii Oliv.	Clusiaceae	mph	GE	Sw	Mitro (Ouémé)		CR
Garcinia smeathmannii (Planch. & Triana)Oliv.	Clusiaceae	mPh	Pt	SDF-Sw	Dangbo-Mitro (Ouémé)	99.82	EN
Gardenia imperialis* K.Schum.	Rubiaceae	mPh	GC	RF	Yarpao	99.82	CR
Gardenia nitida Hook.	Rubiaceae	mph	GC	SDF	Pobè-Lama-Ewè-Gnaouizoumè	97.67	EN
Gouania longipetala Hemsl.	Rhamnaceae	Lmph	GC	SDF	Pobè-Ewè-Pénéssoulou	99.82	EN
Griffonia simplicifolia (Vahl ex DC.)Baillon	Leg.-Caes.	LmPh	At	SDF-Thic	Dogbo-Comè-Avégamey-Badjamè	99.64	EN
Hannoa klaineana Pierre & Engl.	Simaroubaceae	mPh	GC	SDF-RF-Sw	Pobè-Niaouli-Sakété-Igolo	98.21	EN
Harungana madagascariensis Lam. ex Poir.	Clusiaceae	nph	At	Sw	Zogbodomey-Missérété	99.82	EN
Hexalobus crispiflorus A.Rich.	Annonaceae	mPh	GC	RF	Pénéssoulou-Djigbé	99.64	EN
Heteropteris leona (Cav.)Exell.	Malpighiaceae	Lnph	GC	SDF	Dangbo		CR
Holoptelea grandis (Hutch.)Mildbr.	Celtidaceae	mPh	GC	SDF	Pobè-Ewè-Bantè-Bassila-Pénéssoulou-Djougou	93.39	VU
Homalium le-testui Pellegr.	Flacourtiaceae	mPh	GC	SDF	Pobè-Dangbo	98.57	EN
Hunteria umbellata (K. Schum.)Hall.f.	Apocynaceae	mph	GC	SDF	Dangbo-Pobè-Ewè	98.03	EN

Hymenostegia afzelii (Oliv.)Harms	Leg.-Caes.	mph	GC	RF	Sakété-Akpa	99.82	EN
Ipomoea beninensis Akoègninou A. & Lisowski	Convolvulaceae	LHC	S	Sav	Birni-Ndali-Tanguiéta	96.64	EN
Irvingia smithii Hook.f.	Simaroubaceae	mph	SZ	Sav	Tchaourou-3 Rivières-Alibori Supérieur		EN
Khaya grandifoliola C.DC.	Meliaceae	mPh	GC	SDF-RF	Pénéssoulou-Zagnanado	97.67	EN
Khaya senegalensis (Desv.)A.Juss.	Meliaceae	mPh	S	RF-Sav	Dogo-Monts Kouffè-Ouémé Supérieur-Bassila-Pénéssoulou	87.32	EN
Kigelia africana (Lam.)Benth.	Bignoniaceae	Mph	GC	SDF-DF-RF	Lama-Pobè-Dogo-Dassa-Alibori Supérieur-Mékrou-Atacora Mountains	96.6	VU
Kolobopetalum auriculatum Engl.	Menispermaceae	Lnph	GC	SDF	Dangbo-Pobè	99.1	EN
Laccosperma secundiflorum (P. Beauv.)O.Kuntze	Arecaceae	Lmph	GC	Sw	Mondo Tokpa-Lokoli-Tohouè-Dja-Zinvié-Lac Azili	99.64	VU
Laguncularia racemosa (L.)Gaertn.f.	Combretaceae	mPh	PAL	Mgr	Djondji-Bouche du Roi (N 06°15' E 01°54')	99.82	CR
Landolphia calabarica (Stapf)A.E.Bruce	Apocynaceae	LmPh	GO	SDF	Pobè-Niaouli		EN
Landolphia incerta (K. Schum.)Persoon	Apocynaceae	Lmph	GC	RF	Sakété		CR
Landolphia togolana (Hallier f.)Pichon	Apocynaceae	Lmph	GO	SDF	Pobè-Lama	97.32	EN
Lasiodiscus mannii Hook.f.	Rhamnaceae	mph	GC	SDF	Lama-Ewè	98.57	EN
Leptoderris cyclocarpa* Dunn	Leg.-Pap.	Lmph	GO	SDF-RF	Ahozon-Avagbodji-Bembè	98.75	EN
Macaranga barteri Müll.Arg.	Euphorbiaceae	mph	GC	SDF	Pobè-Ahozon	98.21	EN
Macaranga heudelotii Baill.	Euphorbiaceae	mph	GC	RF	Niaouli-Badjamè	99.28	EN
Macaranga schweinfurthii Pax	Euphorbiaceae	mph	GE	Sw	Igolo		CR
Macaranga staudtii Pax	Euphorbiaceae	mph	GE	Sw	Adijèmè (Comè)		CR
Machaerium lunatum (L. f.)Ducke	Leg.-Pap.	nph	GC	Mgr	Ouidah-Togbin (N 06°21' E 02°18')	99.82	CR
Maerua duchesnei (De Wild.)F.White	Capparidaceae	mph	GC	SDF	Pobè-Ewè	95.89	EN
Maesopsis eminii Engl. subsp. eminii	Rhamnaceae	mPh	GC	SDF	Pobè	98.75	CR
Majidea forsteri (Sprague)Radlk.	Sapindaceae	mPh	GC	SDF	Pobè-Ewè-Idadjo	98.21	EN
Manihot glaziovii Müll.Arg.	Euphorbiaceae	mPh	PAL	SDF	Pénéssoulou	99.46	CR
Manilkara obovata Sabine & G.Don	Sapotaceae	mPh	At	RF-Thic	Ahozon-Sèmè-Avagbodji-Bembè-Gnaouizoumè	99.64	EN
Mansonia altissima (A.Chev.)A.Chev.	Sterculiaceae	mPh	GC	SDF	Ewè	95.89	CR
Maranthes robusta (Oliv.)Prance	Chrysobalanaceae	mPh	GC	SDF-RF-Sw	Pobè-Ahozon-Avagbodji-Bembè-Dja	93.39	EN
Martretia quadricornis Beille	Euphorbiaceae	mph	GC	Sw	Monts Kouffè		CR
Maytenus ovatus (Wall ex Wight & Arn.)Loes	Celastraceae	mph	SZ	Thic	Coast	99.28	CR
Microlepia speluncae (L.)Moore	Dennstaedtiaceae	G-Ep	Pt	SDF	Dangbo		CR
Milicia exelsa (Welw.)C.C.Berg	Moraceae	mPh	GC	SDF-DF-RF	Dangbo-Pobè-Ahozon-Lama-Niaouli-Ewè-Dogo-Comè-Badjamè-Avégamey-Aplahoué-Pénéssoulou-Toucountouna	86.07	EN
Millettia barteri (Benth.)Dunn	Leg.-Pap.	Lmph	GC	RF	Dangbo-Mariagléta	99.82	EN
Millettia chrysophylla Dunn	Leg.-Pap.	Lmph	GC	RF	Avagbodji-Bembè	99.82	CR
Millettia griffoniana Baill.	Leg.-Pap.	mph	GC	RF-Sw	Avagbodji-Bembè-Lokoli-Djrègbé	99.82	EN
Millettia warneckei Harms	Leg.-Pap.	mph	GC	RF	Bétékoukou	99.82	CR
Mimusops andogensis Hiern	Sapotaceae	mPh	GC	SDF-RF	Lama-Avagbodji-Bembè-Doumè	96.96	EN
Mitragyna ledermannii (K.Krause) Ridsdale	Rubiaceae	mPh	GC	Sw	Lokoli-Mondo Tokpa-Igolo-Tchakou-Gnaouizoumè-Meridjonou-Idigny (Kétou)	97.85	EN
Monanthotaxis parviflora (Oliv.)Verdc.	Annonaceae	Lnph	GE	SDF	Dangbo-Pobè-Ewè-Monts Kouffè	93.92	EN
Mondia whytei (Hook.f.)Skeels	Asclepiadaceae	Lmph	At	SDF-Fallow	Lama-Ewè-Avégamey-Badjamè	97.5	EN
Monodora myristica (Gaertn.)Dunal	Annonaceae	mPh	GC	Sw	Dangbo-Niaouli	98.57	EN
Morinda morindioides (Baker)Milne-Redh.	Rubiaceae	Lnph	GC	SDF	Pobè-Niaouli	97.85	EN
Musanga cecropioides R.Br.	Moraceae	mPh	GC	SDF	Pobè-Niaouli	99.46	EN
Mussaenda isertiana DC.	Rubiaceae	Lmph	GC	Sw	Mondo Tokpa-Ahozon-Sèmè	98.92	EN
Myrianthus arboreus P.Beauv.	Moraceae	mPh	GC	SDF	Pobè-Niaouli	97.5	EN
Nauclea xanthoxylon (A.Chev.)Aubrév.	Rubiaceae	mph	GE	Sw	Lokoli-Niaouli-Pobè	98.57	EN
Neostenanthera myristicifolia (Oliv.)Exell	Annonaceae	mph	GE	Sw	Igolo		CR
Nesogordonia papaverifera (A.Chev.)R. Capuron	Sterculiaceae	mPh	GC	SDF	Ewè	95.53	CR

Ochna multiflora DC.	Ochnaceae	mph	GO	SDF	Ahozon	99.82	CR
Octoknema borealis Hutch. & Dalziel	Olacaceae	mPh	GO	RF	Avagbodji-Bembè	99.82	CR
Octolobus spectabilis Welw.	Sterculiaceae	nph	GC	SDF	Ewè	96.78	CR
Oligocodon cunliffeae (Wernh.)Keay	Rubiaceae	Lmph	GE	Sw	Mondo Tokpa-Avagbodji-Bembè-Lokoli		EN
Oncinotis glabrata (Baill.)Stapf ex Hiern	Apocynaceae	Lmph	GO	SDF-RF	Mondo Tokpa-Ahozon-Dangbo	95.35	EN
Oncoba spinosa Forsk.	Flacourtiaceae	mph	SZ	SDF-DF	Lama-Dangbo-Avégamey-Kétou-Badjamè-Dassa-Savalou-Igbo-macro-Bantè-Nikki-Goro-Tchaorou-Boukoumbé-Sèmèrè-Gamia-Kotiacou-Bondjagou-Toucountouna-Tanougou	95.35	LR
Pararistolochia goldieana (Hook.f.)Hutch. & Dalziel	Aristolochiaceae	LmPh	GC	SDF-RF	Ahozon-Bantè-Pénéssoulou	93.21	EN
Pararistolochia mannii* (Hook.f.)Keay	Aristolochiaceae	Lnph	GO	RF	Zinvié-Tohouè		EN
Parinari congensis F.Didr.	Chrysobalanaceae	mPh	GC	RF	Monts Kouffè-Samiondji-Okpara river	99.1	EN
Parkia bicolor A.Chev.	Leg.-Mim.	mPh	GC	SDF	Dangbo-Pobè-Niaouli	96.96	EN
Paropsia guineensis Oliv.	Passifloraceae	mPh	GE	SDF	Pobè	98.57	CR
Pauridiantha hirtella (Benth.)Bremek.	Rubiaceae	nph	GC	Sw	Mondo Tokpa-Sèmè		EN
Pentaclethra macrophylla Benth.	Leg.-Mim.	mPh	GC	Sw	Pobè-Niaouli	98.39	EN
Pentadesma butyracea Sabine	Clusiaceae	mPh	SG	RF	Bassila-Pénéssoulou-Toucountouna-Gbèssè (Ségbana)	98.75	EN
Phoenix reclinata Jacq.	Arecaceae	nph	At	RF-Sw	Monts Kouffè-Pénéssoulou-Ouidah-Grand Popo	97.85	EN
Pierreodendron kerstingii* (Engl.)Little	Simaroubaceae	mPh	GC	Sw-RF-RF	Pobè-Zinvié-Tori-Bantè-Pénéssoulou	98.92	EN
Piper guineense Schum. & Thonn.	Piperaceae	LmPh	GC	Sw	Dangbo-Pobè-Niaouli-Lokoli	97.5	EN
Piptadeniastrum africanum (Hook.f.)Brenan	Leg.-Mim.	MPh	GC	SDF	Dangbo-Pobè-Niaouli	95.35	EN
Pityrogramma calomelanos (L.)Link	Adianthaceae	G-Ep	Pt	Sw	Dangbo		CR
Placodiscus boya* Aubrév. & Pellegr.	Sapindaceae	mPh	GO	For	Lama		CR
Platycerium stemaria (Beauv.)Desv.	Polypodiaceae	G-Ep	At	RF	Bantè-Pénéssoulou		EN
Pleiocarpa pycnantha (K.Schum.)Stapf	Apocynaceae	nph	GC	SDF-RF	Dan-Missérété-Avagbodji-Bembè-Lokossa towards Aplahoué	97.85	EN
Pouchetia africana DC.	Rubiaceae	nph	GC	SDF	Pobè-Ewè-Lama	95.53	EN
Premna quadrifolia Schum. & Thonn.	Verbenaceae	nph	GC	SDF	Pobè-Niaouli-Ewè-Aguigadji-Bétékoukou		EN
Pseudospondias microcarpa (A. Rich.)Engl. var. microcarpa	Anacardiaceae	mPh	GE	RF-Sw	Calavi-Bassila-Pénéssoulou	99.64	EN
Psilanthus mannii Hook.f.	Rubiaceae	nph	GC	SDF	Dangbo	99.28	CR
Psychotria articulata (Hiern)Petit	Rubiaceae	mph	GC	Sw	Lokoli-Zinvié-Mariagléta	98.75	EN
Psychotria obscura Benth.	Rubiaceae	nph	GC	SDF-RF	Manigri-Natitingou		EN
Psydrax subcordata (DC.)Bridson	Rubiaceae	mph	GC	SDF	Pobè	99.64	CR
Pterocarpus erinaceus Poir	Leg.-Pap.	mPh	S	Sav	Lama-Dogo-Tui Kilibo-Tchaourou-Ndali-3Rivières-Sota-Goungoun-Savalou-Bantè-Monts Kouffè-Ouémé Supérieur-Alibori Supérieur-Kouandé-Batia		EN
Pterygota macrocarpa K.Schum.	Sterculiaceae	MPh	GC	SDF	Ewè-Kétou	99.64	CR
Pycnanthus angolensis (Welw.)Warb. var. angolensis	Myristicaceae	MPh	GC	SDF	Dangbo-Pobè-Niaouli-Ahozon-Lokoli-Badjamè	94.28	VU
Raphia hookeri Mann & Wendl.	Arecaceae	mph	GC	Sw	Djassin-Sèmè-Igolo-Adjara-Zinvié-Niaouli-Lokoli	97.85	VU
Raphia sudanica A.Chev.	Arecaceae	mph	SZ	RF	Penessoulou-Kouandé-Perma-Savalou-Savè-Gamia-Kota-Yarpao-Tora-Séri-Konkombri	97.5	LR
Raphia vinifera P.Beauv.	Arecaceae	mph	GE	Sw	Avrankou	99.82	CR
Rauvolfia vomitoria Afzel.	Apocynaceae	mph	GC	For-Thic	Coast-Dangbo-Pobè-Niaouli-Ahozon-Avégamey-Pénéssoulou-Djougou	95.89	EN
Rhabdophyllum affine (Hook.f.)Van Tiegh. syn Ouratea affinis Hook.f.	Ochnaceae	nph	GO	SDF-Sw	Pobè-Niaouli-Lokoli	99.1	EN
Rhizophora racemosa G.Mey.	Rhizophoraceae	mPh	PAL	Mgr	Ouidah-Grand Popo-Mitogbodji	99.46	EN
Ricinodendron heudelotii (Baill.)Pierre & Heckel	Euphorbiaceae	mPh	GC	SDF	Pobè-Idadjo-Bassila	97.5	EN
Rinorea brachypetala (Turcz.)O.Kuntze	Violaceae	nph	GC	SDF	Niaouli-Ewè-Kétou	99.46	EN
Rinorea dentata (P. Beauv.)O.Kuntze	Violaceae	mph	GC	SDF	Pobè-Ewè-Igbo-macro	98.21	EN

Rinorea ilicifolia (Welw. ex Oliv.)O. Kuntze	Violaceae	nph	GC	SDF	Ewè	99.82	CR
Rinorea kibbiensis Chipp	Violaceae	nph	GC	SDF-RF	Kétou-Ewè	99.28	EN
Rinorea subintegrifolia (P. Beauv.)O. Kuntze	Violaceae	nph	GC	Sw	Avrankou		CR
Rothmannia munsae (Schweinf. ex Hiern)Petit	Rubiaceae	mph	GC	Sw	Mondo Tokpa-Lokoli	99.64	EN
Rothamannia whitfieldii (Lindl.)Dandy	Rubiaceae	mph	SG	SW-RF	Pobè-Boukou		EN
Sarcophrynium brachystachyum (Benth.)K.Schum.	Marantaceae	G	GC	SDF	Dangbo	99.82	CR
Sarcostemma viminale (L.)R.Br.	Asclepiadaceae	Ch	At	Sandy shores	Cotonou (coast)		CR
Scaevola plumieri L.	Goodeniaceae	Ch	PAL	Sandy shores	Cotonou (coast)		CR
Schrebera arborea A.Chev.	Oleaceae	mPh	GC	SDF	Ewè-Pénéssoulou	99.28	EN
Sesuvium portulacastrum L.	Aïzoaceae	Ch	GO	Mgr	Coast	99.82	CR
Sherbournia bignoniiflora (Welw.)Hua	Rubiaceae	Lmph	GC	SDF	Dangbo-Pobè	97.85	EN
Smeathmannia pubescens Soland. ex R.Br.	Passifloraceae	mph	GC	SDF	Ahozon	97.14	CR
Spathandra blakeoides (G. Don)Jacq.-Félix	Melastomataceae	mph	GC	SDF	Ahozon	98.75	CR
Sphenocentrum jollyanum Pierre	Menispermaceae	nph	GC	SDF	Dangbo-Pobè-Niaouli	91.25	EN
Sphenostylis schweinfurthii Harms	Leg.-Pap.	Ch	SZ	Sav	Natitingou-Pouya-Atacora Mountains	99.1	VU
Spondianthus preussii Engl	Euphorbiaceae	mPh	GC	Sw	Pobè-Lokoli	97.32	EN
Stenotaphrum secundatum (Walt.)Kuntze	Poaceae	G	At	Coast bush	Coast		CR
Streptogyna crinita P.Beauv.	Poaceae	G	SG	SDF	Ewè-Bassila	97.5	EN
Strombosia pustulata Oliv.	Olacaceae	mPh	GC	SDF	Dangbo-Pobè	95	EN
Symphonia globulifera L.f.	Clusiaceae	mPh	PAL	SDF-Sw	Sèmè-Ahozon-Niaouli-Mondo Tokpa-Avagbodji	97.14	EN
Synsepalum dulcificum (Schum. &Thonn.)Daniell	Sapotaceae	mph	GC	Sw	Azovè-Djakotomey-Zagnanado		EN
Synsepalum passargei (Engl.)Penn.	Sapotaceae	mph	At	RF	Yarpao	98.39	CR
Syzygium guineense (Willd.)DC. var. littorale Keay	Myrtaceae	mph	GC	SDF	Ahozon	99.28	CR
Syzygium owariense (P. Beauv.)Benth.	Myrtaceae	mPh	GC	Sw	Mondo Tokpa-Lokoli-Meridjonou	98.57	EN
Tabernaemontana eglandulosa Stapf	Apocynaceae	Lmph	GC	SDF	Dangbo-Pobè-Itchèdè	98.75	EN
Tabernaemontana pachysiphon Stapf	Apocynaceae	mph	GC	SDF	Dangbo-Pobè	96.42	EN
Tapura fischeri Engl.	Dichapetalaceae	mPh	GC	SDF	Pobè-Ewè	98.21	EN
Teclea verdoorniana (Engl. & Mendonça)Mziray	Rutaceae	mph	GC	SDF	Dangbo-Zè-Avégamey-Houéyogbé	99.28	EN
Terminalia brownii Fresen.	Combretaceae	mph	SZ	Sav (hill)	Atacora Mountains	99.82	CR
Terminalia superba Engl. & Diels	Combretaceae	mPh	GC	SDF-RF	Pobè-Athiémé-Dogo-Bantè	95.35	EN
Tetrapleura tetraptera (Schum. & Thonn.)Taub.	Leg.-Mim.	mPh	GC	SDF	Ahozon-Pobè-Niaouli	97.85	EN
Tetraptera andongensis Welw. ex Oliv.	Leg.-Mim.	mph	At	Sav	Tui Kilibo-Monts Kouffè-Bassila-Lougba	99.82	EN
Tetrorchidium didymostemon (Baill.)Pax & Hoffm.	Euphorbiaceae	mph	GC	SDF	Pobè-Niaouli	99.64	EN
Thunbergia atacoriensis Akoègninou & Lisowski	Acanthaceae	LCh	S	RF	Yarpao-Koussoukouangou-Perma	99.46	EN
Thunbergia cynanchifolia Benth.	Acanthaceae	Lmph	GC	SDF	Dangbo		CR
Treculia africana Decne.	Moraceae	mPh	GC	Sw-RF	Pobè-Lokoli-Niaouli-Sakété-Gnaouizoumè	98.57	EN
Tricalysia faranahensis Aubrév. & Pellegr.	Rubiaceae	nph	GO	SDF	Ahozon	96.96	CR
Tricalysia reflexa Hutch.	Rubiaceae	nph	GC	SDF	Dangbo	99.82	CR
Tricalysia reticulata (Benth.)Hiern	Rubiaceae	nph	GO	SDF	Lama	99.64	CR
Trichilia martineaui* Aubrév. & Pellegr.	Meliaceae	mPh	GO	Sw	Niaouli		CR
Trichilia megalanta Harms	Meliaceae	mPh	GO	SDF	Ahozon-Dangbo-Pobè	92.67	EN
Trichilia retusa Oliv.	Meliaceae	mph	SG	RF	Alibori Supérieur		CR
Trichilia tessmannii Harms	Meliaceae	mPh	GC	SDF	Dangbo-Pobè-Niaouli	96.07	EN
Trichoscypha oba Aubrév. & Pellegr.	Anacardiaceae	mph	GO	Coast For	Ahozon-Cococodji-Sèmè	97.5	EN

Triplochiton scleroxylon K.Schum.	Sterculiaceae	mPh	GC	SDF	Dangbo-Pobè-Niaouli-Kétou-Lokoli-Avégamey-Badjamè-Bantè	84.64	EN
Turraea heterophylla J.B.Hall	Meliaceae	Lnph	GO	SDF	Dangbo-Pobè-Lama	99.1	EN
Uapaca paludosa* Aubrév. & Léandri	Euphorbiaceae	mph	GC	Sw	Lokoli	99.82	CR
Urera obovata* Benth.	Urticaceae	nph	GC	SDF	Pobè-Niaouli		DD
Uvaria ovata* (Vahl ex Dunal)A.DC.	Annonaceae	nph	GO	Thic	Houéyogbé		CR
Ventilago africana Gaertn.	Rhamnaceae	Lmph	GC	SDF	Lama	99.82	CR
Vitex ferruginea Schum. & Thonn.	Verbenaceae	mph	GC	Sw	area around Porto Novo		DD
Vitex grandiflora Gürke	Verbenaceae	mPh	GC	Sw	Ahozon-Pobè-Sakété-Kraké-Lokoli-Sogo	97.85	VU
Vitex micrantha Gürke	Verbenaceae	mPh	GC	SDF	Ewè	98.21	CR
Voacanga africana Stapf	Apocynaceae	mph	At	SDF-Thic	Ewè-Pénéssoulou-Pobè-Coast	98.75	EN
Warneckea fascicularis* Planch. ex Benth.	Melastomataceae	mph	GO	RF	Avagbodji-Bembè	99.82	CR
Warneckea memecyloides* (Benth.)Jacq.-Fél.	Melastomataceae	Lmph	GC	Sw-RF-SDF	Gnaouizoumè-Adjohoun-Avagbodji-Bembè-Dangbo-Niaouli-Ewè-Lama	96.78	VU
Xylopia aethiopica (Dunal)A.Rich.	Annonaceae	mPh	GC	Sw-RF	Ahozon-Pobè-N'dokpo-Adjara-Pénéssoulou-Birni-Yarpao	97.14	VU
Xylopia rubescens* Oliv.	Annonaceae	mPh	GO	Sw	Pobè-Mondo Tokpa-Lokoli-Adjohoun-Aplahoué	97.85	EN
Xylopia villosa Chipp	Annonaceae	mPh	GO	SDF	Pobè	98.75	CR
Zanha golungensis Hiern	Sapindaceae	mPh	SG	RF-DF-SDF	Bantè-Bassila-Pénéssoulou-Djougou-Toucountouna-Atacora Mountains	95.35	VU
Zanthoxylum gilletii (De Wild.)Waterman	Rutaceae	mph	GC	SDF	Pobè	99.1	CR
Zanthoxylum zanthoxyloides (Lam.)Zepern. & Timber	Rutaceae	mph	SG	SDF-DF-Thic	Ahozon-Bassila-Ewè-Lama-Coast	88.03	EN
Ziziphus spina-christi (L.)Desf. var. microphylla Hochst. ex A.Rich.	Rhamnaceae	nph	SZ	RF	Porga-Pendjari		EN

LF = Life forms followed Raunkiaer (1934), Schnell (1971), and Keay & Hepper (1954-1972): MPh: megaphanerophyte (> 30 m tall), mPh: mesophanerophyte (8-30 m), mph: microphanerophyte (2-8 m), nph: nanophanerophyte (0.5-2 m), Ch: chamephyte, G: Geophytes, HC: Hemicryptophyte, Th: Therophyte, L.: Liana, Ep: Epiphyte.

