

ECOLOGICAL CONDITIONS AND FLORISTIC DIVERSITY OF AN INSELBERG IN THE SAVANNA ZONE OF IVORY COAST: MT NIANGBO

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Résumé : Les inselbergs sont des systèmes terrestres ressemblant à de véritables îles (isolement pédologique, climatique et floristique). Ils représentent des modèles parfaits pour les études phytogéographiques et écologiques.

L'analyse de deux couvertures photographiques aériennes et du travail sur place avec l'application du « système d'information géographique » rend possible la présentation des cartes de la végétation du Mt. Niangbo pour les années 1956, 1972 et 1992.

Avec une surface de plus de 7 km² le Mt Niangbo est le plus grand inselberg de Côte d'Ivoire. Il se trouve dans le domaine des savanes (« secteur sub-soudanais »), il est âgé probablement de plus de 70 millions d'années. Il est constitué en majorité de gneiss.

La sécheresse pédologique et climatique due aux températures dépassant 60 °C sur la roche et à la forte action du rayonnement solaire est responsable du caractère xérique de l'inselberg. Au pied des pentes on trouve une ceinture de forêt qui profite du ruissellement d'eau. La flore du Mt. Niangbo renferme environ 200 espèces, pour la plupart annuelles. Parmi ces espèces, la majorité est constituée par des éléments soudano-zambéziens. La surface de la roche est occupée par des lichens (*Peltula* spp.). Les pentes très raides portent des tapis d'*Afrotrilepis pilosa* qui forment des flots végétaux. Une végétation arborée se trouve sur les parties planes. Des associations éphémères (avec beaucoup de Lenticulariaceae) se développent dans les zones marécageuses.

Par comparaison entre les couvertures photographiques aériennes et les observations directes, on doit constater que la surface forestière sur le Mt. Niangbo a diminué. Par contre, les tapis d'*Afrotrilepis pilosa* et d'autres associations herbacées ont augmenté de surface. Autour de l'inselberg, la surface forestière a diminué considérablement de 1956 à 1992 à cause de l'extension de l'agriculture.

Mots-clés : Biodiversité, conditions climatiques/pédologiques, Côte d'Ivoire, dynamisme de la végétation, inselberg, modèle numérique de terrain, phytogéographie, système d'information géographique.

Abstract: Inselbergs are terrestrial systems with insular attributes (i.e. they are isolated under edaphic, climatic and floristic aspects) and provide suitable models for studying biogeographical and ecological aspects. Using geographical information systems (GIS) a digital elevation model (DEM) superimposed by vegetation maps for 1956, 1972 and 1992 for Mt Niangbo is presented. Vegetation maps were derived from aerial photographs and verified in the field.

Mt. Niangbo is the largest inselberg of Ivory Coast. Situated in the savanna zone ("secteur sub-soudanais") this inselberg is supposed to have an age of more than 70 million years. Geologically uniform plutonic and metamorphic rocks especially gneiss are dominating. Microclimatological data emphasize the edaphic and climatic dryness of most localities on the inselberg according to the variability of precipitation, high degree of radiation and evapotranspiration. Large amounts of run-off water from the inselberg catchment support an extrazonal forest belt. The flora of Mt Niangbo comprises nearly 200 species of vascular plants. Short-lived ephemerals are preponderant. Phytogeographically Sudano-Zambesian elements dominate. Free rock surfaces are covered by lichens (mainly *Peltula* spp.). Steep slopes bear *Afrotrilepis pilosa*-mats occurring as isolated sub-islands. Gentle slopes and plain surfaces carry patches of forest or related communities. On seepage areas ephemeral flush communities develop characteristically with many carnivorous species. Aerial surveys and field work show that forests on Mt Niangbo were decreasing whereas *Afrotrilepis*-mats and related communities have enlarged their area. In the surroundings the forest area decreased considerably from 1956 up to 1992 due to the large scale-extension of farmland.

Keywords: Biodiversity, climatic/edaphic conditions, inselbergs, island ecology, Ivory Coast, phytogeography, vegetation dynamics.

Introduction

Tropical biomes harbour the most species-rich communities. The reasons for their extraordinary diversity are not completely understood. In recent years oceanic islands have been subjects of biogeographical and ecological studies concerned with species numbers and the parameters that might determine species diversity because they are sharply definable systems.

According to MAC ARTHUR & WILSON (1967) there are terrestrial systems which can be considered as habitat islands. In contrast to oceanic islands however terrestrial inselbergs rarely have been used for ecological studies.

On the global scale a first short comparison of the inselberg vegetation was published by BARTHLOTT *et al.* (1993). Regional studies are known from different parts of the tropics e.g. French Guiana (de GRANVILLE, 1978), Tansania (BJORNSTAD, 1976), Ceylon (WILLIS, 1906).