CT = Chorological types: GC: Guineo-Congolian, GE: Lower Guinean, GO: Upper Guinean, S: Sudanian, SG: Sudano/Guinean transition, SZ: Sudano-Zambezian, At: Tropical Africa, Pt: Pantropical, PAL: Paleotropical.

Hab. = Habitats: Coast For: Coastal forest, DF: Dry forest, For: Forest, RF: Riparian forest, Hab: Habitation, Mgr: Mangrove, Sav: Woodland to Savannah, SDF: Semi-deciduous forest, Sw: Swamp forest, Thic: Thicket.

RI = Rarity Index (RI) estimated for species reported in the field based on 598 vegetation samples.

TC = IUNC-Threatened categories: EX: Extinct, EW: Extinct in the Wild, CR: Critically Endanger, EN: Endanger, VU: Vulnerable, LR: Lower Risk, DD: Data Deficient, NE: Not Evaluated.

Leguminosae: Leg.-Caes.: Leg.-Caesalpinioideae, Leg.-Mim.: Leguminosae-Mimosoideae, Leg.-Pap.: Leguminosae-Papilionoideae.

*: Plant species rare at international level (Hawthorne (1996).

Chapter 6

GENERAL DISCUSSION AND CONCLUSIONS

6.1. General vegetation patterns

During this study, a plant species checklist (Annex) made of 1021 species was generated from our inventory data; they belong to 576 genera and 116 families. This corresponds to c. 34% of the total flora, which is being estimated at 3000 plant species (Project Flora of Benin 2001). Considering the distribution range types, 45% of the species recorded are Guineo-Congolian, 22% are widespread, 19% are Guineo/Sudanian (linking elements), 17% are Sudano-Zambesian and 7% are Sudanian. A list of 280 threatened plant species representing c. 10% of the total flora was made. Ten (10) plant species turned out to be new for the flora of Benin (Table 6.1); all of them are Guineo-Congolian.

Table 6.1: Plant species found to be new for the flora of Benin

Plant species new for the flora of Benin	Family	Plant formation	Distribution in Benin (see Figure 2.1)
Rinorea ilicifolia	Violaceae	Semi-deciduous forest	Ewè (Kétou)
Rinorea brachypetala	Violaceae	Semi-deciduous forest	Ewè (Kétou), Niaouli
Rinorea kibbiensis	Violaceae	Semi-deciduous forest	Ewè (Kétou)
Rothmannia munsae	Rubiaceae	Swamp forest	Lokoli
Uapaca paludosa	Euphorbiaceae	Swamp forest	Lokoli
Hymenodicton pachyantha	Rubiaceae	Semi-deciduous forest	Ewè (Kétou)
Vitex micrantha	Verbenaceae	Semi-deciduous forest	Ewè (Kétou)
Zanthoxyllum rubescens	Rutaceae	Semi-deciduous forest	Ewè (Kétou)
Eugenia salacioides	Myrtaceae	Semi-deciduous forest	Dangbo, Avagbodji
Xylopia villosa	Annonaceae	Semi-deciduous forest	Pobè

We identified 20 vegetation types distributed over 10 phytogeographical districts (PDs), which fit into three floristic regions: the Guineo-Congolian region, the Guineo/Sudanian transition zone and the Sudanian region. The Guineo/Sudanian transition zone was subdivided into the “Guineo-Sudanian” transition sub-zone (characterised by a relative dominance of Guineo-Congolian elements) and the “Sudano-Guinean” transition sub-zone (characterised by a relative dominance of Sudanian elements). These terminologies were used in a similar way as in the phytogeographical subdivision of Cameroon (Letouzey 1968, van der Zon 1992). The proposed phytogeographical map based on vegetation species composition can be regarded as a refinement of the previous ones established on physiognomic basis (Adjanohoun *et al* 1989, Wezel *et al*. 1999, Houinato *et al*. 2000, Akoègninou 2004). There is strong agreement between the major floristic areas and the climatic zones (Akoègninou 2004). The position of the various boundaries can be further improved, as the precision of a biogeographical map primarily depends on the quality of the species distribution data and the analytical tool used. A standardised system of 10 x 10 km grids would be a much better basis for analysis of biogeographical patterns (species richness and distribution patterns) (Knight *et al*. 1982, Lausi & Nimis 1985). This approach would give the opportunity to value all the available floristic data including site floristic lists, botanical collections and taxonomic database.

6.2. The phytogeographical position of Benin

The major phytogeographical studies of Africa are those of White (1979, 1983 & 1993) who proposed a vegetation classification and map for Africa based on the concept that physiognomic data (such as cover and height of the vegetation) are fundamentally different from chorological data on species distribution patterns. Our proposed phytochorological division differs from White’s regional phytogeographical division based on endemism (Table 6.2). This study, as well as other research (Paradis 1983, Adjanohoun 1989, Akoègninou 2004), has shown that the southern Benin (from the coast up to c. 7°30’N) is part of the Guineo-Congolian regional centre of endemism. The flora of semi-deciduous forests in this area has been estimated at about 500 plant species, of which c. 70% are Guineo-Congolian (Sokpon 1995, Akoègninou 2004). We have also come with the evidence that the phytogeographical district (PD) of Zou corresponds to the regional Guinea/Sudanian transition zone of White (1983). Although today the greater part of this area is covered with wooded grasslands (due to cultivation and fire), vestiges of the original vegetation dominated by *Hildegardia barteri*, *Diospyros mespiliformis*, *Manilkara multinervis*, and *Pouteria alnifolia* still exist (Clayton 1958, Charter & Keay 1960).

It should be emphasised that Octoknemataceae (with *Octoknema borealis*) (White 1983) has been the only one Guineo-Congolian endemic family reported in Benin and appears to be restricted to the Ouémé Valley. Now this family is incorporated in the Olacaceae. Furthermore, we found that the flora of Benin comprises nine (9) Guineo-Congolian endemic genera (White 1983), of which 8 (i.e. *Amphimas*, *Anthonotha*, *Distemonanthus*, *Hymenostegia*, *Anthrocaryon*, *Coelocaryon*, and *Discoglypremna*) were confined to the PD of Pobè. The 8th Guineo-Congolian endemic genus (i.e. *Aubrevillea*) was found to be restricted to the PD of Bassila. These facts elucidate the biogeographical particularities of these floristic areas in Benin. We also described the Atacora Chain as of great biogeographical significance and would have played a major ecological role during the quaternary climatic fluctuations. Moreover, the Benin’s endemic plant species *Thunbergia atacoriensis* (Acanthaceae) and the Sudanian endemic genus *Haematostaphis* (Anacardiaceae) appear to be restricted to this landscape unit to further corroborate its biogeographical importance.

Table 6.2: Relationship between our floristic areas and White’s (1983) regional units

Phytogeographical districts	Proposed phytochorological areas (Figures 2.7 & 3.3)	White (1983)’s phytogeographical subdivision
Pobè	Guineo-Congolian region	Guineo-Congolian region
Ouémé Valley	"	Guinea/Sudanian transition zone
Coast	"	"
Plateau	"	"
Zou	Guineo/Sudanian transition zone	"
Bassila	"	Sudanian region
Borgou-Sud	"	"
Borgou-Nord	Sudanian region	"
Atacora Chain	"	"
Mékrou-Pendjari	"	"

6.3. Water availability as the major factor determining vegetation gradients

Rainfall has been described as the most important water factor determining the vegetation gradients in West Africa (Hall & Swaine 1976 & 1981; van Rompaey 1993, van Rompaey & Oldeman 1997, Bongers *et al*. 2004, Tchouto 2004). This study has demonstrated that mean annual rainfall alone can not be considered as the overriding climatic factor underlying the vegetation patterns in West Africa. Water availability – expressed as a function of rainfall, length and intensity of the dry season, and air humidity – turns out to be the major factor determining the vegetation gradient in Benin, and explains 80% of the variation in species composition while the annual rainfall only accounts for 30% of the variation in species composition. This thesis showed that the climatic index of Mangenot provides a better quantitative assessment of climatic conditions at a site than the mean annual rainfall. We suggest the use of such a climatic index in vegetation analysis to reflect the cumulative effect of the various climatic factors.

The importance of seasonal variation in water supply for plant species has largely been ignored in studies conducted in the West African rain forest area, because rain forest has traditionally been seen as “ever wet”, implying non-limiting water supply (Swaine 1996). Recently, however, a number of authors have argued that even occasional soil water deficits may be important determinants of forest plant growth and survival (Becker *et al*. 1988, Grubb 1989, Wright 1992, Brown 1994). Several authors (Swaine 1996, Veenendaal *et al*. 1996, Bongers *et al*. 1999 & 2004) emphasised the length of the dry period and its intensity as a strong determinant of floristic patterns in West Africa. Soil moisture (a function of climate, soil type and topography) is often regarded as the best discriminating factor of plant communities (Markham & Babbedge 1979, Hall & Swaine 1981, van Rompaey 1993, Swaine 1996, Gautier & Spichiger 2004). This is probably due to the fact that the processes by which key nutrients such as nitrogen are made available to the plant are controlled by soil moisture (Scholes 1993, Fairbanks 2000).

Despite the strong dependence of riparian forest communities on soil moisture, our results clearly indicated that their distribution patterns are strongly shaped by the general climate (Natta 2003). This can simply be explained by the fact that the level of the water table is determined by the general climate (rainfall amount and seasonality). Furthermore, our floristic gradient has not strictly followed the latitudinal gradient. This can be illustrated by the phytogeographical districts of Bassila and the Atacora Chain, where the richness in Guineo-Congolian elements (36% & 18% respectively) seems to be in contrast with their latitudinal position. We have interpreted this fact as an imprint of quaternary climate fluctuations (Chapters 2-3).

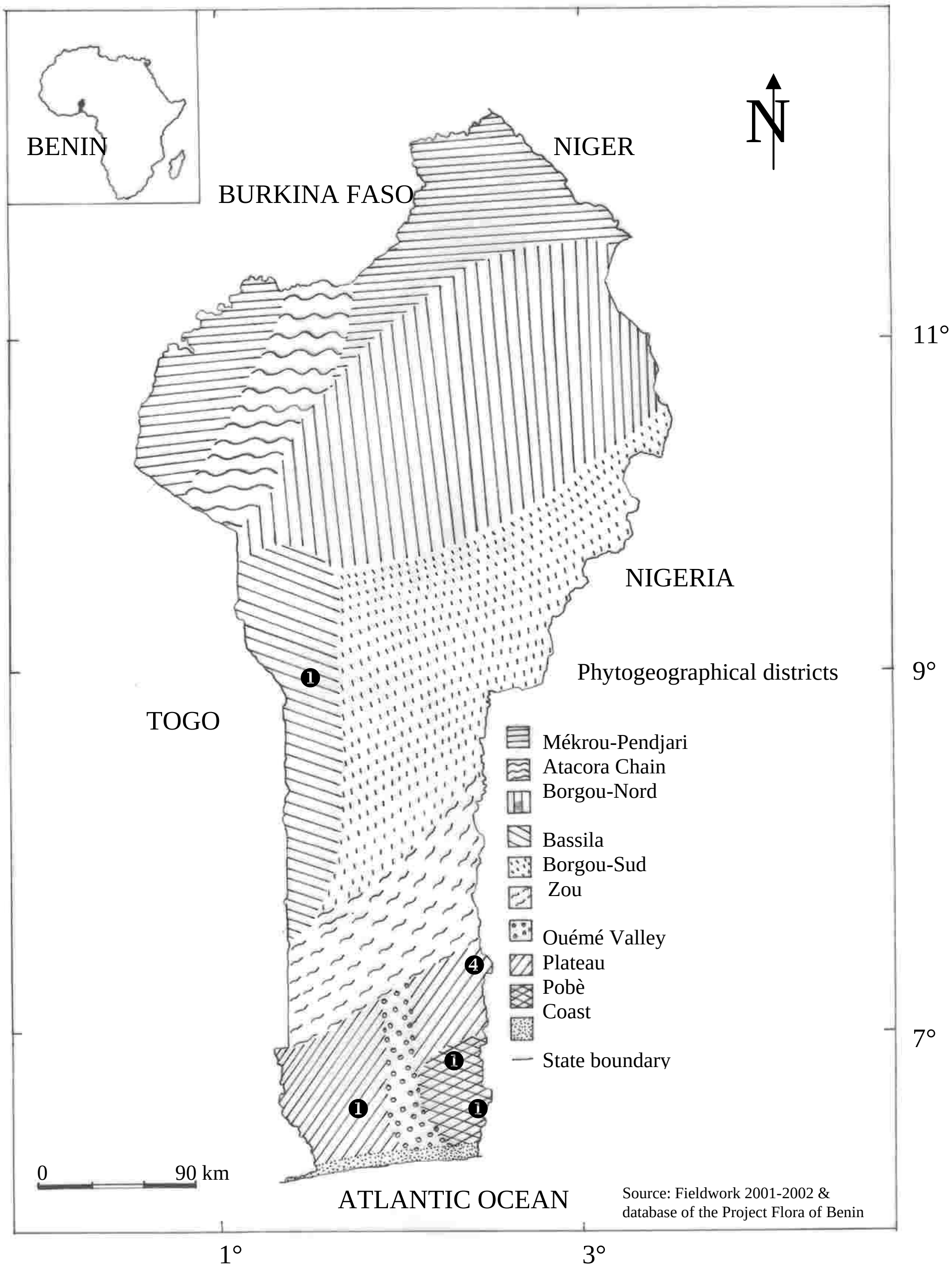
Actually, environmental factors, past climatic fluctuations, and human disturbance appear to act in concert to produce similar ecological conditions that consequently result in similar species assemblages (Holmgren *et al*. 2004). The strong relationship between vegetation patterns, species distribution range types and water availability indicates that plant species and communities are sensitive to climate change.

6.4. Evidence for Late Holocene micro-refuge forest in Benin

An understanding of the present-day location of tropical rain forest requires the use of direct evidence such as palynological and paleobotanical records. Palynological records from southern Benin (Tossou 2002, Salzmann & Hoelzmann 2005) showed that the Dahomey Gap (Figure 4.1) was cover by a semi-deciduous forest during the early-mid Holocene (8500-4000 years BP). This is supported by records of strictly Upper Guinean endemics (Poorter *et al*.

2004) such as *Zanthoxylum gilletii*, *Turraea heterophylla*, *Dennetia tripetala* and *Pierreodendron kerstingii* in semi-deciduous forest remnants we have investigated. We argued that the *Terminalia superba-Piptadeniastrum africanum* community, which corresponds to the West African moist semi-deciduous forest, would have been the dominant forest type that bridged the Upper and Lower Guinean forest blocks during this climatically humid period. During this period, the Upper Guinean forest block would have reached the centre-western Benin and even covered the Atacora Chain up to latitudes of 10^{o}N (Aubréville 1937, Akpagana 1989). The restriction of the *Khaya grandifoliola-Aubrevillea kerstingii* semi-deciduous forest type – a characteristic plant community of Upper Guinea (Guillaumet & Adjanohoun 1971, Kouamé *et al*. 2004) – to this part of Benin corroborates this hypothesis. The restriction of the *Terminalia superba-Piptadeniastrum africanum* forest type to the riverbanks in southern Benin and records of several characteristic semi-deciduous forest plant species (e.g. *Milicia excelsa*, *Khaya grandifoliola*, *Triplochyton scleroxylon* and *Trilepisium madagascariense*) in the riparian forest from the phytogeographical districts of Bassila and the Atacora Chain (Natta 2003, Wala 2005) was interpreted as ecological responses to the general climatic drought stress of late Holocene. This substantiates the hypothesis that riparian forest would have acted as an outpost for rain forest species in glacial times (Medley 1992, Kellman *et al*. 1994, Meave & Kellman 1994).

During the glacial periods of past climatic changes, limited and isolated patches of tropical African rain forest – the so-called rain forest refuges – persisted and survived the unfavourable climatic conditions (Aubréville 1962, Hamilton 1982, Maley 1987, Sosef 1994). Several authors showed that the geographic position of these forest refuges coincides with the distribution patterns of rain forest bio-indicators such as *Rinorea*, *Begonia* and Caesalpinioideae (Achoundong 1996 & 2000, Sosef 1996, and Rietkerk *et al*. 1996, respectively). Bio-indicator species are usually defined as species whose status and ecology provide information on the overall condition of the ecosystem and relative abundance reflect the quality and changes in environmental conditions, both biotic and a-biotic (Heywood & Watson 1995). The interpretation of the semi-deciduous forest patterns in the light of the Holocene pollen assemblages from southern Benin (Tossou 2002, Salzmann & Hoelzmann 2005) led us to consider the investigated forest islands as relics that have survived the late Holocene dry period (3000-2500 yrs BP). We assumed that the subsequent forest expansion after 2500 years BP (Salzmann & Hoelzmann 2005) probably started in the Dahomey Gap from these “small isolated humid pockets”, which can be regarded as areas of medium refugium probability. The geographical positions of these semi-deciduous forest remnants partly coincide with the distribution patterns of *Rinorea* species in Benin (Figure 6.1). The overall distribution pattern of the five *Rinorea* species recorded in Benin seems to indicate areas where semi-deciduous forest survived the late Holocene dry spell. The genus is mostly represented by only one species in each forest site except Ewè, which harbours four species. This study is the first to demonstrate that this site harbours a distinct type of semi-deciduous forest, the *Drypetes aframensis-Nesogordonia papaverifera*, which is floristically similar to the *Celtis* spp.-*Mansonia altissima* community in Ivory Coast (Guillaumet & Adjanohoun 1971). The best representation of *Rinorea* and the dominance of Celtidaceae and Sterculiaceae substantiate the view of Guillaumet & Adjanohoun (1971), who considered this forest type as the climatic climax or primeval type of semi-deciduous forest in West Africa. The geographical position of this forest type in Benin (Figure 6.1) provides the evidence that the northern boundary of the Dahomey Gap can be placed at 7^{o}30’ at least.



Source: Fieldwork 2001-2002 & database of the Project Flora of Benin

Figure 6.1: Map of Benin showing the phytogeographical districts (Chapter 2) and the distribution of *Rinorea* species: *R. brachypetala*, *R. dentata*, *R. ilicifolia*, *R. kibbiensis* & *R. subintegrifolia*. The number indicates the number of species of *Rinorea* recorded at the site.

6.5. Implications for biodiversity conservation

One tool required for implementation of ecosystem-based approache to biodiversity conservation and environmental management is a classification that identifies geographic areas with similar ecosystem characters (Bailley 1983, Omernik 1987 & 1995, Bryce *et al*. 1999, Leathwick *et al* 2003). The cornerstone of ecoregion conservation is a biodiversity vision i.e. a vision built on the findings of a biological assessment. A biological assessment is a record: (1) of the distribution of species, communities, and habitats in the ecoregion, (2) of the ecological processes sustaining that biodiversity and (3) of the current and future threats to its maintenance (CBD 2002). This thesis is a basic contribution to provide this biological assessment for the plant diversity and vegetation conservation in Benin. We identified 20 main plant communities distributed over 10 phytogeographical districts, which fit into three major floristic zones: the Guineo-Congolian Region, the Guineo/Sudanian transition zone and the Sudanian Region. The strong relationship between vegetation types, distribution range types and climate implies that the proposed phytogeographical maps can be used as a spatial framework to guide biodiversity conservation in Benin. Hall & Swaine (1976) stressed that vegetation pattern is a good predictor of environment. Thus, the vegetation typology can be used as surrogate of environment representativeness or diversity in biological reserve selection (van Rompaey 1993, Pienkowski *et al*. 1996, Stoms *et al*. 1998). The aim in applying the representativeness principle for reserve selection is to ensure that all environmental variation is well represented in the selected reserve network (Faith & Walker 1996). Furthermore, vegetation orientated-approach to biodiversity conservation is a very valuable conservation tool in areas like Benin, where distribution data on various biological groups are scarce (Keel *et al*. 1993, Nillson & Götmark 1993, Strittholt & Boerner 1995, Fearnside & Ferraz 1995, Awimbo *et al*. 1996). We expect that a vegetation-based approach, emphasising native plant species and vegetation type richness, can substantially contribute to the conservation of faunal biodiversity including birds, mammals, and insects (Panzer & Schwartz 1998). Our results underline the necessity to include more forest sites into the current protected areas in order to meet the criterion of environmental representiveness and to maximise plant diversity conservation. As illustration, we can cite:

(1) The semi-deciduous forest islands are of great conservation value regardless of their size, since they harbour c. 20% of the total flora that is being estimated to 3000 plant species (Project Flora of Benin 2001). Due to their richness in threatened species and especially in range-restricted species, forest sites such as Pobè (17 range-restricted species), Dangbo (11 species), Ewè (9 species), and Ahozon (8 species) should deserve particular attention. Of greater concern is the forest island of Ewè of which we have highlighted the floristic uniqueness. Globally threatened species such as *Nesogordonia papaverifera* (vulnerable) and *Mansonia altissima* (vulnerable) appear to be confined to this forest site. However, this area of high conservation priority has not yet gained any attention from conservationists and the local human pressure keeps increasing. We recommend that this forest site be included into the protected forest of Dogo-Kétou, which lies c. 10 km away or local population be encouraged in its management.

It is worth mentioning that the forest island of Ahozon, which represents the last coastal forest vestige is still facing significant threat of habitat loss. It provides habitat for 33 threatened plant species, of which 8 are range-restricted species. Unfortunately, it still has not any conservation status and is more exposed to forest degradation.

Each of these forest islands seems to harbour a particular bird community (Lougbéon, pers. comm. 2005), which suggests that the conservation needs are urgent in these areas. The influence of forest species composition and structure on bird communities needs to be investigated. Moreover, we suggest that local communities be assisted and encouraged in the management of communal forest. In order to alleviate the pressure on the forest, alternate income-generating activities should be identified for the local communities.

(2) The forest Lokoli's relict is the last natural Guineo-Congolian swamp forests in Benin, although it has been managed by the local community. It is highly threatened since it is located in close vicinity to settlements. It harbours a fairly dense population of the globally vulnerable species *Hallea ledermannii* (IUCN 2000), whose timber is of high value. We have reported from this forest two plant species (*Rothmannia munsae* and *Uapaca paludosa*) new for the flora of Benin (Table 6.1). The presence of the Red-bellied monkey (*Cercopithecus erythrogaster* subsp. *erythrogaster*), which is an endemic of Benin, makes it a site of national and international conservation priority (NC-IUCN/Benin 2005).

(3) The mangrove forest of Ouidah is under severe threat due to salt extraction using traditional salt production techniques (boiling); it forms the unique and directly available source of firewood. Mangrove management and conservation efforts can be made more effective by better understanding why and how local people are harvesting wood from these forests. Nursery techniques for growing mangrove species (*Rhizophora racemosa* and *Avicennia germinans*) should be developed, and mangrove reforestation should be encouraged.

(4) The Atacora Mountains are of high ecological and biological value. This landscape unit harbours an exclusive vegetation type (the *Synsepalum passargei-Broenadia salicina* riparian community) and the two Beninese endemics *Thunbergia atacorensis* and *Ipomoea beninensis* (Akoègninou & Lisowski 2004).

(5) The inselbergs of the phytogeographical district of Zou harbour the *Hildegardia barteri-Aphania senegalensis* community, which proved to be confined to this land unit. The conservation value of these hilly areas has already been expressed by Yédomonhan (2002), who reported the presence of "local endemic" plant species such as *Eugenia nigerina* (Myrtaceae) and *Cordia millenii* (Boraginaceae).

The protection of the classified forests needs to be reinforced to reduce the uncontrolled logging and land conversion for agriculture; e.g. the classified forest of Goungoun (73 476 ha) and Alibori Supérieur (251 592 ha) (CENATEL 1992) have almost entirely vanished. There is still a considerable lack of detailed knowledge about the vegetation composition in the different protected areas in Benin. Large-scale biodiversity assessment and conservation planning are hampered by lack of an overview of existing knowledge, which is patchy and scattered across diverse published and unpublished sources. To maximise biodiversity conservation both within and outside protected areas, there is an urgent need to coordinate conservation efforts and integrate traditional knowledge and practices in modern conservation strategies (Ntiamoa-Baidu 1995). Very little attempt has been made beyond the local level to explore and develop the biological potential of sacred groves and communal forests for biodiversity conservation. Synthesis is necessary, not only to make better use of the existing biological data, but also to pinpoint more accurately those areas where new data are most urgently required to back active conservation.

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ANNEX

Annex: Plant species checklist of the proposed phytogeographical districts

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
1	Abildgaardia hispidula (Vahl)Lye	Cyperaceae	Th	S	0	0	0	0	0	0	1	0	0	0
2	Abrus fruticulosus Wall. ex Wight & Arn.	Leg.-Pap.	Lnph	PAL	0	1	1	0	1	1	1	0	1	0
3	Abrus precatorius L.	Leg.-Pap.	Lnph	SG	1	1	1	1	1	1	1	1	1	1
4	Abutilon mauritianum (Jacq.)Medic.	Malvaceae	Ch	SG	0	0	1	0	1	1	1	1	0	0
5	Acacia ataxacantha DC.	Leg.-Mim.	Lmph	SG	0	0	0	0	0	0	0	1	0	1
6	Acacia dudgeonii Craib ex Holland	Leg.-Mim.	mph	S	0	0	0	0	0	0	0	0	1	1
7	Acacia gourmaensis A.Chev.	Leg.-Mim.	mph	S	0	0	0	0	0	0	0	1	1	1
8	Acacia hockii De Wild.	Leg.-Mim.	mph	SG	0	0	0	0	0	0	0	0	0	1
9	Acacia macrostachya Reichenb. ex DC.	Leg.-Mim.	mph	S	0	0	0	0	0	0	0	1	1	1
10	Acacia pentagona (Schumach.& Thonn.)Hook.f.	Leg.-Mim.	Lmph	SG	0	1	1	1	1	0	1	1	1	1
11	Acacia polyacantha Willd.	Leg.-Mim.	mPh	SZ	0	0	1	0	1	1	1	1	0	1
12	Acacia senegal (L.)Willd.	Leg.-Mim.	mph	SZ	0	0	0	0	0	0	0	1	1	1
13	Acacia seyal Del.	Leg.-Mim.	mPh	SZ	0	0	0	0	0	0	0	0	1	0
14	Acacia sieberiana DC. var. sieberiana	Leg.-Mim.	mph	SZ	0	0	0	0	1	1	1	1	1	1
15	Acalypha ceraceopunctata Pax	Euphorbiaceae	Th	SZ	0	0	0	0	0	0	0	0	1	0
16	Acalypha ciliata L.	Euphorbiaceae	Th	Pt	0	0	0	0	0	0	0	0	1	0
17	Achyranthes aspera L.	Amaranthaceae	Th	Cos	0	0	1	0	0	1	1	0	1	1
18	Acridocarpus alternifolius (Schum. & Thonn.)Nied.	Malpighiaceae	Lmph	GC	1	1	0	1	0	1	0	0	0	0
19	Acridocarpus smeathmannii (DC.)Guill. & Perr.	Malpighiaceae	mph	GC	0	0	0	0	0	1	0	0	0	0
20	Acroceras gabunense (Hack.)Clayton	Poaceae	Th	GC	0	0	1	0	0	0	0	0	0	0
21	Acroceras zizanoides (Kunth.)Dandy	Poaceae	Hc	Pt	0	0	0	1	0	0	1	0	0	0
22	Acrostichum aureum L.	Adiantaceae	mph	GO	1	0	0	0	0	0	0	0	0	0
23	Adansonia digitata L.	Bombaceae	mPh	SZ	0	0	1	0	0	1	1	1	1	1
24	Adenia cissampeloides (Planch. ex Hook.)Harms	Passifloraceae	Lnph	GC	1	1	1	0	1	1	0	0	1	0
25	Adenia lobata (Jacq.)Engl.	Passifloraceae	Lmph	GC	1	1	1	0	1	1	0	0	1	0
26	Adenia rumicifolia Engl. & Harms var. rumicifolia	Passifloraceae	Lnph	SG	0	0	0	0	1	0	0	0	1	0
27	Adenodolichos paniculatus (Hua)Hutch. & Dalziel	Leg.-Pap.	mph	S	0	0	0	0	1	1	1	1	1	1
28	Adenostemma caffrum DC. var. caffrum	Asteraceae	Th	SG	0	0	0	0	0	0	0	0	1	0
29	Aeglopsis chevalieri Swingle	Rutaceae	nph	GO	0	0	0	1	0	0	0	0	0	0
30	Aerangis biloba (Lindl.)Schltr.	Orchidaceae	Ep	GC	0	0	0	0	0	0	1	0	0	0
31	Afraegle paniculata (Schum.)Engl.	Rutaceae	mph	At	0	0	1	0	1	0	0	0	0	0
32	Aframomum alboviolaceum (Ridley)K.Schum.	Zingiberaceae	Gr	SZ	0	0	0	0	1	0	0	0	0	0
33	Aframomum latifolium (Afzel.)K.Schum.	Zingiberaceae	Gr	SZ	0	0	0	0	0	1	0	0	0	0
34	Aframomum sceptrum (Oliv. & Hanb.)K.Schum.	Zingiberaceae	Gr	GC	1	1	0	1	1	1	1	0	1	0
35	Afrotrilepis pilosa (Boeck.)J.Raynal	Cyperaceae	Hc	SG	0	0	0	0	0	1	0	0	0	0
36	Afzelia africana Smith ex Pers.	Leg.-Caes.	mPh	S	0	1	1	0	1	1	1	1	1	1
37	Agelaea pentagyna (Lam.)Baill.	Connaraceae	Lnph	GC	1	1	1	1	1	1	0	0	0	0
38	Aidia genipiflora (DC.)Dandy	Rubiaceae	mph	GC	1	1	1	0	1	1	0	0	0	0
39	Alafia barteri Oliv.	Apocynaceae	Lmph	GC	1	1	1	0	1	1	0	0	0	0
40	Alafia benthamii (Baill. ex Stapf)Stapf	Apocynaceae	Lmph	GC	0	0	0	0	0	0	0	0	1	0
41	Albizia adianthifolia (Schum.)W.Wight	Leg.-Mim.	mPh	GC	1	1	1	0	1	0	0	0	0	0
42	Albizia chevalieri Harms	Leg.-Mim.	mPh	S	0	0	0	0	0	0	0	0	0	1
43	Albizia ferruginea (Guill. & Perr.)Benth.	Leg.-Mim.	mPh	GC	1	1	1	1	1	1	0	0	0	0
44	Albizia glaberrima (Schum. & Thonn.)Benth.	Leg.-Mim.	mph	GC	1	1	1	1	1	1	1	0	0	0
45	Albizia lebbeck (L.)Benth.	Leg.-Mim.	mPh	Pt	1	1	1	0	0	1	0	0	1	0
46	Albizia malacophylla (A.Rich.)Walp.	Leg.-Mim.	mph	SZ	0	0	0	0	0	0	1	0	0	0
47	Albizia zygia (DC.)J.F.Macbr.	Leg.-Mim.	mPh	SG	1	1	1	1	1	1	1	1	1	0
48	Alchornea cordifolia (Schum.& Thonn.)Müll.Arg.	Euphorbiaceae	mph	GC	1	1	0	1	1	0	1	1	1	0
49	Aleurites moluccana (L.)Willd. var. moluccana	Euphorbiaceae	mPh	Pt	0	0	1	0	0	0	0	0	0	0
50	Allophyllus africanus P.Beauv.	Sapindaceae	mph	Pt	1	1	1	0	1	1	1	1	1	0
51	Allophyllus spicatus (Poir.)Radlk.	Sapindaceae	mph	SZ	0	0	1	0	1	1	0	1	1	1
52	Aloe buettneri Berger	Liliaceae	Ch	SZ	0	0	0	0	1	1	1	1	1	0
53	Alstonia congensis Engl.	Apocynaceae	mPh	GC	0	1	0	1	0	0	0	0	0	0
54	Alysicarpus rugosus (Willd.)DC.	Leg.-Pap.	Th	SG	0	0	0	0	1	0	0	1	0	1
55	Amorphophallus aphyllus (Hook.)Hutch.	Araceae	Gt	SZ	0	0	0	0	0	1	0	0	0	0
56	Amorphophallus dracontioides (Engl.)N.E.Br.	Araceae	Gt	SZ	0	0	0	0	0	1	1	0	0	0

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
57	Amorphophallus flavovirens N.E.Br.	Araceae	Gt	GO	0	1	1	0	1	1	0	0	0	0
58	Ampelocissus leonensis (Hook.f.)Planch.	Vitaceae	mph	S	0	1	1	0	1	1	1	1	1	1
59	Amphimas pterocarpoides Harms	Leg.-Pap.	Mph	GC	0	1	0	1	0	0	0	0	0	0
60	Anchomanes difformis (Blume)Engl.	Araceae	Gt	GC	0	1	1	1	1	1	1	1	1	0
61	Anchomanes welwitschii Rendle	Araceae	Gt	SZ	0	0	0	0	1	1	1	1	1	0
62	Ancistrocarpus densispinosus Oliv.	Tiliaceae	mph	GE	0	1	0	0	0	0	0	0	0	0
63	Ancylobotrys scandens (Schumach. & Thonn.)Pichon	Apocynaceae	Lmph	GC	1	1	1	0	0	0	0	0	1	0
64	Andira inermis (Wright)DC.	Leg.-Pap.	mph	SG	0	0	0	0	1	0	1	0	1	0
65	Andropogon chinensis (Nees)Merr.	Poaceae	Hc	SG	0	0	0	0	0	0	0	0	1	1
66	Andropogon gayanus Kunth. var. gayanus	Poaceae	Hc	S	0	0	0	0	1	1	1	1	1	1
67	Andropogon macrophyllus Stapf.	Poaceae	Hc	GC	0	0	0	0	0	1	1	0	0	0
68	Andropogon pseudapricus Stapf	Poaceae	Th	SG	0	0	0	0	0	0	0	1	1	1
69	Andropogon tectorum Schum. & Thonn.	Poaceae	Hc	SG	0	0	1	0	1	1	1	1	1	0
70	Aneilema beninense (P.Beauv.)Kunth	Commelinaceae	Hc	GC	0	0	0	0	0	0	1	1	0	0
71	Aneilema sp.	Commelinaceae	Hc	.	0	0	0	0	1	1	0	0	0	0
72	Angylocalyx oligophyllus (Bak.)Bak.f.	Leg.-Pap.	nph	GC	0	1	1	1	0	0	0	0	0	0
73	Annona senegalensis Pers.	Annonaceae	nph	SZ	0	0	1	0	1	1	1	1	1	1
74	Anogeissus leiocarpa (DC.)Guill. & Perr.	Combretaceae	mPh	S	0	1	1	0	1	1	1	1	1	1
75	Anthocleista djalonensis A.Chev.	Loganiaceae	mPh	SG	1	0	1	0	1	0	0	0	1	0
76	Anthocleista vogelii Planch.	Loganiaceae	mPh	GC	0	1	0	1	1	0	0	0	1	0
77	Anthonotha crassifolia (Baill.)J.Léonard	Leg.-Pap.	mPh	GC	0	1	0	0	0	0	0	0	0	0
78	Anthonotha macrophylla Pal.Beauv.	Leg.-Caes.	mph	GC	0	1	0	1	0	0	0	0	0	0
79	Anthostema aubryanum Baill.	Euphorbiaceae	mPh	GC	0	0	0	1	0	0	0	0	0	0
80	Antiaris toxicaria Lesch.	Moraceae	MPh	GC	1	1	1	1	1	1	1	1	1	0
81	Antidesma laciniatum Müll.Arg.	Euphorbiaceae	mph	GC	0	1	0	0	0	0	0	0	0	0
82	Antidesma membranaceum Müll.Arg.	Euphorbiaceae	mph	GC	0	1	1	0	1	1	0	0	0	0
83	Antidesma venosum Tul.	Euphorbiaceae	mph	SG	0	0	1	1	1	1	1	1	1	0
84	Aphania senegalensis (Juss. ex Poir.)Radlk.	Sapindaceae	mph	SG	0	1	1	0	1	1	0	0	0	0
85	Apodostigma pallens (Planch. ex Oliv.)Wilczek	Hippocrateaceae	Lmph	SG	0	0	0	0	0	0	0	0	1	0
86	Argocoffeopsis rupestris (Hiern)Robbr.	Rubiaceae	nph	GC	0	1	0	0	1	0	0	0	0	0
87	Aristida kerstingii Pilg.	Poaceae	Th	SZ	0	0	0	0	0	0	0	0	1	1
88	Aristolochia albida Duchartre	Aristolochiaceae	Lmph	SG	0	1	1	0	1	1	1	0	0	1
89	Artabotrys dahomensis Engl. & Diels.	Annonaceae	Lnph	GE	1	1	1	0	0	0	0	0	0	0
90	Artabotrys velutinus Sc.Elliot	Annonaceae	Lnph	GC	1	1	1	0	1	0	0	0	0	0
91	Asparagus africanus Lam.	Liliaceae	nph	SZ	0	0	0	0	1	1	1	1	1	1
92	Asparagus flagellaris (Kunth.)Bak.	Liliaceae	Lnph	SZ	0	0	0	0	0	0	1	1	1	0
93	Asparagus warneckei (Engl.)Hutch.	Araceae	Lnph	GO	0	1	1	0	0	0	0	0	0	0
94	Aspilia africana (Pers.)	Asteraceae	Th	SG	0	0	1	0	1	1	1	1	1	0
95	Aspilia bussei (Schum. & Thonn.)Oliv. & Hiern	Asteraceae	Th	SG	0	0	0	0	1	1	1	1	0	1
96	Aspilia paludosa Berhaut	Asteraceae	Th	SZ	0	0	0	0	0	0	1	0	0	0
97	Aspilia rudis Oliv. & Hiern	Asteraceae	Ch	SZ	0	0	0	0	1	1	1	1	1	1
98	Asystasia gangetica (L.)T.Anders	Acanthaceae	Th	Pt	0	0	1	0	1	1	0	0	0	0
99	Aubrevillea kerstingii (Harms)Pellegr.	Leg.-Mim.	MPh	GC	0	0	0	0	1	0	0	0	0	0
100	Avicennia germinans (L.)L.	Avicenniaceae	mPh	GC	1	0	0	0	0	0	0	0	0	0
101	Baissea zygodioides (K.Schum.)Stapf	Apocynaceae	Lmph	GC	1	1	1	1	0	0	0	0	0	0
102	Balanites aegyptiaca (L.)Del.	Balanitaceae	mph	SZ	0	0	0	0	0	0	0	1	1	1
103	Bambekea racemosa Cogn.	Cucurbitaceae	Lmph	GC	0	1	0	0	0	0	0	0	0	0
104	Bambusa vulgaris Schrad.ex J.C.Wendl.	Poaceae	Gr	SG	0	1	1	0	0	0	0	0	0	0
105	Baphia nitida Lodd.	Leg.-Pap.	mph	GC	1	1	1	0	0	0	0	0	0	0
106	Barleria opaca (Vahl)Ness	Acanthaceae	nph	GC	0	1	0	0	0	0	0	0	0	0
107	Barteria nigritiana Hook.f.	Passifloraceae	mph	GE	1	0	0	0	0	0	0	0	0	0
108	Beilschmiedia mannii (Meisn.)Benth. & Hook.f.	Lauraceae	mph	GC	0	1	0	0	0	0	0	0	0	0
109	Belonophora hypoglauca (Welw. ex Hiern)A.Chev.	Rubiaceae	mph	GC	0	0	0	0	1	0	0	0	1	0
110	Berlinia grandiflora (Vahl)Hutch. & Dalziel	Leg.-Caes.	mPh	SG	0	1	0	1	1	1	1	1	1	0
111	Bewsia biflora (Hack.)Gooss.	Poaceae	Hc	SZ	0	0	0	0	0	0	0	0	1	0
112	Bidens pilosa L.	Asteraceae	Th	SG	0	0	1	0	0	0	0	0	0	0
113	Biophytum umbraculum Welw. Syn. B. petersianum Klotzsch	Oxalidaceae	Th	PAL	0	0	0	0	1	1	1	0	0	1
114	Blepharis linariifolia Pers.	Acanthaceae	Th	SZ	0	0	0	0	0	0	0	0	1	1
115	Blepharis maderaspatensis (L.)Heyne	Acanthaceae	Ch	SG	0	0	0	0	0	0	0	0	1	1
116	Blighia sapida Koenig	Sapindaceae	mPh	Pt	1	1	1	1	1	0	1	1	0	0

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
117	Blighia unijugata Bakker	Sapindaceae	mph	GC	1	1	1	1	1	0	0	0	1	0
118	Blumea pterodonta DC.	Asteraceae	Th	PAL	0	0	1	0	0	0	1	1	0	1
119	Blutaparon vermiculare (L.)Mears	Amaranthaceae	Ch	PAL	1	0	0	0	0	0	0	0	0	0
120	Bombax buonopozense P.Beauv.	Bombacaceae	MPh	GC	0	1	0	0	0	0	0	0	0	1
121	Bombax costatum Pellegr. & Vuill.	Bombacaceae	mph	S	0	0	0	0	1	1	1	1	1	1
122	Borassus aethiopum Mart.	Arecaceae	mPh	SZ	0	0	0	0	1	1	1	1	1	1
123	Brachiaria brizantha (A.Rich.)Stapf	Poaceae	Hc	SG	0	0	0	0	0	0	0	1	0	0
124	Brachiaria deflexa (Schumach.)Robyns	Poaceae	Th	M	0	0	0	0	1	1	0	0	0	0
125	Brachiaria jubata (Figari & De Notaris)Stapf.	Poaceae	Hc	SZ	0	0	0	0	0	1	1	1	0	0
126	Brachiaria ruziziensis R.Germ. & Evrard	Poaceae	Hc	GC	0	0	0	0	0	1	0	0	0	0
127	Brachiaria serrata (Thunb.)Stapf. Syn. B. brachylopha Stapf.	Poaceae	Hc	SZ	0	0	0	0	0	0	1	0	0	0
128	Brachiaria villosa (Lam.)A.Camus Syn. B. distichophylla (Trin.)Stapf.	Poaceae	Th	SZ	0	0	0	0	0	1	1	0	0	0
129	Brachystelma togoense Schlechter	Asclepiadaceae	Gt	SZ	0	0	0	0	0	1	0	0	0	0
130	Bridelia atroviridis Müll.Arg.	Euphorbiaceae	mph	GC	0	1	0	0	1	0	0	0	0	0
131	Bridelia ferruginea Benth.	Euphorbiaceae	mph	SG	0	0	1	0	1	1	1	1	1	1
132	Bridelia grandis Pierre ex Hutch.	Euphorbiaceae	mPh	GC	0	1	0	0	0	0	0	0	0	0
133	Bridelia micrantha (Hochst.)Baill.	Euphorbiaceae	mPh	SG	0	1	1	0	0	0	0	1	0	0
134	Bridelia scleroneura Müll.Arg	Euphorbiaceae	mph	S	0	0	0	0	0	0	1	1	1	1
135	Broenadia salicina (Vahl)Hepper & Wood	Rubiaceae	mPh	SZ	0	0	0	0	0	0	0	0	1	0
136	Burkea africana Hook.	Leg.-Caes.	mph	SZ	0	0	0	0	1	1	1	1	1	1
137	Cadaba farinosa Forsk.	Capparaceae	Lmph	PAL	0	0	0	0	0	0	0	0	0	1
138	Calliandra portoricensis (Jacq.)Benth.	Leg.-Mim.	Lmph	Pt	0	0	0	0	1	0	0	0	0	0
139	Callichilia barteri (Hook.f.)Stapf	Apocynaceae	nph	GC	0	1	0	1	1	0	0	0	0	0
140	Caloncoba echinata (Oliv.)Gilg	Flacourtiaceae	mph	GO	0	0	1	0	0	0	0	0	0	0
141	Calotropis procera (Aiton)W.T.Aiton	Asclepiadaceae	mph	SG	0	0	0	0	0	0	0	0	0	1
142	Calycobolus africanus (G.Don)Heine	Convolvulaceae	Lnph	GC	1	1	1	0	0	0	0	0	0	0
143	Calyptrochilum emarginatum (Sw.)Schltr.	Orchidaceae	Ep	GC	0	0	1	0	1	0	1	1	1	0
144	Campylospermum flavum (Schumach. & Thonn. ex Stapf)Farron	Ochnaceae	nph	GC	0	1	1	1	0	0	0	0	0	0
145	Campylospermum glaberrimum (P.Beauv.)Farron	Ochnaceae	nph	GC	0	0	1	1	0	0	0	0	0	0
146	Campylostemon warneckeanum Loes. ex Fritsch	Celastraceae	Lmph	GC	0	1	1	0	1	0	0	0	0	0
147	Canarium schweinfurthii Engl.	Burseraceae	mPh	GC	0	1	0	0	0	0	0	0	0	0
148	Canavalia ensiformis (Linn.)DC.	Leg.-Pap.	Lnph	SZ	0	0	1	0	0	0	0	0	0	0
149	Caperomia serrata (Turcz.)C.Presl Syn. C. senegalensis Müll.Arg.	Euphorbiaceae	Th	SG	0	0	0	0	0	0	0	0	0	1
150	Capparis erythrocarpos Isert	Capparaceae	nph	GC	1	1	1	0	1	1	1	0	0	0
151	Capparis brassii DC. Syn. C. thonningii Schum.	Capparaceae	Lnph	GC	1	1	1	0	1	0	0	0	0	0
152	Capparis sepiaria L. var. fischeri (Pax)De Wolf	Capparaceae	Lnph	SZ	0	0	0	0	1	0	0	1	1	1
153	Capparis viminea Hook.f. & Thoms. ex Oliv.	Capparaceae	Lmph	GE	0	1	0	0	0	0	0	0	0	0
154	Carapa procera DC.	Meliaceae	mPh	GC	0	0	1	1	0	0	0	0	0	0
155	Cardiospermum halicacabum L.	Sapindaceae	Lmph	Pt	0	1	1	0	1	0	1	0	0	0
156	Carissa edulis (Forssk.)Vahl	Apocynaceae	nph	PAL	0	0	1	0	0	1	0	0	0	0
157	Carpolobia lutea G.Don	Polygalaceae	mph	GC	1	1	1	1	0	0	0	0	0	0
158	Casearia calodendron Gilg	Flacourtiaceae	mph	GO	1	1	0	0	0	0	0	0	0	0
159	Cassia sieberiana DC.	Leg.-Caes.	mPh	S	0	1	1	0	1	0	1	1	1	1
160	Cassia sp	Leg.-Caes.	nph	.	0	0	0	0	0	0	0	1	0	0
161	Cassipourea barteri (Hook.f.)N.E.Br.	Rhizophoraceae	mPh	GC	1	0	0	0	0	0	0	0	0	0
162	Cassipourea congoensis DC.	Rhizophoraceae	mph	SG	0	1	1	1	1	1	0	0	0	0
163	Ceiba pentandra (L.)Gaertn.	Bombacaceae	MPh	Pt	1	1	1	1	1	1	0	1	0	0
164	Celosia isertii Towns.	Amaranthaceae	Lnph	GC	0	0	0	0	0	0	1	0	0	0
165	Celosia laxa Schum. & Thonn.	Amaranthaceae	LTh	PAL	0	1	0	0	0	0	0	0	0	0
166	Celosia trigyna L.	Amaranthaceae	Th	PAL	1	1	1	1	0	0	0	0	0	0
167	Celtis mildbraedii Engl.	Celtidaceae	mPh	GC	0	1	1	0	0	0	0	0	0	0
168	Celtis prantlii Priemer ex Engl. Syn. C. brownii Rendle	Celtidaceae	mph	GC	1	1	1	1	1	1	0	0	0	0
169	Celtis toka (Forssk.)Hepper & Wood Syn. C. integrifolia Lam.	Celtidaceae	mPh	SZ	0	0	0	0	1	0	0	1	1	1
170	Celtis zenkeri Engl.	Celtidaceae	MPh	GC	0	1	1	1	1	1	0	0	0	0
171	Centaurea praecocox Oliv. & Hiern	Asteraceae	Hc	SZ	0	0	0	0	0	0	0	0	1	0
172	Centrosema pubescens Benth.	Leg.-Pap.	Lmph	GC	1	1	1	0	0	0	1	0	0	0
173	Ceratotheca sesamoides Endl.	Pedaliaceae	Ch	SZ	0	0	0	0	0	0	0	1	1	1
174	Cercestis mirabilis (N.E.Br.)Bogner	Araceae	mPhEp	GE	0	1	1	1	0	0	0	0	0	0
175	Ceropegia fusiformis N.E.Br.	Asclepiadaceae	Gt	GO	0	1	0	0	0	0	0	0	0	0
176	Ceropegia racemosa N.E.Br.	Asclepiadaceae	Gt	SG	0	0	0	0	0	0	1	0	0	0