The vegetation of West African inselbergs is well known due to several works (e.g. MILDBRAED, 1922; SCHNELL, 1952; RICHARDS, 1957; ADJANOHOON, 1964; HAMBLER, 1964; BONARDI, 1966; LETOUZEY, 1968; VILLIERS, 1981; REITSMA *et al.*, 1992).

Own field work is continually under way since 1990. Using geographical information systems (GIS) a digital elevation model (DEM) for Mt. Niangbo is presented. Vegetation maps based on stereophotogrammetrical interpretation of aerial photographs from different periods (1956, 1972) and on investigations in the field are provided and will be discussed concerning long-term vegetational changes.

For botanical purposes the application of geographical information systems is relatively new. This work is aimed to be continued under aspects of vegetation dynamics and biodiversity.

Methods

By the use of ATLAS-GIS and IDRISI a three dimensional Digital Elevation Model (DEM) of Mt Niangbo with calculated slope and aspect patterns was created. The interpretation of aerial photographs (from 1956 and 1972) provided maps containing informations about the change of land use and the distribution of natural vegetation units. The three dimensional model of Mt Niangbo allows correlations between certain geomorphological features and the occurrence of vegetation types.

Study site

Mt Niangbo (8° 49' N., 5° 11' 30" W. Figure 1.a) covers an area of 7,13 km². The distance between the most northern and the southern summits is more than 7 km. Approximately 4 km to the north of Mt Niangbo there are three smaller inselbergs. Further rock outcrops of small size can be found in large numbers in the entire region.

Climate

Climatological data about Mt Niangbo are available from the station Niakaramandougou (fig. 2) located a few kilometers southwest of the inselberg. The climate is characterized by a dry season from November until March and a rainy season from April to October. Mean annual rainfall is 1163 mm. August and September are the wettest months with more than 200 mm precipitation. Following the classification of THORNTHWAITE this region belongs to the BA'w type. Especially during the dry season the summits of Mt Niangbo are fog-covered in the early morning. During this period the harmattan (northeasterly trade-wind bringing dry air from the Sahara) can drop the relative humidity below 20% with daytime temperatures above 40 °C.