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
177	Ceropegia yorubana Schlechter	Asclepiadaceae	Gt	GO	1	1	0	0	0	0	0	0	0	0
178	Chaetacme aristata Planch.	Celtidaceae	mph	GC	0	1	1	0	0	0	0	0	0	0
179	Chamaecrista absus (L.)H.S.Irwin & Barneby	Leg.-Caes.	Ch	PAL	0	0	0	0	0	0	0	1	0	1
180	Chamaecrista mimosoides Stapf Syn. Cassia mimosoides L.	Leg.-Mim.	Ch	PAL	0	0	0	0	1	1	1	1	1	1
181	Chasmanthera dependens Hochst.	Menispermaceae	Lnph	GC	0	1	0	0	1	0	0	0	0	0
182	Chassalia kolly (Schumach.)Hepper	Rubiaceae	nph	GC	1	1	1	1	1	1	0	1	1	0
183	Chionanthus mannii (Soler.)Stearn Syn. Linociera mannii Soler.	Oleaceae	mph	GC	0	1	1	0	0	0	0	0	0	0
184	Chionanthus niloticus (Oliv.)Stearn Syn. Linociera nilotica Oliv.	Oleaceae	mph	SG	0	0	0	0	1	0	1	1	1	0
185	Chlorophytum blepharophyllum Schweinf.	Liliaceae	Hc	SZ	0	0	0	0	0	0	1	0	0	0
186	Chlorophytum inornatum Ker-Gawl.	Liliaceae	Gt	GO	0	1	0	0	0	0	0	0	0	0
187	Chlorophytum macrophyllum (A.Rich.)Aschers.	Liliaceae	Gt	SG	0	0	1	0	0	1	1	1	0	0
188	Chlorophytum togoense Engl.	Liliaceae	Gt	SG	0	0	0	0	1	0	1	0	0	0
189	Christiana africana DC.	Tiliaceae	mPh	Pt	0	0	1	0	1	0	0	0	0	0
190	Chromolaena odorata (L.)R.King & H.Robinson	Asteraceae	nph	Pt	1	1	1	1	1	1	1	0	0	0
191	Chrysanthellum indicum DC. Subsp. afroamericanum B.L.Turner	Asteraceae	Th	Pt	0	0	0	0	0	0	0	1	0	0
192	Chrysobalanus icaco L. subsp. atacorensis (A.Chev.)F.White	Chrysobalanaceae	mPh	SZ	0	0	0	0	0	0	0	0	1	0
193	Chrysobalanus icaco L. subsp. icaco	Chrysobalanaceae	mph	GC	1	0	0	0	0	0	0	0	0	0
194	Chrysophyllum albidum G.Don	Sapotaceae	mPh	GC	0	1	1	0	1	0	0	0	0	0
195	Chytranthus macrobotrys (Gilg.)Exell & Mendonça	Sapindaceae	mph	GC	0	1	0	0	0	0	0	0	0	0
196	Cienfuegosia heteroclada Sprague	Malvaceae	Hc	SZ	0	0	0	0	0	0	0	0	0	1
197	Cissus aralioides (Welw. ex Baker)Planch.	Vitaceae	Lnph	SG	0	1	0	0	1	0	1	1	1	0
198	Cissus corylifolia (Baker)Planch.	Vitaceae	Gr	GC	0	0	0	0	0	0	1	1	0	0
199	Cissus cymosa Schum. & Thonn.	Vitaceae	LmPh	SZ	0	0	1	0	1	0	0	0	1	0
200	Cissus doeringii Gilg & M.Brandt	Vitaceae	Hc	SG	0	0	0	0	0	0	1	1	0	1
201	Cissus glaucophylla Hook.	Vitaceae	Lnph	GC	1	1	1	0	1	0	0	0	0	0
202	Cissus gracilis Guill. & Perr.	Vitaceae	mph	GO	0	1	1	0	0	0	0	0	0	0
203	Cissus palmatifida (Baker)Planch.	Vitaceae	Lnph	SZ	0	0	0	0	1	1	1	0	1	0
204	Cissus petiolata Hook.f.	Vitaceae	Lnph	GC	0	1	1	0	1	0	0	0	0	0
205	Cissus populnea Guill. & Perr. var. populnea	Vitaceae	LHc	S	0	0	1	0	1	1	1	1	1	1
206	Cissus quadrangularis L.	Vitaceae	Lmph	SZ	1	1	1	0	0	1	1	0	0	1
207	Cissus rufescens Guill. & Perr.	Vitaceae	Gr	SZ	0	0	1	0	1	1	1	0	0	0
208	Clappertonia ficifolia (Willd.)DC.	Tiliaceae	nph	GC	1	0	0	0	0	0	0	0	0	0
209	Clausena anisata (Willd.)Benth.	Rutaceae	mph	SG	1	1	1	0	1	1	0	0	0	0
210	Cleistopholis patens (Benth.)Engl. & Diels	Annonaceae	mPh	GC	1	1	1	1	1	0	0	0	0	0
211	Clematis hirsuta Guill. & Perr. var. hirsuta	Ranunculaceae	LHc	SZ	0	0	0	0	0	0	1	0	0	0
212	Clerodendrum capitatum (Willd.)Schum. & Thonn.	Verbenaceae	Lmph	GC	1	1	1	0	1	1	1	1	1	1
213	Clerodendrum inaequipetiolatum Good	Verbenaceae	Lmph	GE	0	1	0	0	0	0	0	0	0	0
214	Clerodendrum polycephalum Baker	Verbenaceae	mph	GC	0	0	0	0	0	0	0	1	0	0
215	Clerodendrum thyrsoideum Gürke	Verbenaceae	Lmph	GC	0	0	0	1	0	0	0	0	0	0
216	Clerodendrum volubile P.Beauv. var. volubile	Verbenaceae	Lmph	GC	1	0	0	0	0	0	0	0	0	0
217	Cnestis ferruginea Vahl ex DC.	Connaraceae	nph	GC	1	1	1	1	1	1	0	0	0	0
218	Cnestis longiflora Schellenb.	Connaraceae	Lmph	GC	1	1	1	1	1	0	0	0	0	0
219	Coccinia grandis (L.)Voigt	Cucurbiutaceae	Lmph	GC	1	1	1	0	1	0	0	0	0	0
220	Cochlospermum planchoni Hook.f.	Cochlospermaceae	nph	SG	0	0	0	0	0	1	1	1	1	1
221	Cochlospermum tinctorium Perr. ex A.Rich.	Cochlospermaceae	nph	S	0	0	0	0	1	0	0	1	1	1
222	Coelocaryon preussii Warb.	Myristicaceae	mPh	GC	0	1	0	0	0	0	0	0	0	0
223	Coffea ebracteolata (Hiern)Brenan	Rubiaceae	Lnph	GC	0	1	1	0	1	0	0	0	0	0
224	Cola gigantea A.Chev.	Sterculiaceae	mPh	GC	1	1	1	1	1	1	0	0	0	0
225	Cola lateritia K.Schum.	Sterculiaceae	mph	GC	0	0	0	1	0	0	0	0	0	0
226	Cola laurifolia Mast.	Sterculiaceae	mPh	SG	0	0	1	1	0	1	1	0	1	1
227	Cola millenii K.Schum.	Sterculiaceae	mph	GC	1	1	1	1	1	1	0	0	0	0
228	Cola nitida (Vent.)Schott. & Endl.	Sterculiaceae	mph	GC	0	1	1	0	0	0	0	0	0	0
229	Coldenia procumbens L.	Boraginaceae	Th	SZ	0	0	0	0	0	0	0	0	0	1
230	Combretum acutum Laws	Combretaceae	Lmph	S	0	0	0	0	0	0	0	0	0	1
231	Combretum adenogonium Steud. ex A.Rich.	Combretaceae	mph	SG	0	0	1	0	0	1	1	1	1	1
232	Combretum bipindense Engl. & Diels	Combretaceae	LmPh	GC	0	0	1	0	0	0	0	0	0	0
233	Combretum collinum Fresen	Combretaceae	mph	SG	0	0	1	0	1	1	1	1	1	1
234	Combretum dolichopetalum Engl. & Diels	Combretaceae	Lmph	GC	0	1	1	1	0	0	0	0	0	0
235	Combretum glutinosum Perr. ex DC.	Combretaceae	mph	S	0	0	0	0	0	0	0	1	1	1
236	Combretum hispidum Laws	Combretaceae	Lnph	GC	0	1	0	0	0	0	0	0	0	0

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
237	Combretum indicum (L.)Jongkind Syn. Quisqualis indica L.	Combretaceae	LmPh	Pt	0	0	1	1	0	1	0	0	0	1
238	Combretum lecardii Engl. & Diels	Combretaceae	Lnph	SG	0	0	1	0	0	0	0	1	1	0
239	Combretum micranthum G.Don	Combretaceae	mph	S	0	0	0	0	0	0	0	1	1	1
240	Combretum molle R.Br. ex G.Don	Combretaceae	mph	SZ	0	0	1	0	1	1	1	1	1	1
241	Combretum mucronatum Schum. & Thonn.	Combretaceae	Lnph	GC	0	1	1	0	1	0	1	0	1	0
242	Combretum nigricans Lepr. ex Guill. & Perr.	Combretaceae	mph	S	0	0	0	0	1	1	1	1	1	1
243	Combretum paniculatum Vent.	Combretaceae	Lnph	SG	0	1	1	1	1	1	1	1	1	0
244	Combretum platypterum (Welw.)Hutch.	Combretaceae	Lmph	GC	0	1	0	0	0	0	0	0	0	0
245	Combretum racemosum P.Beauv.	Combretaceae	Lmph	GC	0	1	1	1	1	1	0	0	1	0
246	Combretum sericeum G.Don	Combretaceae	Hc	SZ	0	0	0	0	0	0	0	0	1	0
247	Commelina benghalensis L. var. bengalensis	Commelinaceae	Hc	GC	0	0	0	0	1	0	1	1	0	1
248	Commelina diffusa Burm.f. subsp. diffusa	Commelinaceae	Hc	Pt	0	0	1	0	1	1	1	1	1	0
249	Commelina nigritana Benth.	Commelinaceae	Hc	SZ	0	0	0	0	0	0	0	1	0	0
250	Commiphora pedunculata (Kotschy & Peyr.)Engl.	Burseraceae	nph	SZ	0	0	0	0	0	0	0	0	1	0
251	Connarus africanus Lam.	Connaraceae	mph	GC	0	1	0	1	0	0	0	0	0	0
252	Conocarpus erectus L.	Combretaceae	mph	PAL	1	0	0	0	0	0	0	0	0	0
253	Corchorus olitorus L.	Tiliaceae	Ch	Pt	0	0	0	0	0	0	0	0	0	1
254	Cordia platythyrsa Baker	Boraginaceae	mph	SG	0	1	0	0	0	0	0	0	0	0
255	Cordia senegalensis Juss.	Boraginaceae	nph	GC	0	1	0	0	0	0	0	0	0	0
256	Cordyla pinnata (Lepr. ex A.Rich.)Milne-Redh.	Leg.-Caes.	mPh	S	0	0	0	0	0	0	1	1	0	0
257	Costus afer Ker-Gawl.	Zingiberaceae	Gr	At	0	1	1	0	1	0	1	1	0	1
258	Costus spectabilis (Fenzl)K.Schum.	Zingiberaceae	Gt	SZ	0	0	0	0	1	0	1	1	0	0
259	Crassocephalum rubens (Juss. ex Jacq)S.Moore	Asteraceae	Th	Pt	0	0	0	0	1	0	0	0	0	0
260	Crateva adansonii DC. subsp. adansonii	Capparaceae	mph	PAL	0	0	0	0	0	1	1	1	1	1
261	Cremaspora triflora (Thonn.)K.Schum.	Rubiaceae	nph	At	1	1	1	1	1	1	0	1	1	0
262	Crinum jagus (Thomps.)Dandy	Amaryllidaceae	Gb	SG	0	0	0	1	0	1	0	0	0	0
263	Crinum nubicum Hann. Syn.C. humile A.Chev.	Amaryllidaceae	Gb	SZ	0	0	0	0	0	1	1	0	0	0
264	Crossopteryx febrifuga (G. Don)Benth.	Rubiaceae	mph	SZ	0	0	0	0	1	1	1	1	1	1
265	Crotalaria cleomifolia Welw. ex Baker	Leg.-Pap.	Ch	SZ	0	0	0	0	0	0	0	0	0	1
266	Crotalaria gorensis Guill. & Perr.	Leg.-Pap.	Ch	SG	0	0	0	0	0	0	0	0	0	1
267	Crotalaria macrocalyx Benth.	Leg.-Pap.	Ch	SZ	0	0	0	0	1	0	0	0	1	1
268	Crotalaria microcarpa Hochst. ex Benth.	Leg.-Pap.	Ch	SZ	0	0	0	0	1	0	0	0	0	0
269	Crotalaria pallida Aiton	Leg.-Pap.	Ch	Pt	1	0	0	0	0	0	1	0	0	0
270	Croton nigritanus Scott-Elliot	Euphorbiaceae	nph	GC	0	0	0	1	0	0	0	0	0	0
271	Crudia senegalensis Planch. ex Benth.	Leg.-Caes.	mPh	GC	0	1	0	1	0	0	0	0	0	0
272	Cryptolepis sanguinolenta (Lind.)Schltr.	Asclepiadaceae	Lmph	SG	0	0	0	0	0	0	0	0	1	0
273	Ctenium elegans Kunth	Poaceae	Th	S	0	0	0	0	0	0	0	1	0	1
274	Ctenium newtonii Hack.	Poaceae	Hc	SG	0	0	0	0	0	0	0	0	0	1
275	Culcasia barombensis N.E.Br. Syn. C. angolensis Welw. ex Schott	Araceae	Lmph	GO	0	1	0	0	0	0	0	0	0	0
276	Culcasia saxatilis A.Chev.	Araceae	LmPh	GC	0	1	1	1	0	0	0	0	0	0
277	Culcasia scandens P.Beauv.	Araceae	Lmph	GC	1	1	1	1	1	0	1	0	0	0
278	Curculigo pilosa (Schum. & Thonn.)Engl.	Hypoxidaceae	Gr	PAL	0	0	1	0	1	1	1	1	0	0
279	Cussonia arborea Hochst. ex A.Rich.	Araliaceae	mph	S	0	0	0	0	1	1	1	1	1	1
280	Cuviera acutiflora DC.	Rubiaceae	mph	GC	0	1	0	0	0	0	0	0	0	0
281	Cuviera macroura K.Schum.	Rubiaceae	mph	GC	0	1	0	1	0	0	0	0	0	0
282	Cyanotis angusta C.B.Clarke	Commelinaceae	Gb	SZ	0	0	0	0	0	0	0	1	0	0
283	Cyanotis caespitosa Kotschy & Peyr.	Commelinaceae	Hc	SZ	0	0	0	0	1	0	0	0	0	0
284	Cyanotis lanata Benth.	Commelinaceae	Ch	SG	0	0	1	0	0	1	0	0	0	0
285	Cyanotis longifolia Benth.	Commelinaceae	Hc	SG	0	0	0	0	0	0	1	1	0	0
286	Cyathula prostrata (L.)Blume	Amaranthaceae	Th	Pt	0	0	1	0	1	0	1	0	0	0
287	Cyclosorus dentatus (Forssk.)Ching.	Thelypteridaceae	Ch	Pt	0	0	0	0	0	0	0	0	1	0
288	Cyclosorus striatus Cop.	Thelypteridaceae	Ch	GC	0	1	1	1	0	0	0	0	0	0
289	Cynometra megalophylla Harms	Leg.-Caes.	mPh	GC	0	0	1	1	0	1	0	0	0	0
290	Cynometra vogelii Hook.	Leg.-Caes.	mPh	GC	0	0	0	1	0	0	0	0	0	0
291	Cyperus laxus Lam.	Cyperaceae	Hc	GC	0	0	1	0	0	0	0	0	0	0
292	Cyperus rotundus L.	Cyperaceae	Gt	Pt	0	0	1	0	0	0	0	0	0	0
293	Cyperus sphacelatus Rottb.	Cyperaceae	Hc	Pt	0	0	0	0	0	1	1	0	0	0
294	Cyperus tenuiculmis Boeck.	Cyperaceae	HC	SG	0	0	0	0	0	0	1	0	0	0
295	Cyphostemma flavicans (Baker)Descoings	Vitaceae	Gt	SG	0	0	0	0	1	1	1	1	1	1
296	Cyphostemma crotalarioides (Planch.)Desc. ex Wild & R.B.Drumm.	Leg.-Pap.	Hc	SZ	0	0	0	0	1	0	1	1	1	1

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
297	Cyphostemma jatrophoides (Welw. ex Baker)Desc.	Vitaceae	Hc	SZ	0	0	0	0	0	1	0	1	1	0
298	Cyrtorchis ringens (Rchb.f.)Summerh.	Orchidaceae	Ep	GC	0	0	0	0	1	0	1	0	1	0
299	Dalbergia ecastaphyllum (L.)Taub.	Leg.-Pap.	mph	AN	1	0	0	0	0	0	0	0	0	0
300	Dalbergia afzeliana G.Don	Leg.-Pap.	LmPh	GC	0	1	1	1	1	0	0	0	1	0
301	Dalbergia lactea Vatke	Leg.-Pap.	Lmph	GE	1	1	1	1	1	0	1	0	0	0
302	Dalbergia saxatilis Hook.f. var. saxatilis	Leg.-Pap.	Lnph	GC	0	0	0	1	0	0	0	0	1	0
303	Dalbergia setifera Hutch. & Dalziel	Leg.-Pap.	mph	GO	1	0	0	0	0	0	0	0	0	0
304	Dalbergiella welwitschii (Baker)Baker f.	Leg.-Pap.	Lmph	GC	0	0	0	1	1	1	1	1	0	0
305	Daniellia oblonga Oliv.	Leg.-Caes.	MPh	GE	0	1	0	0	0	0	0	0	0	0
306	Daniellia oliveri (Rolfe)Hutch. & Dalziel	Leg.-Caes.	mPh	SZ	0	0	1	0	1	1	1	1	1	1
307	Deinbollia pinnata (Poir.)Schumach. & Thonn.	Sapindaceae	nph	GC	1	1	1	0	1	1	0	0	0	0
308	Dennettia tripetala Baker f.	Annonaceae	mph	GC	0	0	1	0	0	0	0	0	0	0
309	Desmodium adscendens (Sw.)DC.	Leg.-Pap.	Ch	GC	1	0	0	1	0	0	0	0	1	0
310	Desmodium gangeticum (L.)DC.	Leg.-Pap.	nph	PAL	0	0	1	0	1	1	1	1	1	1
311	Desmodium ramosissimum G.Don	Leg.-Pap.	Th	PAL	0	0	0	0	1	0	1	0	0	0
312	Desmodium salicifolium (Poir.)DC. var. salicifolium	Leg.-Pap.	nph	SG	0	0	1	0	1	1	1	1	1	1
313	Desmodium velutinum (Willd.)DC.	Leg.-Pap.	Ch	PAL	0	0	1	0	1	1	1	1	1	1
314	Detarium microcarpum Harms	Leg.-Caes.	mph	S	0	0	0	0	1	1	1	1	1	1
315	Detarium senegalense J.F.Gmel.	Leg.-Caes.	mPh	SG	0	1	1	0	1	0	0	0	0	0
316	Dialium guineense Willd.	Leg.-Caes.	mPh	GC	1	1	1	1	1	1	1	0	1	0
317	Dichapetalum crassifolium Chodat var. crassifolium	Dichapetalaceae	Lmph	GC	1	1	0	0	0	0	0	0	0	0
318	Dichapetalum madagascariense Poir	Dichapetalaceae	Lmph	GC	1	1	1	1	1	1	0	0	0	0
319	Dichapetalum oblongum (Hook.f. ex Benth.)Engl	Dichapetalaceae	nph	GC	0	0	1	1	0	1	0	0	0	0
320	Dichapetalum pallidum (Oliv.)Engl.	Dichapetalaceae	mph	GC	0	1	0	0	0	0	0	0	0	0
321	Dichapetalum toxicarium (G.Don)	Dichapetalaceae	mph	GO	0	0	0	1	0	0	0	0	0	0
322	Dichrostachys cinerea (L.)Wight & Arn	Leg.-Mim.	nph	SG	0	0	0	0	1	1	1	1	1	1
323	Dicoma sessiliflora Harv.	Asteraceae	Hc	SZ	0	0	0	0	0	1	0	0	0	0
324	Dicoma tomentosa Cass.	Asteraceae	Th	Pt	0	0	0	0	0	0	1	1	0	0
325	Dictyandra arborescens Hook.f.	Rubiaceae	mph	GE	1	1	1	0	0	0	0	0	0	0
326	Dictyandra involucrata (Hook.f.)Hiern	Rubiaceae	Lnph	GC	0	1	1	0	0	0	0	0	0	0
327	Digitaria diagonalis (Nees)Stapf	Poaceae	Hc	SG	0	0	0	0	0	0	0	1	0	0
328	Dioclea reflexa Hook.f.	Leg.-Pap.	Lmph	Pt	1	1	1	1	0	0	0	0	0	0
329	Dioscorea abyssinica Hochst. ex Kunth	Dioscoraceae	Gt	SG	0	0	0	0	0	0	1	0	0	0
330	Dioscorea bulbifera L. var. bulbifera	Dioscoraceae	Gt	Pt	1	0	1	0	1	1	1	1	1	1
331	Dioscorea dumetorum (Kunth)Pax	Dioscoraceae	Gt	SZ	0	1	0	0	1	1	1	1	1	1
332	Dioscorea hirtiflora Benth. subsp. hirtiflora	Dioscoraceae	Gt	SZ	0	1	1	0	1	1	0	0	0	0
333	Dioscorea odoratissima Pax	Dioscoraceae	Gt	SG	1	1	1	0	1	1	0	0	0	0
334	Dioscorea preussii Pax	Dioscoraceae	Gt	GC	0	1	1	0	0	0	0	0	0	0
335	Dioscorea quartiniana A.Rich.	Dioscoraceae	Gt	SZ	0	1	1	0	1	1	0	0	0	0
336	Dioscorea sansibarensis Pax	Dioscoraceae	Gt	GC	0	0	0	0	0	0	1	0	1	0
337	Dioscorea smilacifolia De Wild.	Dioscoraceae	Gt	GC	1	1	1	0	0	0	0	0	0	0
338	Dioscoreophyllum cumminsii (Stapf)Diels	Menispermaceae	Lnph	GC	0	1	1	0	0	0	0	0	0	0
339	Diospyros abyssinica (Hiern)F.White	Ebenaceae	mPh	GC	0	0	1	0	1	1	0	0	1	0
340	Diospyros mespiliformis Hochst. ex A.DC.	Ebenaceae	mPh	SZ	0	0	1	1	1	1	1	1	1	1
341	Diospyros monbuttensis Gürke	Ebenaceae	mph	GC	0	1	1	1	1	1	0	0	0	0
342	Diospyros soubreana F.White	Ebenaceae	nph	GC	0	1	1	0	1	0	0	0	0	0
343	Diospyros tricolor (Schum. & Thonn.)Hiern	Ebenaceae	nph	GC	1	0	0	0	0	0	0	0	0	0
344	Dissotis thollonii Cogn. ex Buett.	Melastomataceae	Ch	GC	0	0	0	0	0	0	0	0	1	0
345	Distemonanthus benthamianus Baill.	Leg.-Caes.	mPh	GC	0	1	0	0	0	0	0	0	0	0
346	Dolichos stenophyllus Harms	Leg.-Pap.	Hc	SZ	0	0	0	0	0	1	0	0	0	0
347	Dombeya ledermannii Engl.	Sterculiaceae	mph	SZ	0	0	0	0	1	0	0	0	0	0
348	Dombeya quinqueseta (Del.)Exell	Sterculiaceae	mph	At	0	0	0	0	0	0	0	1	1	1
349	Dovyalis afzelii Gilg	Flacourtiaceae	mph	GO	0	0	1	0	0	0	0	0	0	0
350	Dracaena arborea (Willd.)Link	Dracaenaceae	mph	GC	1	1	1	1	1	1	0	1	0	0
351	Dracaena fragrans (L.)Ker Gawl.	Dracaenaceae	mph	GC	0	1	0	0	0	0	0	0	0	0
352	Dracaena mannii Bakker	Dracaenaceae	nph	GC	0	1	0	0	0	0	0	0	0	0
353	Dracaena surculosa Lindl. var. surculosa	Dracaenaceae	nph	GC	0	1	1	1	1	0	0	0	0	0
354	Dregea crinita (Oliv.)Bullock	Asclepiadaceae	Lmph	GC	0	1	0	0	0	0	0	0	0	0
355	Drypetes aframensis Hutch.	Euphorbiaceae	mph	GO	0	0	1	0	0	0	0	0	0	0
356	Drypetes floribunda (Müll.Arg.)Hutch.	Euphorbiaceae	mph	GC	1	1	1	0	1	1	0	0	0	0

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
357	Drypetes gilgiana (Pax)Pax & Hoffm.	Euphorbiaceae	nph	GC	0	0	1	0	0	0	0	0	0	0
358	Drypetes principum (Müll.Arg.)Hutch.	Euphorbiaceae	mph	GC	0	1	0	0	0	0	0	0	0	0
359	Dyschoriste perrottetii (Nees)O.Kuntze	Acanthaceae	nph	SG	0	0	1	0	0	0	0	0	1	0
360	Dyschoriste perrottetii (Nees)O.Kuntze	Acanthaceae	nph	SG	0	0	0	0	0	0	1	0	0	0
361	Echinops longifolius A.Rich.	Asteraceae	nph	SZ	0	0	0	0	0	0	0	0	1	0
362	Ectadiopsis oblongifolia (Meisn.)Schltr.	Asclepiadaceae	nph	SG	0	0	0	0	1	0	1	1	1	0
363	Ehretia cymosa Thonn.	Boraginacee	mph	GC	0	0	1	0	1	1	1	0	0	0
364	Ekebergia capensis Sparrm. Syn. E. senegalensis A.Juss.	Meliaceae	mPh	SZ	0	0	1	0	1	1	1	1	1	0
365	Elaeis guineensis Jacq.	Arecaceae	mPh	GC	1	1	1	1	1	1	1	1	1	0
366	Elaephorbia drupifera (Thonn.)Stapf	Euphorbiaceae	mPh	GO	0	0	0	1	0	0	0	0	0	0
367	Elephantopus mollis Kunth	Asteraceae	Th	PAL	0	0	0	0	0	0	0	1	1	0
368	Elephantopus senegalensis (Klatt)Oliv. & Hiern.	Asteraceae	Th	SG	0	0	0	0	0	0	1	1	0	0
369	Elytraria marginata Vahl	Acanthaceae	Hc	GC	0	0	0	0	0	1	0	0	0	0
370	Embelia guineensis Baker	Myrsinaceae	Lmph	GC	0	0	1	0	1	0	0	0	0	0
371	Encephalartos barteri Carruth.	Cycadaceae	Ch	S	0	0	0	0	1	0	0	0	0	0
372	Englerastrum gracillimum Th.C.E.Fries	Lamiaceae	Th	SZ	0	0	0	0	0	0	0	1	0	0
373	Englerastrum schweinfurthii Briq.	Lamiaceae	Th	SZ	0	0	0	0	1	0	0	0	0	0
374	Englerophytum oblanceolatum (S.Moore)T.D.Penn.	Sapotaceae	nph	SG	0	0	1	0	1	0	0	0	0	0
375	Entada abyssinica Steud. ex A.Rich.	Leg.-Mim.	mph	SZ	0	0	0	0	0	0	0	0	1	0
376	Entada africana Guill. & Perr.	Leg.-Mim.	mph	SZ	0	0	0	0	1	1	1	1	1	1
377	Entada gigas (L.)Fauwc. & Rendle	Leg.-Mim.	LmPh	GC	0	1	0	0	0	0	0	0	0	0
378	Eragrostis tremula Steud.	Poaceae	Th	PAL	0	0	0	0	0	0	0	0	0	1
379	Eremospatha macrocarpa (Mann & Wendl.)Wendl.	Arecaceae	LmPh	GC	0	0	0	1	0	0	0	0	0	0
380	Eriocoelum kerstingii Gilg. ex Engl. var. kerstingii	Sapindaceae	mPh	SZ	0	0	0	0	0	0	0	0	1	0
381	Eriosema glomeratum (Guill. & Perr.)Hook.f.	Leg.-Pap.	Ch	SG	0	0	0	0	1	1	1	1	0	0
382	Eriosema griseum Baker	Leg.-Pap.	Hc	SZ	0	0	0	0	1	1	0	0	1	0
383	Eriosema molle Hutch. ex Milne-Redh.	Leg.-Pap.	Ch	GO	0	0	0	0	0	1	0	0	0	0
384	Eriosema pelligrinii Tisser	Leg.-Pap.	Hc	SZ	0	0	0	0	0	0	0	1	0	0
385	Eriosema psoraloides (Lam.)G.Don	Leg.-Pap.	Ch	SZ	0	0	0	0	0	0	1	0	0	0
386	Erythrina senegalensis A.DC.	Leg.-Pap.	mph	SG	0	1	0	0	1	1	1	0	1	1
387	Erythrina vogelii Hook.f.	Leg.-Pap.	mPh	GC	0	1	0	0	0	0	0	0	0	0
388	Erythrococca africana (Bail.)Prain	Euphorbiaceae	nph	GC	0	1	1	0	0	0	0	0	0	0
389	Erythrococca anomala (Juss. ex Poir.)Prain	Euphorbiaceae	nph	GC	0	0	1	1	0	1	0	0	0	0
390	Erythrophleum africanum (Benth.)Harms	Leg.-Caes.	nph	SZ	0	0	0	0	0	0	0	1	1	0
391	Erythrophleum suaveolens (Guill. & Pierr.)Brenan	Leg.-Caes.	mPh	SG	0	0	0	0	1	1	0	0	0	0
392	Erythroxylum emarginatum Thonn.	Erytroxylaceae	mph	SG	0	0	1	1	1	1	0	0	0	0
393	Euclinia longiflora Salisb.	Rubiaceae	Lmph	GC	0	1	0	0	0	0	0	0	0	0
394	Eugenia nigerina A.Chev. ex Hutch. & Dalziel	Myrtaceae	mph	GC	0	0	0	0	0	1	0	0	0	0
395	Eugenia salacioides M.A.Lawson ex Hutch. & Dalziel	Myrtaceae	mph	GO	0	1	0	1	0	0	0	0	0	0
396	Eulophia cristata (Sw.)Steud.	Orchiadaceae	Gt	SG	0	0	0	0	0	0	1	1	1	0
397	Eulophia milnei Rchb.f. var. milnei	Orchiadaceae	Gt	GE	0	0	0	0	0	0	0	0	1	0
398	Euphorbia convolvuloides Hochst. ex Benth.	Euphorbiaceae	Th	S	0	0	0	0	0	1	0	1	1	0
399	Euphorbia poissonii Pax	Euphorbiaceae	nph	S	0	0	0	0	1	1	0	0	1	0
400	Euphorbia polycnemoides Hochst ex Boiss.	Euphorbiaceae	Th	SZ	0	0	0	0	0	1	0	0	0	0
401	Evolvulus alsinoides L.	Convolvulaceae	Ch	Pt	0	0	0	0	0	0	0	1	0	0
402	Excoecaria grahamii Stapf. Syn. Sapium grahamii (Stapf)Prain	Euphorbiaceae	Hc	SZ	0	0	0	0	1	0	1	0	1	1
403	Fadogia agrestis Schweinf. ex Hiern	Rubiaceae	Ch	S	0	0	0	0	1	1	1	1	1	1
404	Fadogia cienkowskii Schweinf.	Rubiaceae	Ch	SZ	0	0	0	0	1	0	1	1	1	1
405	Fadogia erythrophloea (K.Schum. & K.Krause)Hutch. & Dalziel	Rubiaceae	mph	SZ	0	0	0	0	1	0	0	1	1	0
406	Feretia apodanthera Del.	Rubiaceae	nph	S	0	0	0	0	1	1	1	1	1	1
407	Ficus abutifolia (Miq.)Miq.	Moraceae	mph	SZ	0	0	0	0	0	1	0	0	1	0
408	Ficus artocarpoides Warb. Syn. F. elegans (Miq.)Miq.	Moraceae	Epmph	GC	0	1	0	0	0	0	1	0	0	0
409	Ficus capreaeifolia Del.	Moraceae	mph	SZ	0	0	1	0	1	0	1	0	0	0
410	Ficus craterostoma Mildbr. & Burret	Moraceae	Epmph	GC	0	1	0	0	0	0	0	0	0	0
411	Ficus exasperata Vahl	Moraceae	mPh	GC	0	1	0	0	1	0	1	0	0	0
412	Ficus glumosa Delile	Moraceae	mph	S	0	0	0	0	1	1	0	1	0	1
413	Ficus ingens (Miq.)Miq.	Moraceae	mPh	SZ	0	0	0	0	1	1	1	1	1	1
414	Ficus lutea Vahl Syn. F. vogelii (Miq.)Miq.	Moraceae	mph	GC	0	0	0	1	0	0	0	0	0	0
415	Ficus lyrata Warb.	Moraceae	mphEp	GC	0	1	0	1	1	0	0	0	0	0
416	Ficus mucuso Ficalho	Moraceae	MPh	GC	0	1	1	0	0	0	0	0	0	0

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417	Ficus natalensis Hoschst. subsp. leprieurii (Miq.)C.C.Berg	Moraceae	mphEp	GC	0	0	0	1	0	0	0	1	0	0
418	Ficus ovata Vahl	Moraceae	mph	GC	1	1	1	0	1	0	1	0	0	0
419	Ficus platyphylla Delile	Moraceae	MPh	SG	0	0	0	0	1	1	1	1	1	1
420	Ficus polita Vahl subsp. polita	Moraceae	mph	GC	1	1	0	0	1	0	0	0	0	0
421	Ficus recurvata De Wild. Syn. F. goliath A.Chev.	Moraceae	mphEp	GC	0	1	1	0	0	0	0	0	0	0
422	Ficus sagittifolia Mildbr. & Burret	Moraceae	mphEp	GC	0	1	0	1	0	0	0	0	0	0
423	Ficus sur Forssk. Syn. Ficus capensis Thunb.	Moraceae	mph	SG	0	1	1	1	1	1	1	1	1	0
424	Ficus sycomorus L. subsp. gnaphalocarpa (Miq.)Berg	Moraceae	mph	SZ	0	0	0	0	1	1	0	1	1	1
425	Ficus thonningii Blume	Moraceae	mph	At	0	0	1	0	1	0	0	1	1	0
426	Ficus trichopoda Baker Syn. F. congensis Engl.	Moraceae	mph	GC	0	1	0	1	0	0	1	1	1	0
427	Ficus umbellata Vahl	Moraceae	mPh	SG	0	0	0	0	0	1	0	0	0	0
428	Ficus vallis-choudae Delile	Moraceae	mph	SZ	0	0	0	0	0	0	0	0	1	0
429	Ficus variifolia Warb.	Moraceae	mPh	SG	0	1	0	0	1	1	1	0	0	0
430	Ficus vogeliana (Miq.)Miq.	Moraceae	mPh	GC	0	1	0	1	0	0	0	0	0	0
431	Flabellaria paniculata Cav.	Malpighiaceae	Lmph	GC	1	1	1	1	1	0	0	0	0	0
432	Flacourtia flavescens Willd.	Flacourtiaceae	mph	GC	0	1	1	0	1	1	1	1	1	0
433	Flagellaria guineensis Schumacher	Flagellariaceae	Lnph	GC	1	0	1	0	0	0	0	0	0	0
434	Floscopa africana (P.Beauv.)C.B.Clarke	Commelinaceae	nph	GC	0	0	1	0	0	0	0	0	0	0
435	Flueggea virosa (Roxb. ex Willd.)Voigt subsp. virosa	Euphorbiaceae	nph	Pt	0	1	1	0	1	1	1	1	1	1
436	Funtumia africana (Benth.)Stapf	Apocynaceae	mPh	GC	0	1	0	0	0	0	0	0	0	0
437	Funtumia elastica (Preuss)Stapf	Apocynaceae	mPh	GC	0	0	1	0	0	0	0	0	0	0
438	Gaertnera paniculata Benth.	Rubiaceae	mph	GC	1	0	0	1	0	0	0	0	0	0
439	Garcinia livingstonei T.Anders.	Clusiaceae	mPh	SZ	0	0	0	0	0	0	0	0	1	1
440	Garcinia ovalifolia Oliv.	Clusiaceae	mph	SG	0	0	0	0	0	0	0	0	1	0
441	Garcinia smeathmannii (Planch. & Triana)Oliv.	Clusiaceae	mPh	GC	0	1	0	0	0	0	0	0	0	0
442	Gardenia aqualla Stapf & Hutch.	Rubiaceae	mph	SZ	0	0	0	0	1	1	1	1	1	1
443	Gardenia erubescens Stapf & Hutch.	Rubiaceae	nph	S	0	0	0	0	1	1	1	1	1	1
444	Gardenia imperialis K.Schum.	Rubiaceae	mPh	SG	0	0	0	0	0	0	0	0	1	0
445	Gardenia nitida Hook.	Rubiaceae	mph	GC	0	1	1	1	0	1	0	0	0	0
446	Gardenia sokotensis Hutch.	Rubiaceae	mph	SZ	0	0	0	0	0	0	0	1	1	1
447	Gardenia ternifolia Schum. & Thonn. Syn G. triacantha DC.	Rubiaceae	nph	SZ	0	0	0	0	1	1	1	1	1	1
448	Gardenia tricantha DC.	Rubiaceae	mph	SZ	0	0	0	0	0	1	0	0	0	0
449	Gladiolus dalenii Van Geel Syn. G. psittacinus Hook.f.	Iridaceae	Gb	SZ	1	0	0	0	0	1	1	0	0	0
450	Gloriosa superba L. Syn. G. simplex L.	Liliaceae	LGb	GC	0	1	1	0	0	1	1	1	1	0
451	Glyphaea brevis (Spreng.)Monachino	Tiliaceae	mph	GC	1	1	1	1	0	0	0	0	0	0
452	Gnidia kraussina Meisn.	Thymeliaceae	Hc	SZ	0	0	0	0	1	0	0	0	0	0
453	Gongronema angolense (N.E.Br.)Bull.	Asclepiadaceae	Lmph	SG	1	1	1	0	0	0	0	0	0	0
454	Gongronema latifolium Benth.	Asclepiadaceae	Lmph	SG	1	1	1	1	0	0	0	0	0	0
455	Gouania longipetala Hemsl.	Rhamnaceae	Lmph	GC	0	0	1	0	0	0	0	0	0	0
456	Grewia barombiensis K.Schum.	Tiliaceae	mph	GC	0	0	0	1	0	0	0	0	0	0
457	Grewia barteri Burret	Tiliaceae	mph	SZ	0	0	0	0	1	0	1	1	1	1
458	Grewia bicolor Juss.	Tiliaceae	mph	SZ	0	0	0	0	0	0	0	0	1	1
459	Grewia carpinifolia Juss.	Tiliaceae	mph	GC	1	1	1	0	1	0	0	0	0	0
460	Grewia cissoides Hutch. & Dalziel	Tiliaceae	nph	S	0	0	0	0	1	0	1	1	1	1
461	Grewia flavescens Juss.	Tiliaceae	mph	SZ	0	0	0	0	0	0	0	0	0	1
462	Grewia lasiodiscus K.Schum.	Tiliaceae	mph	SZ	0	0	0	0	0	0	0	1	1	1
463	Grewia malacocarpa Mast.	Tiliaceae	Lmph	GC	0	1	0	1	0	0	0	0	0	0
464	Grewia venusta Fresen. Syn. G. mollis Auct.	Tiliaceae	nph	SZ	0	0	1	0	1	1	1	1	1	0
465	Griffonia simplicifolia (Vahl)ex DC.)Baillon	Leg.-Caes.	LmPh	SG	0	0	1	0	0	0	0	0	0	0
466	Guiera senegalensis J.F.Gmel.	Combretaceae	nph	SZ	0	0	0	0	0	0	0	1	0	1
467	Gymnema sylvestre (Retz.)Schult.	Asclepiadaceae	Lmph	Pt	0	0	0	0	0	1	0	0	0	0
468	Haematostaphis barteri Hook.f.	Anacardiaceae	mph	S	0	0	0	0	0	0	0	0	1	0
469	Hannoa klaineana Pierre & Engl.	Simaroubaceae	mPh	GC	0	1	0	0	0	0	0	0	0	0
470	Hannoa undulata (Guill. & Perr.)Planch.	Simaroubaceae	mph	S	0	0	0	0	0	1	1	1	1	1
471	Harissonia abyssinica Oliv.	Simaroubaceae	mph	SG	1	1	1	0	0	1	0	0	0	0
472	Harungana madagascariensis Lam. ex Poir.	Clusiaceae	mph	PAL	0	0	0	1	0	0	0	0	0	0
473	Haumaniastrum lilacinum (Oliv.)J.K.Morton	Lamiaceae	Ch	SZ	0	0	0	0	0	0	1	0	0	0
474	Heliotropium indicum L.	Boraginacee	Th	SG	0	0	1	0	0	0	1	0	0	0
475	Hexalobus crispiflorus A.Rich.	Annonaceae	mPh	SG	0	0	0	0	1	0	0	0	0	0
476	Hexalobus monopetalus (A.Rich.)Engl. & Diels	Annonaceae	mph	SZ	0	0	0	0	1	0	1	1	1	1

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
477	Hibiscus asper Hook.f.	Malvaceae	nph	SG	0	0	0	0	0	0	0	0	1	1
478	Hibiscus lunariifolius Willd.	Malvaceae	Lmph	PAL	0	0	1	0	0	0	0	0	0	0
479	Hibiscus owariensis P.Beauv.	Malvaceae	nph	GC	0	0	1	0	0	0	0	0	0	0
480	Hibiscus panduriformis Burm.f.	Malvaceae	nph	PAL	0	0	0	0	0	1	0	1	0	1
481	Hibiscus rostellatus Guill. & Perr.	Malvaceae	Lnph	GC	0	0	0	0	0	0	1	0	0	0
482	Hibiscus sterculiifolius (Guill. & Perr.)Steud.	Malvaceae	nph	SG	0	0	0	0	0	1	0	0	0	0
483	Hildegardia barteri (Mast.)Kosterm.	Sterculiaceae	mPh	SG	0	1	1	1	0	1	0	0	0	0
484	Hilleria latifolia (Lam.)H.Walt.	Phytolaccaceae	Ch	PAL	0	1	1	0	0	0	0	0	0	0
485	Holarrhena floribunda (G.Don)Dur. & Schinz	Apocynaceae	mph	SG	1	1	1	1	1	1	1	1	0	1
486	Holoptelea grandis (Hutch.)Mildbr.	Celtidaceae	MPh	GC	0	1	1	1	1	0	0	0	0	0
487	Homalium africanum (Hook.f.)Benth.	Flacourtiaceae	mPh	GC	0	0	0	1	0	0	0	0	0	0
488	Homalium le-testui Pellegr.	Flacourtiaceae	mPh	GC	0	1	0	0	0	0	0	0	0	0
489	Hoslundia opposita Vahl	Lamiaceae	nph	M	1	1	1	0	1	1	1	1	1	1
490	Hugonia platysepala Welw. ex Oliv.	Linaceae	Lmph	GC	0	1	1	1	0	0	0	0	0	0
491	Hunteria umbellata (K.Schum.)Hall.f.	Apocynaceae	mph	GC	0	1	1	0	0	0	0	0	0	0
492	Hybanthus enneaspermus (L.)F.Muell.	Violaceae	Ch	PAL	0	0	0	0	0	0	1	0	0	0
493	Hymenocardia acida Tul. var. acida	Euphorbiaceae	mph	SZ	0	0	0	0	1	1	1	1	1	1
494	Hymenodicton pachyantha K.Krause	Rubiaceae	mPh	GC	0	0	1	0	0	0	0	0	0	0
495	Hymenostegia afzelii (Oliv.)Harms	Leg.-Caes.	mPh	GC	0	0	1	0	0	0	0	0	0	0
496	Hyparrhenia involucrata Stapf	Poaceae	Th	S	0	0	0	0	1	0	0	1	0	1
497	Hyparrhenia smithiana (Hook.f.)Stapf var. major Clayton	Poaceae	Hc	S	0	0	0	0	1	1	1	0	0	0
498	Hypoestes triflora (Vahl)Soland. ex Roem. & Schum.	Acanthaceae	nph	SG	0	0	0	0	1	0	0	0	0	1
499	Hypoestes triflora (Vahl)Soland. ex Roem. & Schum.	Acanthaceae	nph	SG	0	0	0	0	0	0	0	0	1	0
500	Hypselodelphis violacea (Ridley)Milne.Redh.	Marantaceae	Gr	GC	0	1	1	1	1	0	0	0	0	0
501	Hyptis spicigera Lam.	Lamiaceae	Ch	Pt	0	0	0	0	0	0	0	0	0	1
502	Icacina oliviformis (Poiret)J.Raynal Syn. I. senegalensis A.J.	Icacinaceae	nph	SG	0	0	0	0	1	0	0	1	0	0
503	Icacina trichantha Oliv.	Icacinaceae	Lnph	GE	0	1	1	0	0	0	0	0	0	0
504	Impatiens irvingii Hook.f.	Balsaminaceae	Hyd	GC	0	0	0	0	0	0	0	0	0	0
505	Imperata cylindrica (L.)Raeuschel	Poaceae	Hc	Pt	0	0	0	0	1	1	1	0	0	0
506	Indigofera dendroides Jacq.	Leg.-Pap.	Th	SZ	0	0	0	0	1	1	1	1	1	1
507	Indigofera garckeana Vatke	Leg.-Pap.	nph	SZ	0	0	0	0	0	1	1	0	1	0
508	Indigofera geminata Baker	Leg.-Pap.	nph	S	0	0	0	0	0	0	0	1	1	1
509	Indigofera hirsuta Linn.	Leg.-Pap.	Ch	PAL	0	0	0	0	1	0	0	0	0	1
510	Indigofera leprieuri Baker f.	Leg.-Pap.	nph	SZ	0	0	0	0	0	1	1	1	0	1
511	Indigofera leptoclada Harms	Leg.-Pap.	Hc	S	0	0	0	0	0	0	0	0	1	1
512	Indigofera macrocalyx Guill. & Perr.	Leg.-Pap.	Ch	SZ	0	0	0	0	0	0	0	0	0	1
513	Indigofera macrophylla Schum.	Leg.-Pap.	Lnph	GC	1	0	0	0	0	1	0	0	0	0
514	Indigofera polysphaera Baker	Leg.-Pap.	nph	SG	0	0	0	0	0	1	0	1	0	0
515	Ipomoea aquatica (L.)Ker Gawl	Convolvulaceae	Lnph	GC	1	0	0	1	0	0	0	0	0	0
516	Ipomoea argentaurata Forssk.	Convolvulaceae	Gr	S	0	0	0	0	1	0	1	1	1	1
517	Ipomoea beninensis Akoègninou & Lisowski	Convolvulaceae	LHc	S	0	0	0	0	0	0	1	0	1	0
518	Ipomoea chrysochaetia Hall.f.	Convolvulaceae	Lnph	GC	0	0	0	0	0	0	0	0	0	1
519	Ipomoea eriocarpa R.Br.	Convolvulaceae	Lnph	Pt	0	0	0	0	0	1	0	0	0	1
520	Ipomoea heterotricha Didr.	Convolvulaceae	Th	SG	0	0	0	0	0	0	0	1	0	1
521	Ipomoea mauritiana Hall.f.	Convolvulaceae	Lmph	Pt	1	1	1	1	0	1	1	1	0	1
522	Ipomoea nil (L.)Roth.	Convolvulaceae	Th	GC	0	0	1	0	0	0	0	0	0	0
523	Ipomoea rubens Choisy	Convolvulaceae	LGr	SG	0	0	0	0	0	0	0	0	0	0
524	Ipomoea vagans Baker	Convolvulaceae	Lnph	SZ	0	0	0	0	0	0	1	0	0	0
525	Irvingia gabonensis (Aubry Lecomte ex O'Rorke)Baill.	Simaroubaceae	MPh	GC	1	0	1	0	0	0	0	0	0	0
526	Irvingia smithii Hook.f.	Simaroubaceae	mPh	SZ	0	0	0	0	0	0	1	1	0	0
527	Isoberlinia doka Craib & Stapf	Leg.-Caes.	mPh	S	0	0	0	0	1	1	1	1	1	1
528	Isoberlinia tomentosa (Harms)Craib & Stapf	Leg.-Caes.	mPh	SZ	0	0	0	0	0	0	1	1	1	1
529	Isodictyophorus reticularus (A.Chev.)J.K.Morton	Lamiaceae	Ch	GO	0	0	0	0	0	0	0	0	1	0
530	Ixora brachypoda DC.	Rubiaceae	mph	SG	1	0	0	1	1	0	0	1	1	0
531	Jasminum dichotomum Vahl	Oleaceae	Lmph	GC	0	0	0	0	1	1	1	0	1	0
532	Jasminum pauciflorum Benth.	Oleaceae	Lnph	GC	0	0	1	0	1	0	0	0	0	0
533	Justicia tenella (Nees)T.Anders.	Acanthaceae	nph	SG	0	0	0	0	0	0	0	0	1	0
534	Kaempheria aethiopica (Schweinf.)Solms-Laub.	Zingiberaceae	Gt	SG	0	0	1	0	1	1	1	1	1	1
535	Kalanchoe crenata (Andrews)Haw.	Crassulaceae	nph	SG	0	0	0	0	0	0	0	0	0	1
536	Kanahia laniflora (Forsk.)R.Br.	Asclepiadaceae	nph	SG	0	0	1	0	0	0	0	0	0	0

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
537	Keetia hispida (Benth.)Bridson	Rubiaceae	Lmph	GC	1	1	1	0	0	0	0	0	1	0
538	Keetia mannii (Hiern)Bridson	Rubiaceae	nph	GC	0	0	0	1	0	0	1	0	0	0
539	Keetia multiflora (Schumach. & Thonn.)Bridson	Rubiaceae	Lmph	GC	1	1	1	1	1	0	0	0	0	0
540	Keetia setosa (Hiern)Bridson	Rubiaceae	Lmph	GC	0	0	0	0	1	0	1	0	0	0
541	Keetia venosa (Oliv.)Bridson	Rubiaceae	Lmph	SG	0	0	0	0	0	1	1	1	0	0
542	Khaya grandifoliola C.DC.	Meliaceae	MPh	GC	0	0	0	1	1	0	0	0	0	0
543	Khaya senegalensis (Desr.)A.Juss.	Meliaceae	mPh	S	0	0	0	0	1	1	1	1	1	1
544	Kigelia africana (Lam.)Benth.	Bignoniaceae	mph	SG	0	1	1	0	1	1	1	0	1	1
545	Kinghamia nigritana (Benth.)C.Jeffrey	Asteraceae	nph	SZ	0	0	0	0	0	0	1	0	0	0
546	Kolobopetalum leonense Hutch. & Dalziel	Menispermaceae	Lnph	GC	0	1	0	0	0	0	0	0	0	0
547	Laccosperma secundiflorum (P.Beauv.)O.Kuntze	Arecaceae	Lmph	GC	0	0	0	1	0	0	0	0	0	0
548	Lactuca tuberosa A.Chev.	Asteraceae	Gt	SZ	0	0	0	0	0	1	1	0	0	0
549	Lagenaria breviflora (Benth.)Roberty	Cucurbitaceae	Lmph	SG	0	0	1	0	0	0	0	0	1	0
550	Laguncularia racemosa (L.)Gaertn.f.	Combretaceae	mPh	PAL	1	0	0	0	0	0	0	0	0	0
551	Landolphia calabarica (Stapf)E.A.Bruce	Apocynaceae	LmPh	GC	0	1	1	0	0	0	0	0	0	0
552	Landolphia hirsuta (Hua)Pichon	Apocynaceae	LmPh	GC	0	1	1	0	1	0	0	0	0	0
553	Landolphia incerta (K.Schum.)Persoon	Apocynaceae	Lmph	GC	0	1	0	0	0	0	0	0	0	0
554	Landolphia landolphioides (Hall.f.)A.Chev.	Apocynaceae	LmPh	GE	0	0	0	0	1	0	0	0	0	0
555	Landolphia owariensis P.Beauv.	Apocynaceae	LmPh	GC	1	0	0	0	0	1	0	0	1	0
556	Landolphia togolana (Hallier f.)Pichon	Apocynaceae	Lmph	GC	0	1	1	0	0	0	0	0	0	0
557	Lannea acida A.Rich.	Anacardiaceae	mPh	S	0	0	0	0	1	1	1	1	1	1
558	Lannea barteri (Oliv.)Engl. Syn. L. kerstingii Engl. & K.Krause	Anacardiaceae	mPh	S	1	0	1	0	1	1	1	1	1	1
559	Lannea microcarpa Engl. & K.Krause	Anacardiaceae	mPh	SZ	0	0	0	0	0	0	0	1	1	1
560	Lannea nigritana (Sc.Elliot)Keay var. nigritana	Anacardiaceae	mPh	GC	1	1	1	0	1	0	1	0	0	0
561	Lannea welwitschii (Hiern)Engl.	Anacardiaceae	mph	GC	0	1	0	0	0	0	0	0	0	0
562	Lantana camara L.	Verbenaceae	Lmph	SG	0	0	1	0	0	1	1	0	0	0
563	Lantana trifolia L.	Verbenaceae	Ch	PAL	0	0	0	0	0	0	1	0	0	0
564	Lantana ukambensis (Vatke)Verdc. Syn. L. rhodesiensis Mold.	Verbenaceae	Ch	SZ	0	0	0	0	0	1	1	1	1	1
565	Lasiodiscus mannii Hook.f.	Rhamnaceae	mph	GC	0	0	1	0	0	0	0	0	0	0
566	Lasiomorpha senegalensis Schott	Araceae	Gr	GC	0	0	0	1	0	0	0	0	0	0
567	Lecaniodiscus cupanioides Planch.	Sapindaceae	mph	GC	1	1	1	0	1	1	1	0	0	0
568	Leea guineensis G.Don	Leeaceae	Lnph	SG	0	1	1	1	1	1	0	0	0	0
569	Leersia hexandra Sw.	Poaceae	Hc	Pt	0	0	0	0	1	0	0	0	1	0
570	Lepidagathis alopecuroides (Vahl)R.Br. ex Griseb.	Acanthaceae	Ch	Pt	0	0	1	0	0	0	0	0	0	1
571	Lepidagathis anobrya Nees	Acanthaceae	Hc	SZ	0	0	0	0	1	0	1	1	1	1
572	Lepidagathis collina (Endl.)Milne-Redh.	Acanthaceae	HC	SZ	0	0	0	0	0	0	0	0	0	1
573	Lepistemone owariense (P.Beauv.)Hall.f.	Convolvulaceae	Lnph	SG	0	0	0	1	0	0	0	1	0	1
574	Leptadenia hastata (Pers.)Decne.	Asclepiadaceae	ch	SZ	0	0	0	0	0	1	1	1	1	0
575	Leptaulus daphnoides Benth.	Icacinaceae	mph	GC	0	1	0	0	0	0	0	0	0	0
576	Leptoderris brachyptera (Benth.)Dunn	Leg.-Pap.	Lmph	GC	1	1	1	1	1	0	0	0	0	0
577	Leptoderris cyclocarpa Dunn	Leg.-Pap.	Lmph	GO	1	0	0	0	0	0	0	0	0	0
578	Leptonychia pubescens Keay	Sterculiaceae	mph	GC	0	1	1	1	0	0	0	0	0	0
579	Leucas martinicensis (Jacq.)R.Br.	Lamiaceae	Th	Pt	0	0	0	0	0	0	0	0	1	0
580	Lippia multiflora Moldenke	Verbenaceae	nph	SG	0	0	0	0	1	1	1	1	0	1
581	Loeseneriella africana Willd. var. africana	Hippocrateaceae	Lmph	Pt	1	1	1	0	1	1	1	1	1	1
582	Lomariopsis guineensis (Undersw.)Alston.	Lomariopsidaceae	Lnph	GC	0	0	0	1	0	0	0	0	0	0
583	Lonchocarpus cyanescens (Schum. & Thonn.)Benth.	Leg.-Pap.	Lmph	SG	1	1	1	1	1	1	1	1	0	0
584	Lonchocarpus laxiflorus Guill. & Perr.	Leg.-Pap.	mph	S	0	0	0	0	0	0	0	1	1	1
585	Lonchocarpus sericeus (Poir.)Kunth	Leg.-Pap.	mph	SG	0	1	1	1	1	1	1	0	1	0
586	Lophira lanceolata Van Tiegh. ex Keay	Ochnaceae	mph	S	0	0	0	0	1	1	1	0	1	0
587	Loudetia simplex (Nees)C.E.Hubb.	Poaceae	Hc	SG	0	0	0	0	0	1	0	1	0	1
588	Ludwidjia abyssinica A.Rich.	Onagraceae	nph	GC	0	1	0	0	0	0	0	0	0	0
589	Luffa cylindrica (L.)M.J.Roem Syn. L. aegyptiaca Mill.	Cucurbitaceae	Lnph	Pt	0	0	1	0	1	0	0	0	0	0
590	Lygodium microphyllum (Cav.)R.Br.	Schizaeaceae	Lmph	Pt	0	0	0	1	0	0	0	0	0	0
591	Macaranga barteri Müll.Arg.	Euphorbiaceae	mph	GC	1	1	0	0	0	0	0	0	0	0
592	Macaranga heudelotii Baill.	Euphorbiaceae	mph	GC	0	0	1	1	0	0	0	0	0	0
593	Machaerium lunatum (L.f.)Ducke	Leg.-Pap.	nph	GC	1	0	0	0	0	0	0	0	0	0
594	Macrosphyra longistyla (DC.)Hiern	Rubiaceae	nph	S	1	1	1	0	1	1	1	1	1	0
595	Maerua angolensis DC.	Capparaceae	mph	SG	0	0	0	0	0	0	1	1	0	1
596	Maerua duchesnei (De Wild.)F.White	Capparaceae	mph	GC	0	1	1	0	0	0	0	0	0	0

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
597	Maesopsis eminii Engl. subsp. eminii	Rhamnaceae	mPh	GC	0	1	0	1	0	0	0	0	0	0
598	Majidea forsteri (Sprague)Radlk.	Sapindaceae	MPh	GC	0	1	1	0	1	0	0	0	0	0
599	Mallotus oppositifolius (Geisel.)Müell.Arg.	Euphorbiaceae	nph	PAL	1	1	1	0	1	1	0	0	0	0
600	Manihot glaziovii Müll.Arg.	Euphorbiaceae	mPh	GC	0	0	0	0	1	0	0	0	0	0
601	Manilkara multinervis (Baker)Dubard	Sapotaceae	mph	SG	0	0	1	0	1	1	0	1	1	0
602	Manilkara obovata Sabine & G.Don	Sapotaceae	mPh	GC	1	0	0	1	0	0	0	0	0	0
603	Mansonia altissima (A.Chev.)A.Chev. var. altissima	Sterculiaceae	mPh	GC	0	0	1	0	0	0	0	0	0	0
604	Maranthes polyandra (Benth.)Prance	Chrysobalanaceae	mph	S	0	0	0	0	1	1	1	1	0	0
605	Maranthes robusta (Oliv.)Prance Syn. Parinari robusta Oliver	Chrysobalanaceae	MPh	GC	1	1	0	0	1	0	0	0	0	0
606	Maranthochloa purpurea (Ridley)Milne.Redh.	Maranthaceae	nph	GC	0	1	0	0	0	0	0	0	0	0
607	Margaritaria discoidea (Baill.)Webster	Euphorbiaceae	mph	SG	0	1	1	0	1	1	1	1	1	0
608	Mariscus cylindristachyus Steud. Syn. M.alternifolius auct.	Cyperaceae	Hc	Pt	1	0	0	0	1	1	1	1	0	0
609	Markamia tomentosa (Benth.)K.Schum. ex Engl.	Bignoniaceae	mph	GC	0	0	1	0	1	0	0	0	0	0
610	Martretia quadricornis Beille	Euphorbiaceae	mph	GC	0	0	0	1	0	0	0	0	0	0
611	Maytenus heterophylla (Eckl. & Zeyh.)Robson	Celastraceae	mph	SZ	0	0	0	0	1	1	1	1	1	1
612	Maytenus serrata (Hochst. ex A.Rich.)R.Wilczek	Celastraceae	mph	GC	1	0	0	0	0	0	0	0	0	0
613	Melanthera elliptica O.Hoffm.	Asteraceae	Hc	SZ	0	0	0	0	0	0	1	0	0	1
614	Melastomastrum segregatum (Benth.)A. & R.Fern.	Melastomataceae	Ch	GE	0	0	0	1	0	0	1	0	0	0
615	Memecylon afzelii G.Don var. afzelii	Melastomataceae	Lnph	GC	0	0	1	1	0	1	0	0	0	0
616	Merremia hederacea Burm.f.	Convolvulaceae	Lnph	PAL	0	0	1	0	0	0	0	0	0	0
617	Merremia kentrocaulos (C.B.Clarke)Rendle	Convolvulaceae	Lnph	Pt	0	0	0	0	0	0	1	0	0	0
618	Mezoneuron benthamianum Baill.	Leg.-Caes.	Lmph	GC	0	1	1	0	1	1	1	0	0	0
619	Microdesmis puberula Hook.f. ex Planchon	Pandaceae	mph	GC	0	1	1	1	0	0	0	0	0	0
620	Microlepia speluncae (L.)Moore	Dennstaedtiaceae	Gr	GC	0	1	0	0	0	0	0	0	0	0
621	Mikania cordata (Burm. f.)B.L.Robins var. cordata	Asteraceae	LTh	GC	0	0	0	1	0	0	0	0	0	0
622	Milicia excelsa (Welw.)C.C.Berg	Moraceae	MPh	GC	1	1	1	1	1	1	1	1	1	0
623	Millettia barteri (Benth.)Dunn	Leg.-Pap.	Lmph	GC	0	1	0	0	0	0	0	0	0	0
624	Millettia chrysophylla Dunn	Leg.-Pap.	LmPh	GC	0	0	0	1	0	0	0	0	0	0
625	Millettia griffoniana Baill.	Leg.-Pap.	mph	GC	0	0	0	1	0	0	0	0	0	0
626	Millettia thonningii (Schum. & Thonn.)Baker	Leg.-Pap.	mph	GC	0	1	1	0	1	1	0	1	1	0
627	Millettia warneckei Harms	Leg.-Pap.	mph	GC	0	0	1	0	0	1	0	0	0	0
628	Mimosa pigra L.	Leg.-Mim.	nph	Pt	0	0	1	0	0	0	1	0	0	0
629	Mimusops andogensis Hiern	Sapotaceae	mPh	GC	0	0	1	0	1	1	0	0	1	0
630	Mimusops kummel Bruce ex A.DC.	Sapotaceae	mph	SZ	0	0	0	1	1	0	0	0	0	0
631	Mitragyna inermis (Willd.)O.Kuntze	Rubiaceae	mph	S	0	0	0	0	1	1	1	0	0	1
632	Mitragyna ledermannii (K. Krause)Ridsdale	Rubiaceae	mPh	GC	0	0	0	1	0	0	0	0	0	0
633	Momordica cabrae (Cogn.)Jeffrey	Cucurbitaceae	Lmph	GC	0	1	1	0	0	0	0	0	0	0
634	Momordica charantia L.	Cucurbitaceae	Lnph	Pt	1	1	0	0	0	0	0	0	0	0
635	Momordica cissoides Benth.	Cucurbitaceae	Lnph	GC	0	1	1	0	0	0	0	0	0	0
636	Monanthotaxis parvifolia (Oliv.)Verdc.	Annonaceae	Lnph	GE	0	1	1	1	0	0	0	0	0	0
637	Mondia whitei (Hook.f.)Skeels	Asclepiadaceae	Lmph	SG	0	1	1	0	0	0	0	0	0	0
638	Monechma ciliatum (Jacq.)Milne-Redh.	Acanthaceae	nph	SG	0	0	0	0	0	1	0	1	0	1
639	Monechma depauperatum (Jacq.)Milne	Acanthaceae	nph	SZ	0	0	0	0	0	1	0	0	1	0
640	Monodora myristica (Gaertn.)Dunal	Annonaceae	mPh	GC	0	1	1	0	0	1	0	0	0	0
641	Monodora tenuifolia Benth.	Annonaceae	mph	GC	0	1	1	1	1	1	0	0	0	0
642	Monotes kerstingii Gilg	Dipterocarpaceae	mph	S	0	0	0	0	1	0	1	1	0	0
643	Morelia senegalensis A.Rich.	Rubiaceae	mph	SG	0	0	1	1	1	1	1	0	1	1
644	Morinda lucida Benth.	Rubiaceae	mph	Pt	1	1	1	1	1	1	1	1	0	0
645	Morinda morindioides (Baker)Milne-Redh.	Rubiaceae	Lnph	GC	1	1	1	0	0	1	1	0	0	0
646	Motandra guineensis (Thonn.)A.DC.	Apocynaceae	Lmph	SG	0	1	1	0	1	0	0	0	0	0
647	Mucuna pruriens (L.)DC. var. pruriens	Leg.-Pap.	Lmph	Pt	0	1	1	0	1	0	1	1	0	0
648	Mukia maderaspatana (L.)M.Roem.	Cucurbitaceae	Lnph	Pt	0	0	0	0	0	1	1	0	0	1
649	Musanga cecropioides R.Br.	Moraceae	mPh	GC	0	1	0	0	0	0	0	0	0	0
650	Mussaenda arcuata Lam.ex Poir.	Rubiaceae	Lmph	Pt	0	0	0	0	0	0	0	0	1	0
651	Mussaenda elegans Schum. & Thonn.	Rubiaceae	Lmph	GC	0	1	1	1	1	0	0	0	0	0
652	Mussaenda isertiana DC.	Rubiaceae	Lmph	GC	1	0	0	1	0	0	0	0	0	0
653	Myrianthus arboreus P.Beauv.	Moraceae	mPh	GC	0	1	1	1	0	0	0	0	0	0
654	Napoleonaea imperialis P.Beauv.	Lecythidaceae	mph	GE	0	0	1	0	1	0	0	0	0	0
655	Napoleonaea vogelii Hook. & Planch.	Lecythidaceae	mph	GC	0	1	1	1	1	1	0	0	0	0
656	Nauclea vanderguchtii (De Wild.)Petit	Rubiaceae	Lmph	GE	0	0	0	1	0	0	0	0	0	0

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
657	Nauclea xanthoxylon (A.Chev.)Aubrév.	Rubiaceae	mph	GE	0	0	0	1	0	0	0	0	0	0
658	Nelsonia canescens (Lam.)Spreng.	Acanthaceae	Ch	Pt	0	0	0	0	0	0	1	1	1	0
659	Neorautanenia mitis (A.Rich.)Verdc.	Leg.-Pap.	LCh	SZ	0	0	0	0	1	1	1	0	1	0
660	Nephrolepis biserrata (Sw.)Schott	Davalliaceae	HcEp	Pt	1	1	0	1	0	0	1	0	0	0
661	Nesogordonia papaverifera (A.Chev.)R.Capuron	Sterculiaceae	mph	GC	0	1	1	0	0	0	0	0	0	0
662	Neuropeltis velutina Hallier f.	Convolvulaceae	LmPh	GC	0	1	1	0	0	0	0	0	0	0
663	Newbouldia laevis (P.Beauv.)Seem. ex Bureau	Boraginaceae	mph	GC	1	1	1	1	1	0	0	0	0	0
664	Nymphaea lotus L.	Nymphaeaceae	Hyd	PAL	0	0	0	1	0	0	0	0	0	0
665	Ochna membranacea Oliv.	Ochnaceae	mph	GC	0	0	1	0	1	0	1	0	0	0
666	Ochna multiflora DC.	Ochnaceae	mph	GO	1	0	0	0	0	0	0	0	0	0
667	Ochna rhizomatosa (Tiegh.)Keay	Ochnaceae	nph	S	0	0	0	0	1	0	1	1	1	0
668	Ochna schweinfurthiana F.Hoffm.	Ochnaceae	mph	SZ	0	0	0	0	1	1	1	1	0	0
669	Octoknema borealis Hutch. & Dalziel	Olacaceae	mPh	GO	0	0	0	1	0	0	0	0	0	0
670	Octolobus spectabilis Welw.	Sterculiaceae	nph	GC	0	0	1	0	0	0	0	0	0	0
671	Olax gambecola Baill.	Olacaceae	nph	GC	1	1	1	0	0	0	0	1	0	0
672	Olax subscorpioidea Oliv. var. subscorpioidea	Olacaceae	mph	GC	1	1	1	1	1	1	0	0	1	0
673	Oligocodon cunliffeae (Wernham)Keay	Rubiaceae	Lnph	GE	0	0	0	1	0	0	0	0	0	0
674	Olyra latifolia L.	Poaceae	nph	GC	1	1	1	0	1	0	0	1	0	0
675	Oncinotis glabrata (Baill.)Stapf ex Hiern	Apocynaceae	Lmph	GC	1	1	0	0	0	0	0	0	0	0
676	Oncoba spinosa Forsk.	Flacourtiaceae	mph	SZ	0	0	1	0	1	1	1	1	1	0
677	Oncocalamus mannii (Wendl.)Wendl.	Arecaceae	LmPh	GE	0	0	0	1	0	0	0	0	0	0
678	Opilia amentacea Roxb.	Opiliaceae	Lmph	SZ	1	1	1	0	1	1	1	1	1	1
679	Oplismenus hirtellus (L.)P.Beauv.	Poaceae	Ch	SG	1	1	1	0	1	0	1	1	1	0
680	Orthosiphon rubicundus (D.Don)Benth.	Lamiaceae	Hc	PAL	0	0	0	0	0	0	0	1	0	0
681	Osmunda regalis L.	Osmundaceae	Ch	Pt	0	0	0	0	0	0	0	0	1	0
682	Oxyanthus formosus Hook.f. ex Planch.	Rubiaceae	mph	GC	0	0	0	0	0	1	0	0	0	0
683	Oxyanthus pallidus Hiern	Rubiaceae	mph	GC	0	0	1	0	0	0	0	0	0	0
684	Oxyanthus racemosus (Schum. & Thonn.)Keay	Rubiaceae	nph	GC	1	1	1	0	1	1	1	0	0	0
685	Oxyanthus speciosus DC.	Rubiaceae	nph	SG	0	1	0	0	1	0	0	0	0	0
686	Oxyanthus subpunctatus (Hiern)Keay	Rubiaceae	nph	GC	0	0	1	1	0	0	0	0	0	0
687	Oxyanthus unilocularis Hiern	Rubiaceae	mph	GC	0	1	1	1	1	0	1	0	0	0
688	Oxytenanthera abyssinica (A.Rich.)Munro	Poaceae	mph	SZ	0	0	0	0	1	0	0	0	1	0
689	Ozoroa insignis Delile	Anacardiaceae	mph	S	0	0	0	0	0	1	0	1	1	1
690	Palisota hirsuta (Thunb.)K.Schum. ex Engl.	Commelinaceae	nph	GC	0	1	1	1	0	0	0	0	0	0
691	Pancovia bijuga Willd.	Sapindaceae	mph	GC	1	1	1	1	1	1	0	0	0	0
692	Pandanus candelabrum P.Beauv.	Pandanaceas	mph	SG	0	0	0	0	1	0	0	0	0	0
693	Pandiaka angustifolia (Vahl)Hepper	Amaranthaceae	Th	Pt	0	0	0	0	1	1	1	1	1	1
694	Pandiaka involucrata (Moq.)B.D.Jackson	Amaranthaceae	Ch	S	0	0	0	0	1	1	1	1	0	0
695	Panicum maximum Jacq.	Poaceae	Hc	GC	0	1	1	0	0	1	1	0	0	0
696	Panicum parvifolium Lam.	Poaceae	Ch	SG	0	0	0	0	1	0	0	0	0	0
697	Pararistolochia goldieana (Hook.f.)Hutch. & Dalziel	Aristolochiaceae	LGr	GC	1	0	1	0	1	0	0	0	0	0
698	Parinari congensis F.Didr.	Chrysobalanaceae	MPh	SG	0	0	1	0	1	1	1	0	0	0
699	Parinari curatellifolia Planch. ex Benth.	Chrysobalanaceae	mph	SZ	0	0	0	0	1	1	1	1	1	0
700	Parkia bicolor A.Chev.	Leg.-Mim.	mPh	GC	0	1	1	0	0	1	0	0	0	0
701	Parkia biglobosa (Jacq.)R.Br. ex G.Don f.	Leg.-Mim.	mPh	S	0	0	1	0	1	1	1	1	1	1
702	Paropsia guineensis Oliv.	Passifloraceae	mPh	GE	0	1	0	0	0	0	0	0	0	0
703	Paspalum scrobiculatum L.	Poaceae	Hc	Pt	1	0	0	0	0	0	1	1	0	0
704	Passiflora foetida L.	Passifloraceae	Lnph	Pt	0	0	0	0	0	1	0	0	0	0
705	Paullinia pinnata L.	Sapindaceae	Lmph	At	1	1	1	1	1	1	1	1	1	1
706	Pauridiantha hirtella (Benth.)Bremek.	Rubiaceae	mph	GC	0	0	0	1	0	0	0	0	0	0
707	Pavetta corymbosa (DC.)F.N.Williams	Rubiaceae	mph	SG	1	1	1	1	1	1	1	0	1	1
708	Pavetta crassipes K.Schum.	Rubiaceae	nph	SZ	0	0	0	0	1	1	1	1	1	1
709	Pennisetum pedicellatum Trin.	Poaceae	Th	PAL	0	0	0	0	0	0	0	1	1	1
710	Pennisetum polystachion (L.)Schult.	Poaceae	Th	Pt	0	0	0	0	0	1	0	0	0	0
711	Pennisetum purpureum Schumach.	Poaceae	Hc	Pt	0	0	0	0	0	0	0	0	0	1
712	Pennisetum subangustum (Schumach.)Stapf & C.E.Hubb.	Poaceae	Th	SG	0	0	0	0	0	0	0	0	0	1
713	Pennisetum unisetum (Nees)Benth.	Poaceae	Hc	SZ	0	0	0	0	0	1	0	0	1	0
714	Pentaclethra macrophylla Benth.	Leg.-Mim.	mPh	GC	0	1	1	0	0	0	0	0	0	0
715	Pentadesma butyracea Sab.	Clusiaceae	mPh	SG	0	0	0	0	1	0	0	0	1	0
716	Pentodon pentandrus (Schum. & Thonn.)Vatke	Rubiaceae	Th	At	1	0	0	0	0	0	0	0	0	0

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
717	Pergularia daemia (Forssk.)Chiov.	Asclepiadaceae	Lmph	SG	0	0	0	0	0	0	0	0	1	1
718	Pericopsis laxiflora (Benth.)van.Meeuwen	Leg.-Pap.	mph	S	0	0	0	0	1	1	1	1	1	1
719	Periploca nigrescens Afzel.	Asclepiadaceae	Lmph	GC	1	1	1	0	1	1	1	1	0	0
720	Peristrophe bicalyculata (Retz.)Nees	Acanthaceae	Th	Pt	0	0	0	0	0	0	0	0	1	1
721	Phaulopsis imbricata (Forssk.)Sweet. subsp. imbricata	Acanthaceae	Ch	GC	0	0	1	0	1	1	0	1	1	0
722	Phaulopsis barteri (T.Anders.)Lindau	Acanthaceae	nph	SG	0	0	0	0	0	0	0	0	1	0
723	Phaulopsis ciliata (Willd.)Hepper	Acanthaceae	nph	SG	0	0	0	0	0	0	1	0	0	0
724	Phoenix reclinata Jacq.	Arecaceae	nph	SG	0	0	0	1	1	1	1	1	0	0
725	Phragmites karka (Retz.)Steud.	Poaceae	nph	PAL	0	0	0	1	0	0	0	0	0	0
726	Phyllanthus muellerianus (O.Ktze.)Exell	Euphorbiaceae	Lmph	SG	1	0	1	0	1	0	1	1	1	0
727	Phyllanthus reticulatus Poir. var. reticulatus	Euphorbiaceae	nph	SZ	0	0	1	0	0	1	1	1	1	1
728	Phymatodes scolopendria (Burm.)Ching	Polypodiaceae	Ep	GC	0	1	0	0	0	0	0	0	0	0
729	Pierreodendron kerstingii (Engl.)Little	Simaroubaceae	mph	GO	0	1	1	0	1	0	0	0	0	0
730	Piliostigma reticulatum (DC.)Hochst.	Leg.-Caes.	mph	S	0	0	0	0	0	0	0	1	0	1
731	Piliostigma thonningii (Schumach.)Milne-Redh.	Leg.-Caes.	mph	SG	0	0	0	0	1	1	1	1	1	1
732	Piper guineense Schum. & Thonn.	Piperaceae	LmPh	GC	0	1	1	1	0	0	0	0	0	0
733	Piptadeniastrum africanum (Hook.f.)Brenan	Leg.-Mim.	MPh	GC	0	1	1	0	0	0	0	0	0	0
734	Pittosporum viridiflorum Sims subsp. dalziellii (Hutch.)Cuf.	Pittosporaceae	mph	GC	0	0	0	0	0	0	0	0	1	0
735	Plastoma africanum P.Beauv.	Lamiaceae	Th	PAL	0	0	0	0	0	0	0	1	0	0
736	Platycerium angolense Welw.	Polypodiaceae	Ep	At	0	0	0	0	1	0	0	0	0	0
737	Platycerium stemaria (Beauv.)Desv.	Polypodiaceae	Ep	At	0	0	0	1	1	0	0	0	0	0
738	Pleiocarpa pycnantha (K.Schum.)Stapf	Apocynaceae	nph	GC	1	1	1	1	0	0	0	0	0	0
739	Pleioceras barteri Baill.	Apocynaceae	nph	GC	1	1	1	0	0	0	0	0	0	0
740	Plumbago zeylanica L.	Plumbaginaceae	nph	SG	0	0	0	0	1	0	0	0	0	0
741	Polycarpaea linearifolia (DC.)DC.	Caryophyllaceae	Th	SZ	0	0	0	0	0	0	0	0	1	1
742	Polygala arenaria Willd.	Polygalaceae	Th	SG	0	0	0	0	0	1	0	0	0	1
743	Polygala butyracea Heckel	Polygalaceae	Th	SZ	0	0	0	0	0	0	0	1	0	0
744	Polysphaeria arbuscula K.Schum.	Rubiaceae	mph	SZ	0	0	0	0	1	1	0	0	1	0
745	Pouchetia africana DC.	Rubiaceae	nph	SG	0	0	1	0	0	0	0	0	0	0
746	Pouteria alnifolia (Baker)Roberty	Sapotaceae	mph	GC	1	1	1	1	1	1	1	1	1	0
747	Pouzolzia guineensis Benth.	Urticaceae	Ch	GC	0	0	1	0	0	0	0	0	0	0
748	Premna angolensis Güerke	Verbenaceae	nph	GC	0	1	1	0	1	0	0	0	0	0
749	Premna quadrifolia Schum. & Thonn.	Verbenaceae	nph	GO	0	1	1	0	1	0	0	0	0	0
750	Prosopis africana (Guill. & Perr.)Taub.	Leg.-Mim.	mPh	S	0	0	0	0	1	1	1	1	1	1
751	Protea madiensis Oliv Syn. P. elliotii C.H.Wright	Proteaceae	mph	SZ	0	0	0	0	0	1	0	1	0	0
752	Pseudarthria confertiflora (A.Rich.)Baker	Leg.-Pap.	nph	SZ	0	0	0	0	0	1	1	1	0	0
753	Pseudarthria hookeri Wight & Arn. var. hookeri	Leg.-Pap.	nph	SZ	0	0	0	0	0	0	1	0	0	0
754	Pseudocedrela kotschyi (Schweinf.)Harms.	Meliaceae	mph	S	0	0	0	0	1	1	1	1	1	1
755	Pseudospondias microcarpa (A.Rich.)Engl. var. microcarpa	Anacardiaceae	mPh	SG	0	0	0	1	1	0	0	0	0	0
756	Psilanthus mannii Hook.f.	Rubiaceae	nph	GC	0	1	0	0	0	0	0	0	0	0
757	Psorospermum glaberrimum Hochr.	Hypericaceae	mph	SG	0	0	0	0	1	1	1	1	1	1
758	Psorospermum tenuifolium Hook.	Hypericaceae	mph	GE	0	0	0	0	0	0	0	0	1	0
759	Psychotria articulata (Hiern)Petit	Rubiaceae	mph	GC	0	0	0	1	0	0	0	0	0	0
760	Psychotria calva Hiern	Rubiaceae	nph	GC	1	1	1	1	1	1	0	0	1	0
761	Psychotria psychotrioides (DC.)Roberty	Rubiaceae	nph	SG	0	0	0	0	1	1	1	1	1	0
762	Psychotria vogeliana Benth.	Rubiaceae	nph	SG	1	1	1	1	1	1	1	1	1	0
763	Psydrax acutiflora (Hiern)Bridson	Rubiaceae	nph	GC	0	0	0	0	1	0	0	0	0	0
764	Psydrax horizontalis (K. Schum. & Thonn.)Bridson	Rubiaceae	Lmph	SG	1	1	1	0	0	0	0	0	1	0
765	Psydrax parviflora (Afzel.)Bridson	Rubiaceae	nph	GO	1	1	1	0	1	0	0	0	0	0
766	Psydrax subcordata (DC.)Bridson	Rubiaceae	mph	GC	0	1	0	1	0	0	0	0	0	0
767	Pteleopsis suberosa Engl. & Diels	Combretaceae	mph	SZ	0	0	0	0	1	1	1	1	1	1
768	Pterocarpus erinaceus Poir	Leg.-Pap.	mPh	S	0	0	1	0	1	1	1	1	1	1
769	Pterocarpus santalinoides DC.	Leg.-Pap.	mph	SG	0	0	1	1	1	1	1	1	1	1
770	Pterygota macrocarpa K.Schum.	Sterculiaceae	mph	GC	0	0	1	0	0	0	0	0	0	0
771	Pupalia lappacea (L.)A; Juss.	Amaranthaceae	Ch	PAL	0	0	1	0	1	1	0	0	0	1
772	Pycnanthus angolensis (Welw.)Warb. var. angolensis	Myristicaceae	mPh	GC	1	1	1	1	0	0	0	0	0	0
773	Pycreus polystachyos (Rottb.)P.Beauv.	Cyperaceae	Hc	Pt	1	0	0	0	0	0	0	0	0	0
774	Pyrenacantha canaliculata Pierre Syn. P. vogeliana Baill.	Icacinaceae	Lmph	GC	0	1	0	0	0	0	0	0	0	0
775	Raphia hookeri Mann & Wendl.	Arecaceae	mph	GC	0	0	1	1	0	0	0	0	0	0
776	Raphia sudanica A.Chev.	Arecaceae	mph	SZ	0	0	0	0	1	0	0	1	1	0

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
777	Raphia vinifera P.Beauv.	Arecaceae	mph	GE	0	0	0	1	0	0	0	0	0	0
778	Raphionacme brownii Scott Ell.	Asclepiadaceae	Gt	S	0	0	0	0	0	0	1	0	0	0
779	Rauvolfia vomitoria Afzel.	Apocynaceae	mph	SG	1	1	1	0	1	1	0	1	0	0
780	Reissantia indica (Willd.)N.Hallé	Celastraceae	Lnph	GC	1	1	1	0	1	1	1	1	1	0
781	Rhabdophyllum affine (Hook.f.)Van Tiegh.	Ochnaceae	nph	GO	0	1	1	0	0	0	0	0	0	0
782	Rhaphiostylis beninensis (Hook.f. ex Planch.)Planch. ex Benth.	Icacinaceae	Lnph	GC	1	1	1	1	1	0	0	0	0	0
783	Rhigiocarya racemifera Miers	Menispermaceae	Lnph	GC	0	1	1	1	0	0	0	0	0	0
784	Rhinacanthus virens (Nees)Milne-Redh. var. virens	Acanthaceae	Ch	GC	0	0	1	0	0	1	0	0	0	0
785	Rhizophora racemosa G.F.W.Mey	Rhizophoraceae	mPh	Pt	1	0	0	0	0	0	0	0	0	0
786	Rhus natalensis Bernh. ex Krause	Anacardiaceae	mph	SZ	0	0	0	0	0	0	0	1	1	1
787	Rhynchosia minima (L.)DC. var. minima	Leg.-Pap.	Th	Pt	0	0	0	0	1	1	1	1	0	0
788	Rhynchosia pycnostachya (DC.)Meikle	Leg.-Pap.	Lmph	GC	0	0	1	0	0	0	0	1	0	0
789	Rhynchosia sublobata (Schumach.)Meikle	Leg.-Pap.	LCh	SG	0	0	0	0	0	1	0	0	0	0
790	Ricinodendron heudelotii (Baill.)Pierre & Heckel	Euphorbiaceae	mPh	GC	0	1	1	0	1	0	0	0	0	0
791	Rinorea brachypetala (Turcz.)Kuntze	Violaceae	nph	GC	0	0	1	0	0	0	0	0	0	0
792	Rinorea dentata (P.Beauv.)Kuntze	Violaceae	mph	GC	0	1	0	0	1	0	0	0	0	0
793	Rinorea ilicifolia (Welw. ex Oliv.)Kuntze	Violaceae	nph	GC	0	0	1	0	0	0	0	0	0	0
794	Rinorea kibbiensis Chipp.	Violaceae	nph	GC	0	0	1	0	0	0	0	0	0	0
795	Ritchiea capparioides (Andr.)Britten var. capparoides	Capparaceae	Lnph	GC	1	1	1	0	1	1	0	0	0	0
796	Ritchiea erecta Hook.f. Syn. R. pentaphylla Gilg & Bened.	Capparaceae	nph	GE	0	1	1	0	1	1	0	0	0	0
797	Rothamannia longiflora Salisb.	Rubiaceae	mph	GC	1	1	1	1	1	0	1	0	0	0
798	Rothamannia urcelliformis (Hiern)Robyns	Rubiaceae	mph	GC	0	1	1	0	1	0	0	0	0	0
799	Rothmannia munsae (Schweinf. ex Hiern)E.M.A.Petit	Rubiaceae	mPh	GC	0	0	0	1	0	0	0	0	0	0
800	Rourea coccinea (Thonn. ex Schum.)Benth.	Connaraceae	nph	GC	1	1	1	1	1	1	1	1	1	0
801	Rourea thomsonii (Thonn. ex Schum.)Benth.	Connaraceae	Lmph	GC	0	1	1	1	1	0	0	0	0	0
802	Ruellia praetermissa Schweinf. ex Lindau	Acanthaceae	Ch	GC	0	0	0	0	0	1	1	0	0	0
803	Rungia grandis T.Anders.	Acanthaceae	nph	GC	0	1	0	0	0	0	0	0	0	0
804	Rutidea parviflora DC.	Rubiaceae	Lmph	SG	0	1	0	1	0	0	0	0	0	0
805	Rutidea smithii Hiern	Rubiaceae	Lmph	GC	1	1	1	1	0	0	0	0	0	0
806	Rytigynia canthioides (Benth.)Robyns	Rubiaceae	mph	GC	1	1	1	0	1	1	0	1	0	0
807	Rytigynia senegalensis Blume	Rubiaceae	mph	SG	0	0	1	0	1	1	0	0	0	0
808	Rytigynia umbellulata (Hiern)Robyns	Rubiaceae	mph	SG	1	1	1	0	1	1	0	0	0	1
809	Saba senegalensis (A.DC.)Pichon	Apocynaceae	LmPh	GO	0	0	0	0	1	1	1	1	1	0
810	Saba thompsonii (A.Chev.)Pichon	Apocynaceae	LmPh	GC	1	1	1	0	1	1	1	1	1	0
811	Sabicea brevipes Wernh.	Rubiaceae	Lnph	GC	0	0	0	0	0	0	0	0	1	0
812	Sabicea calycina Benth.	Rubiaceae	Lnph	GC	0	0	1	0	0	0	0	0	0	0
813	Sacciolepis africana C.E.Hubbard & Snowden	Poaceae	Hc	SZ	0	0	0	0	0	0	0	0	1	0
814	Salacia bussei Loes. Syn. S. baumannii (Loes.)Exell & Mendonça	Hippocrateaceae	Lnph	GC	0	0	0	0	1	0	0	0	0	0
815	Salacia longipes (Oliv.)N.Hallé	Hippocrateaceae	nph	GC	1	1	1	1	1	0	0	0	0	0
816	Salacia pallescens Oliv.	Hippocrateaceae	nph	GC	1	1	1	0	1	1	0	0	0	0
817	Salacia senegalensis (Lam.)DC.	Hippocrateaceae	Lnph	GC	0	1	0	0	0	0	0	1	0	0
818	Sansevieria liberica Gérôme & Labory	Dracaenaceae	Gr	GC	1	1	1	0	1	1	1	1	0	1
819	Sarcocephalus latifolius (Smith)Bruce	Rubiaceae	mph	At	0	0	0	0	1	1	1	1	1	1
820	Sarcophrynium brachystachyum (Benth.)K.Schum.	Marantaceae	Gr	GC	0	0	0	0	0	0	0	0	1	0
821	Scadoxus multiflorus (Martyn)Raf. Subsp. multiflorus	Amaryllidaceae	Gb	SG	0	0	1	0	1	1	1	0	0	0
822	Schizachyrium exile (Hochst.)Pilg.	Poaceae	Th	PAL	0	0	0	0	0	0	0	0	1	0
823	Schizachyrium sanguineum (Retz.)Alston	Poaceae	Hc	Pt	0	0	0	0	1	1	1	0	0	1
824	Schrebera arborea A.Chev.	Oleaceae	mPh	GC	0	0	1	0	1	0	0	0	0	0
825	Scilla sudanica A.Chev.	Liliaceae	Gt	S	0	0	0	0	0	0	1	1	0	0
826	Scleria achtenii De Wild.	Cyperaceae	Hc	SG	1	0	0	0	0	0	0	0	1	0
827	Scleria depressa (C.B.Cl.)Nelmes	Cyperaceae	Hc	GC	0	0	0	1	1	0	1	1	1	0
828	Scleria lagöensis Boeck.	Poaceae	Hc	Pt	0	0	0	0	0	0	0	1	0	0
829	Scleria naumanniana Boeck.	Cyperaceae	Hc	GC	0	0	1	1	0	0	0	0	0	0
830	Sclerocarya birrea (A.Rich.)Hochst.)	Anacardiaceae	mph	S	0	0	0	0	1	0	0	0	1	1
831	Secamone afzelii (Schultes)K.Schum.	Asclepiadaceae	Lmph	GC	1	1	1	1	1	1	1	1	0	0
832	Securidaca longipedunculata Fres.	Polygalaceae	mph	SZ	0	0	0	0	1	1	1	1	1	1
833	Senna obtusifolia (L.)H.S.Irwin & Barneby	Leg.-Caes.	Ch	Pt	0	0	0	0	0	0	0	1	0	1
834	Sesbania leptocarpa DC.	Leg.-Pap.	nph	GC	1	0	0	0	0	0	0	0	0	0
835	Sesbastiana chamaelea (L.)Müll.Arg.	Euphorbiaceae	Ch	PAL	0	0	0	0	0	0	0	0	1	0
836	Sesuvium portulacastrum L.	Aïzoaceae	Ch	GO	1	0	0	0	0	0	0	0	0	0

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
837	Setaria barbata (Lam.)Kunth	Poaceae	Th	Pt	0	0	0	0	0	1	0	0	0	0
838	Setaria chevalieri Stapf	Poaceae	Hc	GC	0	0	0	0	0	1	1	0	0	0
839	Setaria megaphylla (Steud.)Th.Dur.& Schinz	Poaceae	Hc	GC	0	1	1	0	1	1	1	1	0	0
840	Setaria pumila (Poir.)Roem. & Schult.	Poaceae	Th	PAL	0	0	0	0	0	0	0	1	0	0
841	Sherbournia bignoniiflora (Welw.)Hua	Rubiaceae	Lmph	GC	0	1	0	0	0	0	0	0	0	0
842	Shirakia elliptica (Hochst.)Kruijt.	Euphorbiaceae	mPh	SG	0	0	0	0	1	0	0	1	1	0
843	Sida acuta Burm.f. subsp. acuta	Malvaceae	Ch	Pt	0	0	0	0	1	1	1	1	0	1
844	Sida collina Schlechtend. Syn. S. corymbosa R.E.Fr.	Malvaceae	Ch	GC	0	0	0	0	0	0	1	0	0	0
845	Sida cordifolia L.	Malvaceae	nph	Pt	0	0	0	0	0	0	0	0	0	1
846	Sida pilosa Retz. Syn. S. vernonicifolia Lam.	Malvaceae	Ch	SG	0	0	0	0	0	0	1	0	0	0
847	Sida rhombifolia L.	Malvaceae	nph	GC	0	0	0	0	1	0	1	0	0	0
848	Sida urens L. var. urens	Malvaceae	Lnph	GC	0	0	0	0	1	0	1	1	1	0
849	Simicratea welwitschii (Oliv.)N.Hallé	Hippocrateaceae	Lmph	GC	1	1	1	0	0	0	0	0	0	0
850	Smeathmannia pubescens Soland. ex R.Br.	Passifloraceae	nph	GC	1	0	0	0	0	0	0	0	0	0
851	Smilax anceps Willd. Syn. S. kraussiana Meissner	Smilacaceae	LGr	SG	1	1	1	1	1	1	1	0	1	0
852	Solanum erianthum G.Don Syn. S. verbascifolium L.	Solanaceae	nph	Pt	0	0	0	0	1	0	0	0	0	0
853	Solanum terminale Forssk. subsp inconstans (C.H.Wright)Heine	Solanaceae	Lmph	GC	0	0	1	0	0	0	0	0	0	0
854	Solanum torvum Sw.	Solanaceae	nph	GC	0	0	1	0	0	0	0	0	0	0
855	Solenostemon monostachyus P.Beauv.	Lamiaceae	Th	GC	0	0	0	0	0	0	0	0	1	0
856	Sorindeia warneckei Engl.	Anacardiaceae	Lmph	GC	1	1	1	1	1	1	0	0	0	0
857	Sparganophorus sparganophara (L.)Jeffrey	Asteraceae	Th	Pt	0	0	0	0	0	1	0	0	0	0
858	Spathandra blakeoides (G.Don)Jacq.-Félix	Melastomataceae	mph	GC	1	0	0	0	0	0	0	0	0	0
859	Spathodea campanulata P.Beauv.	Bignoniaceae	MPh	GC	0	1	1	1	1	1	0	0	0	0
860	Spermacoce filifolia (Schmach. & Thonn.)J.-P.Lebrun & Stork	Rubiaceae	Th	SG	0	0	0	0	1	0	0	0	0	1
861	Spermacoce octodon (Hepper)J.-P. Lebrun & Stork	Rubiaceae	Ch	SG	0	0	0	0	0	0	0	1	0	0
862	Spermacoce radiata (DC.)Sieber ex Hiern	Rubiaceae	Th	SG	0	0	0	0	1	0	1	1	1	1
863	Spermacoce ruelliae DC.	Rubiaceae	Th	SG	0	0	0	0	1	1	1	0	0	0
864	Spermacoce stachydea DC.	Rubiaceae	Th	SG	0	0	0	0	1	1	1	1	1	1
865	Sphenocentrum jollyanum Pierre	Menispermaceae	nph	GC	0	1	1	1	0	0	0	0	0	0
866	Sphenostylis schweinfurthii Harms	Leg.-Pap.	Hc	SZ	0	0	0	0	0	0	0	1	1	0
867	Spondianthus preussii Engl. subsp. preussii	Euphorbiaceae	mPh	GC	0	1	0	1	0	0	0	0	0	0
868	Spondias mombin L.	Anacardiaceae	mPh	Pt	1	1	1	0	1	0	1	1	1	0
869	Sporobolus paniculatus (Trin.)Dur. & Schinz.	Poaceae	Hc	PAL	0	0	0	0	0	0	1	0	0	0
870	Sporobolus pyramidalis P.Beauv.	Poaceae	Hc	SZ	0	0	0	0	1	1	1	1	0	1
871	Stachyanthus occidentalis (Keay & Miège)Boutique	Icacinaceae	Lnph	GO	0	1	1	1	1	0	0	0	0	0
872	Steganotaenia araliacea Hochst. var. araliacea	Apiaceae	mph	SG	0	0	0	0	0	0	0	1	1	1
873	Sterculia setigera Del.	Sterculiaceae	mph	S	0	0	0	0	1	1	1	1	1	1
874	Sterculia tragacantha Lindl.	Sterculiaceae	mPh	SG	1	1	1	1	1	1	1	1	1	0
875	Stereospermum kunthianum Cham. var. kunthianum	Bignoniaceae	mph	SZ	0	0	0	0	1	1	1	1	1	1
876	Streptogyna crinita P.Beauv.	Poaceae	Gr	GC	0	1	1	0	1	0	0	0	0	0
877	Striga asiatica (L.)Kuntze	Scrophulariaceae	Th	PAL	0	0	0	0	0	0	0	0	0	1
878	Strombosia pustulata Oliv. Syn. S. glaucescens Engl.	Olacaceae	mPh	GC	0	1	0	1	0	0	0	0	0	0
879	Strophanthus barteri Franck.	Apocynaceae	Lmph	GC	1	1	0	0	0	0	0	0	0	0
880	Strophanthus hispidus DC.	Apocynaceae	Lmph	GC	1	1	1	0	1	0	1	1	0	0
881	Strophanthus sarmentosus DC.	Apocynaceae	Lnph	GC	1	1	1	1	1	0	1	1	1	0
882	Strychnos barteri Soler.	Loganiaceae	LMPh	GC	0	0	1	0	0	0	0	0	0	0
883	Strychnos floribunda Gilg	Loganiaceae	LmPh	GC	0	1	1	0	0	0	0	0	0	0
884	Strychnos innocua Delile	Loganiaceae	mph	SZ	0	0	0	0	1	1	1	1	1	1
885	Strychnos nigritana Baker	Loganiaceae	LmPh	GC	0	1	1	0	1	1	0	0	1	0
886	Strychnos spinosa Lam.	Loganiaceae	mph	PAL	0	0	0	0	1	1	1	1	1	1
887	Strychnos splendens Gilg	Loganiaceae	LmPh	GC	0	1	1	0	1	0	0	0	1	0
888	Stylochiton hypogaeus Lepr.	Araceae	Gt	S	0	0	0	0	1	1	1	1	1	1
889	Stylochiton lancifolius Kotschy & peyr.	Araceae	Gr	S	0	0	0	0	0	0	0	1	0	1
890	Stylosanthes fruticosa (Retz.)Alston	Leg.-Pap.	Ch	PAL	0	0	0	0	0	0	0	1	0	1
891	Swartzia madagascariensis Desv.	Leg.-Caes.	mph	SZ	0	0	0	0	1	0	1	1	1	0
892	Symphonia globulifera L.f.	Clusiaceae	mPh	GC	1	1	1	1	0	0	0	0	0	0
893	Synaptolepis retusa H.Pearson	Thymeliaceae	Hc	SZ	0	0	0	1	0	0	1	1	1	0
894	Synsepalum brevipes (Baker)Pennington	Sapotaceae	mPh	GC	0	1	1	1	1	0	0	0	0	0
895	Synsepalum passargei (Engl.)Penn.	Sapotaceae	mph	SZ	0	0	0	0	0	0	0	1	1	0
896	Syzigium guineense (Willd.)DC. subsp. guineense	Myrtaceae	mph	At	0	0	1	0	1	1	1	1	1	1

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
897	Syzygium guineense (Willd.)DC. var. littorale Keay	Myrtaceae	mph	GC	1	0	0	0	1	0	0	0	0	0
898	Syzygium owariense (P.Beauv.)Benth.	Myrtaceae	mPh	GC	0	0	0	1	0	0	0	0	0	0
899	Tabernaemontana eglandulosa Stapf	Apocynaceae	Lmph	GC	0	1	0	0	0	0	0	0	0	0
900	Tabernaemontana pachysiphon Stapf	Apocynaceae	mph	GC	0	1	0	1	0	0	0	0	0	0
901	Tacazzea apiculata Oliv.	Asclepiadaceae	Lmph	SG	0	0	0	1	0	0	0	1	0	1
902	Tacca leontopetaloides (L.)O.Kuntze	Taccaceae	G	PAL	0	0	1	0	1	1	1	1	0	0
903	Talinum triangulare (Jacq.)Willd.	Portulacaceae	Ch	PAL	0	0	0	0	1	1	1	0	0	0
904	Tamarindus indica L.	Leg.-Caes.	mPh	Pt	0	0	1	0	1	1	1	1	1	1
905	Tapura fischeri Engl.	Dichapetalaceae	mph	GC	0	1	1	0	0	0	0	0	0	0
906	Tarenna bipindensis (K.Schum.)Bremek.	Rubiaceae	Lnph	GC	0	1	0	0	0	0	0	0	0	0
907	Tarenna calliblepharis N.Hallé Syn. T. conferta (Benth.)Hiern	Rubiaceae	Lnph	GE	0	1	0	0	1	0	0	0	0	0
908	Tephrosia bracteolata Guill. & Perr.	Leg.-Pap.	Ch	SG	0	0	0	0	1	1	1	1	1	1
909	Tephrosia elegans Schumach.	Leg.-Pap.	Ch	SG	0	0	0	0	1	1	1	1	0	1
910	Tephrosia gracilipes Gill. & Perr.	Leg.-Pap.	Th	SZ	0	0	0	0	0	0	0	0	0	1
911	Tephrosia linearis (Willd.)Pers.	Leg.-Pap.	th	SG	0	0	0	0	0	0	0	1	0	1
912	Tephrosia pedicellata Baker	Leg.-Pap.	Ch	SG	0	0	0	0	0	1	1	1	1	1
913	Tephrosia platycarpa Guill. & Perr. Syn. T. flexuosa G.Don	Leg.-Pap.	Ch	SG	0	0	0	0	0	1	0	0	1	1
914	Tephrosia purpurea (L.)Pers. subsp. purpurea	Leg.-Pap.	Ch	PAL	0	0	0	0	1	0	0	0	0	0
915	Tephrosia villosa (L.)Pers.	Leg.-Pap.	Ch	Pt	0	0	0	0	0	1	0	0	0	0
916	Teramnus buettneri (Harms)Baker f.	Leg.-Pap.	Ch	SZ	0	0	0	0	0	0	1	0	0	0
917	Teramnus micans (Baker)Baker f.	Leg.-Pap.	LCh	SG	0	0	0	0	0	0	0	1	0	0
918	Terminalia avicennioides Guill. & Perr.	Combretaceae	mph	S	0	0	0	0	1	1	1	1	1	1
919	Terminalia brownii Fres.	Combretaceae	mph	SZ	0	0	0	0	0	0	0	0	1	1
920	Terminalia laxiflora Engl. & Diels	Combretaceae	mPh	S	0	0	0	0	1	0	0	1	1	1
921	Terminalia macroptera Guill. & Perr.	Combretaceae	mph	S	0	0	0	0	0	1	1	1	0	1
922	Terminalia schimperiana Hochst.	Combretaceae	mph	S	0	0	1	0	1	1	1	1	1	1
923	Terminalia superba Engl. & Diels	Combretaceae	mPh	GC	0	1	0	1	1	0	0	0	0	0
924	Tetracera alnifolia Willd.	Dilleniaceae	Lmph	GC	1	1	1	1	1	0	0	0	1	0
925	Tetrapleura andongensis Welw. ex Oliv.	Leg.-Mim.	mPh	SG	0	0	0	0	1	0	1	0	0	0
926	Tetrapleura tetraptera (Schum. & Thonn.)Taub.	Leg.-Mim.	mPh	GC	1	1	1	0	0	0	0	0	0	0
927	Tetrorchidium didymostemon (Baill.)Pax & Hoffm.	Euphorbiaceae	mph	GC	0	1	1	0	0	0	0	0	0	0
928	Thonningia sanguinea Vahl.	Balanophoraceae	Par	GC	0	1	0	0	0	1	0	0	0	0
929	Thunbergia atacoriensis Akoègninou & Lisowski	Acanthaceae	LCh	SZ	0	0	0	0	0	0	0	0	1	0
930	Thunbergia togoensis Lindau	Acanthaceae	LCh	SG	0	0	0	0	0	0	1	0	0	0
931	Tiliacora funifera (Miers)Oliv.	Menispermaceae	Lmph	GC	0	1	1	0	0	0	0	0	0	0
932	Tinnea barteri Gurke	Lamiaceae	nph	SZ	0	0	0	0	1	1	1	1	1	1
933	Trachyphrynium braunianum (K.Schum.)Baker	Marantaceae	Lmph	GC	0	1	0	0	0	0	0	0	0	0
934	Trachypogon spicatus (L.f.)Kuntze	Poaceae	Hc	SZ	0	0	0	0	0	0	0	0	1	0
935	Tragia senegalensis Müll.Arg.	Euphorbiaceae	Lnph	S	0	0	1	0	1	1	1	1	1	1
936	Treculia africana Desc. subsp. africana	Moraceae	MPh	GC	0	1	1	1	0	0	0	0	0	0
937	Trema orientalis (L.)Blume	Celtidaceae	mph	Pt	1	1	1	1	1	1	0	0	1	0
938	Tricalysia faranahensis Aubrév. & Pellegr.	Rubiaceae	nph	GE	1	0	0	0	0	0	0	0	0	0
939	Tricalysia okelensis Hiern var. okelensis	Rubiaceae	mph	SZ	0	0	0	0	1	0	0	0	1	1
940	Tricalysia reflexa Hutch.	Rubiaceae	nph	GC	0	1	0	0	0	0	0	0	0	0
941	Tricalysia reticulata (Benth.)Hiern	Rubiaceae	nph	GO	0	0	0	1	0	0	0	1	0	0
942	Trichilia emetica Vahl subsp. emetica	Meliaceae	mph	SZ	0	0	0	0	1	1	1	1	1	1
943	Trichilia megalanta Harms	Meliaceae	mPh	GO	1	1	1	0	0	1	0	0	0	0
944	Trichilia monadelpha Harms.	Meliaceae	MPh	GC	0	1	1	0	0	0	0	0	0	0
945	Trichilia prieureana A.Juss. subsp. prieureana	Meliaceae	mph	GC	1	1	1	1	1	0	0	0	0	0
946	Trichilia retusa Oliv.	Meliaceae	mPh	SG	0	0	0	0	0	0	0	1	0	0
947	Trichilia tessmannii Harms. Syn. T. lanata A.Chev.	Meliaceae	mPh	GC	0	1	1	0	0	0	0	0	0	0
948	Trichoscypha oba Aubrév. & Pellegr.	Anacardiaceae	mph	GO	1	0	0	0	0	0	0	0	0	0
949	Tricliceras pilosum (Willd.)R.Fern.	Turneraceae	Th	SZ	0	0	0	0	0	0	0	1	0	0
950	Triclisia subcordata Oliv.	Menispermaceae	Lnph	SG	1	1	1	1	1	1	1	1	0	0
951	Trilepisium madagascariense DC. Syn. Bosqueia angolensis Ficalho	Moraceae	mPh	GC	0	1	0	1	1	0	1	0	0	0
952	Triplochiton scleroxylon K.Schum.	Sterculiaceae	MPh	GC	0	1	1	1	1	1	0	0	0	0
953	Tripogon minimus (A.Rich.)Steud.	Poaceae	Hc	SG	0	0	0	0	0	0	0	0	0	1
954	Tristachya superba Schweinf. & Asch.	Poaceae	Hc	SZ	0	0	0	0	0	0	0	1	0	0
955	Triumfetta rhomboidea Jacq. var. rhomboidea	Tiliaceae	nph	Pt	0	0	0	0	1	0	0	1	0	1
956	Turraea heterophylla J.B.Hall	Meliaceae	Lnph	GO	0	1	1	0	0	0	0	0	0	0

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
957	Tylophora cameroonica N.E.Br.	Asclepiadaceae	Lmph	GC	1	0	0	0	0	0	0	0	0	0
958	Tylophora dahomensis K.Schum.	Asclepiadaceae	Lmph	SG	1	0	0	0	0	0	0	0	0	0
959	Tylophora oblonga N.E.Br.	Asclepiadaceae	Lmph	GC	1	1	0	0	0	0	0	0	0	0
960	Tylophora sylvatica Decne.	Asclepiadaceae	Lnph	GC	0	1	1	0	0	0	0	0	0	0
961	Uapaca heudelotii Baill.	Euphorbiaceae	mPh	GC	0	1	1	0	1	0	0	0	0	0
962	Uapaca paludosa Aubrév. & Léandri	Euphorbiaceae	mPh	GC	0	0	0	1	0	0	0	0	0	0
963	Uapaca somon Aubrév. & Léandri Syn. Uapaca togoensis Pax	Euphorbiaceae	mPh	S	0	0	0	0	1	1	1	1	1	0
964	Urera obovata Benth.	Urticaceae	nph	GO	0	1	1	0	0	0	0	0	0	0
965	Urginea altissima (Linn.f.)Baker	Liliaceae	Gb	SZ	0	0	0	0	0	1	0	0	0	0
966	Urginea ensifolia (Thonning)Hepper	Liliaceae	Gb	SZ	0	0	0	0	1	0	0	1	1	0
967	Usteria guineensis Willd.	Loganiaceae	Lmph	GC	1	0	1	0	1	0	0	0	1	0
968	Uvaria angolensis Welw. ex Oliv. var. angolensis	Annonaceae	Lmph	GC	0	0	0	0	0	0	0	0	1	0
969	Uvaria chamae P.Beauv.	Annonaceae	Lmph	GC	1	1	1	0	1	1	1	0	1	0
970	Uvariodendron sp	Annonaceae	nph	GC	0	1	0	0	0	0	0	0	0	0
971	Vangueria madagascariensis J.F.Gmel. Syn. V. venosa Robyns	Rubiaceae	mph	GC	0	0	0	0	0	0	0	0	1	0
972	Vangueriella nigerica (Robyns)Verdc.	Rubiaceae	mph	SG	0	1	1	0	1	1	0	0	0	0
973	Vangueriella spinosa (Schumach. & Thonn.)Verdc.	Rubiaceae	mph	SG	0	0	1	0	1	1	1	0	1	0
974	Ventilago africana Gaertn.	Rhamnaceae	Lmph	GC	0	1	0	0	0	0	0	0	0	0
975	Vepris verdoorniana (Excell & Mendonça)W.Mziray	Rutaceae	mph	GC	0	0	1	1	0	0	0	0	0	0
976	Vernonia camporum A.Chev.	Asteraceae	nph	SZ	0	0	0	0	1	1	1	1	0	1
977	Vernonia cinerea (L.)Less	Asteraceae	Th	Pt	0	0	0	0	0	1	1	0	0	0
978	Vernonia colorata (Willd.)Drake	Asteraceae	mph	SZ	0	0	1	0	1	1	1	0	1	1
979	Vernonia galamensis (Cass.)Less Syn. V. pauciflora (Willd.)Less.	Asteraceae	Th	SZ	0	0	0	0	0	1	1	0	1	0
980	Vernonia glaberrima Welw. ex O.Hoffm.	Asteraceae	nph	SZ	0	0	0	0	0	0	1	0	0	0
981	Vernonia guineensis Benth.	Asteraceae	nph	SZ	0	0	0	0	1	1	1	1	0	0
982	Vernonia nigritana Oliv. & Hiern	Asteraceae	Ch	SZ	0	0	0	0	0	1	0	0	0	0
983	Vernonia pumila Kotschy & Peyr.	Asteraceae	Hc	SZ	0	0	0	0	0	0	1	1	0	0
984	Vernonia purpurea Sch.Bip.	Asteraceae	nph	SZ	0	0	0	0	0	0	0	1	0	0
985	Vetiveria nigritana (Benth.)Stapf	Poaceae	Hc	SZ	0	0	0	0	0	0	0	0	0	1
986	Vicoa leptoclada (Webb)Dandy	Asteraceae	Th	SG	0	0	0	0	0	1	1	1	1	1
987	Vigna ambacensis Baker	Leg.-Pap.	LCh	SG	0	0	0	0	0	1	1	1	0	1
988	Vigna gracilis (Guill. & Perr.)Hook.f.	Leg.-Pap.	Lnph	SG	1	0	0	0	0	1	0	0	0	0
989	Vigna racemosa (G.Don)Hutch. & Dalziel	Leg.-Pap.	LCh	SG	0	0	0	0	0	1	0	1	0	1
990	Vigna reticulata Hook.f.	Leg.-Pap.	Lmph	SG	0	0	1	0	0	0	0	0	0	0
991	Vitellaria paradoxa C.F.Gaertn.	Sapotaceae	mPh	S	0	0	0	0	1	1	1	1	1	1
992	Vitex chrysocarpa Planch. ex Benth.	Verbenaceae	mph	SZ	0	0	1	0	1	1	0	1	1	1
993	Vitex doniana Sweet	Verbenaceae	mph	SZ	1	0	1	0	1	1	1	1	1	1
994	Vitex grandifolia Gürke	Verbenaceae	mph	GC	1	1	0	0	1	0	1	0	0	0
995	Vitex madiensis Oliv. Syn. V. simplicifolia Oliv.	Verbenaceae	mph	SZ	0	0	0	0	0	1	1	1	1	0
996	Vitex micrantha Gürke	Verbenaceae	mPh	GO	0	0	1	0	0	0	0	0	0	0
997	Voacanga africana Stapf	Apocynaceae	mph	SG	0	0	0	0	1	0	0	1	0	0
998	Waltheria indica L.	Sterculiaceae	nph	Pt	0	0	0	0	1	1	1	1	0	1
999	Warneckea fascicularis Planch. ex Benth.	Melastomataceae	mph	GO	0	0	0	1	0	0	0	0	0	0
1000	Warneckea memecyloides (Benth.)Jacq.-Fél.	Melastomataceae	Lmph	GC	0	1	1	0	0	0	0	0	0	0
1001	Whitfieldia elongata (P.Beauv.)De Wild. & Th.Dur.	Acanthaceae	Ch	GE	0	1	0	0	0	0	0	0	0	0
1002	Wissadula amplissima (L.)R.E.Fries	Malvaceae	Th	SZ	0	0	1	1	1	1	1	1	1	1
1003	Xeroderris stuhlmannii (Taub.)Mendonça & Sousa	Leg.-Pap.	mph	SZ	0	0	0	0	1	1	1	1	1	1
1004	Ximenia americana L.	Olacaceae	nph	Pt	0	0	0	0	1	1	1	1	1	1
1005	Xylopia aethiopica (Dunal)A.Rich.	Annonaceae	mPh	SG	1	1	0	1	0	0	0	0	0	0
1006	Xylopia parviflora (A.Rich.)Benth.	Annonaceae	mph	SG	1	1	1	1	1	0	1	0	1	0
1007	Xylopia rubescens Oliv.	Annonaceae	mPh	GO	0	1	1	1	0	0	0	0	0	0
1008	Xylopia villosa Chipp	Annonaceae	mPh	GO	0	1	0	0	0	0	0	0	0	0
1009	Zacateza pedicellata (K.Schum.)Bull.	Asclepiadaceae	LmPh	GE	0	0	0	1	0	0	0	0	0	0
1010	Zanha golungensis Hiern	Sapindaceae	mPh	SG	0	0	0	0	1	1	1	1	1	0
1011	Zanthoxyllum rubescens Planch. ex Hook.f.	Rutaceae	mPh	GC	0	0	1	0	0	0	0	0	0	0
1012	Zanthoxylum gilletii (De Wild.)Waterman	Rutaceae	mph	GC	0	1	1	0	0	0	0	0	0	0
1013	Zanthoxylum leprieurii Guill. & Perr.	Rutaceae	mph	GC	0	1	1	0	0	0	0	0	0	0
1014	Zanthoxylum zanthoxyloides (Lam.)Zepernick & Timber	Rutaceae	mph	SG	1	0	1	0	1	1	0	0	1	1
1015	Zehneria hallii C.Jeffrey	Cucurbitaceae	Lnph	SG	0	1	0	0	0	1	0	0	0	0
1016	Zephyranthes tubispatha Herb.	Amaryllidaceae	Gb	PAL	0	0	0	0	0	0	1	0	0	0

No	Plant species	Family	LF	Chor.	CO	PO	PL	OV	BA	ZO	BS	BN	AT	M-P
1017	Ziziphus abyssinica Hochst. ex A.Rich.	Rhamnaceae	mph	SZ	0	0	0	0	0	0	0	0	1	1
1018	Ziziphus mauritiana Lam.	Rhamnaceae	mph	PAL	0	0	0	0	0	0	0	0	0	1
1019	Ziziphus mucronata Willd.	Rhamnaceae	mph	SZ	0	0	1	0	1	1	1	1	1	1
1020	Ziziphus spina-christi (L.)Desf. var. microphylla Hochst. ex A.Rich.	Rhamnaceae	mph	SZ	0	0	0	0	0	0	0	0	0	1
1021	Zornia glochidiata Rchb. ex DC.	Leg.-Pap.	Th	SG	0	0	0	0	0	0	0	0	0	1

LF: Life form follows Raunkiaer (1934), Schnell (1971), and Keay & Hepper (1954-1972): MPh: megaphanerophyte (> 30 m tall), mPh: mesophanerophyte (8-30 m), mph: microphanerophyte (2-8 m), nph: nanophanerophyte (0.5-2 m), Ch: chamaephyte, HC: Hemicryptophyte, Th: Therophyte, G: Geophyte (Gb: with bulb, Gr: with rhizome and Gt: with tuber), Hyd: Hydrophyte, L.: Liana, Ep: Epiphyte.

Chor.: Chorology: GC: Guineo-Congolian, GE: Lower Guinean, GO: Upper Guinean, S: Sudanian, SG: Sudano/Guinean transition, SZ: Sudano-Zambezian, At: Tropical Africa, Pt: Pantropical, PAL: Paleotropical, and Cos: Cosmopolitan.

Phytogeographgical districts: CO: Côtier, PO: Pobè, PL: Plateau, VO: Vallée de l’Ouémé, BA: Bassila, ZO: Zou, BS: Borgou-Sud, BN: Borgou-Nord, AT: Chaîne de l’Atacora, M-P: Mékrou-Pendjari.

Leg.-Caes.: Leg.-Caesalpinioideae, Leg.-Mim.: Leguminosae-Mimosoideae, Leg.-Pap.: Leguminosae-Papilionoideae.

Presence/absence: 0: species was not recorded during our field survey, which does not mean that the species is absent from the area; 1: species was recorded during our field survey.

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Front cover: Semi-deciduous forest of Lama, Benin (Adomou, 2001)

Back cover: riparian forest of Adjiro (Ouémé river), Benin (van der Maesen, 1998)

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PROPOSITIONS

1. Water availability – expressed as a function of rainfall, length and intensity of the dry season, and air humidity – is the major factor determining the vegetation patterns in Benin rather than the annual rainfall amount considered alone *(this thesis, chapter 3)*.

2. The semi-deciduous forest islands in the Dahomey Gap are probably relics of a once more humid and continuous forest that survived the Holocene dry period (4000-2500 years BP) *(this thesis, chapter 4)*.

3. The Holocene, in contrast to all other ages, epochs, and eras that are characterised by natural evolutionary and geological phenomena, is distinguished by being the age during which human activities have had a marked, and for the most part extremely detrimental, effect on the rest of the biosphere *(Alan Kazlev 2002)*.

4. Incorporating local values into projects helps ensure that biodiversity conservation initiatives are compatible with local concerns and builds respect and trust between local communities and project managers.

5. Always remember the past, for therein lies the future; if forgotten, we are destined to repeat it (*African proverb*).

6. Each moment of seeking is a moment of finding. "*Elk moment van zoeken is een moment van vinden*". *(Dutch proverb)*.

Propositions to the thesis "Vegetation patterns and environmental gradients in Benin: Implications for biogeography and conservation". Aristide Cossi Adomou, 21 September 2005; Wageningen, the Netherlands.