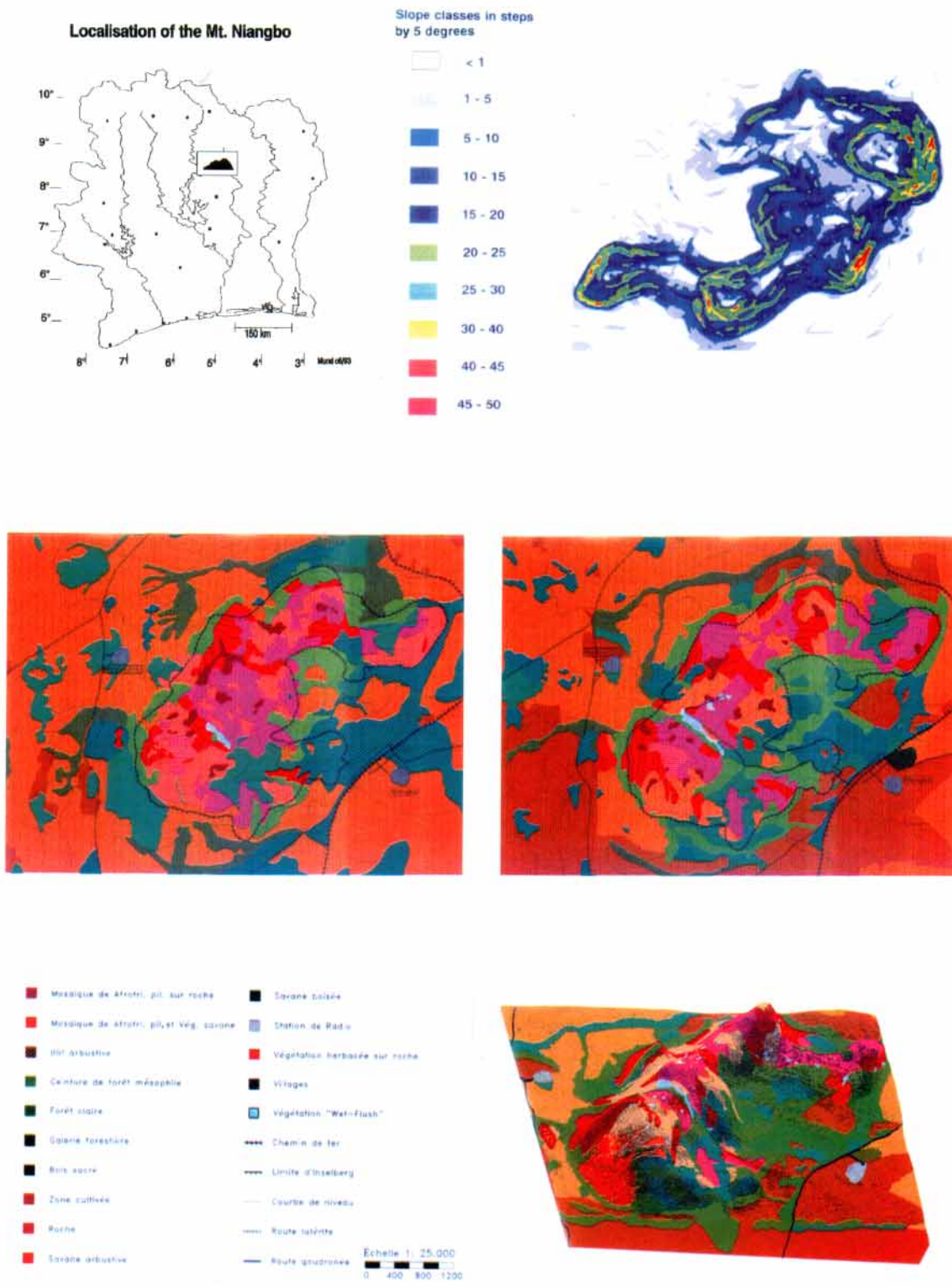


Figure 1

a: Localization of Mt. Niangbo, Ivory coast. b: Slope classes. c, d, e: Vegetation maps of Mont Niangbo in 1956, 1972 and 1992 based on aerial photographs using geographical information systems.

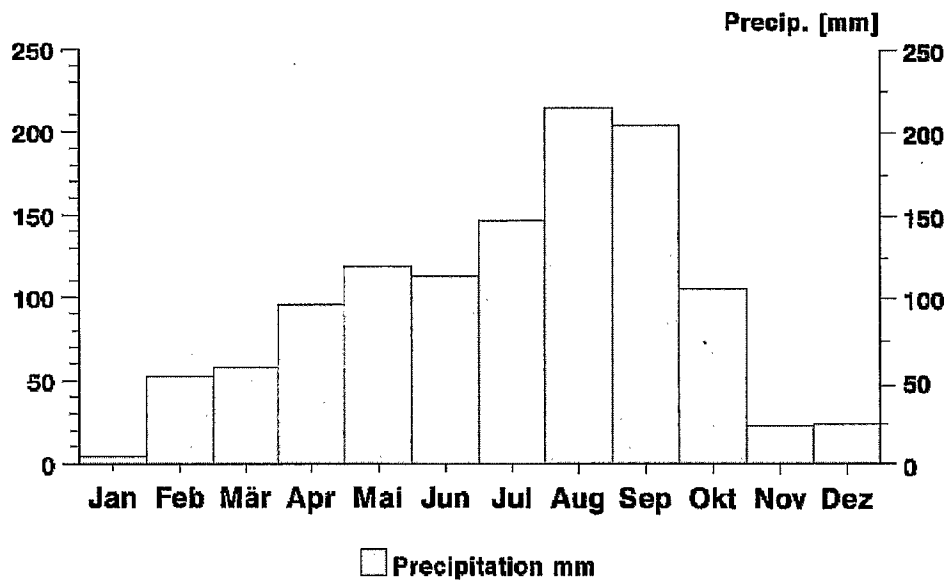


Figure 2

Climatic graph of Niakaramdougou (Côte d'Ivoire), the nearest station to Mt Niangbo. (Localisation 8° 39' N/5° 23' W, Elevation 349 m, Climatic type Köppen Aw; Troll V,2; Lauer A2sh, Mean annual temperature 26,4 °C, Annual precipitation 1163 mm. Mund 01/93. Data base ASECNA/Abidjan 1979).

Minimum temperatures during the dry season sometimes fall below 10° C with dew in the morning hours. Even in the rainy season the climate of Mt. Niangbo is relatively dry. Temperatures on the bare rock exceed 60 °C (caused by high radiation of over 1000 W/m²) while the relative humidity is falling below 30%. Due to the edaphic and climatic dryness of most localities Mt Niangbo, like inselbergs in general, can be considered as an arid habitat complex which strongly differs from the surroundings.

Geomorphology

Geomorphologically inselbergs are well known (BREMER & JENNINGS, 1978). Inselbergs mostly consisting of precambrian granites or gneisses (like Mt Niangbo which is probably more than 70 mio. years old) can be found in each climatic region of Ivory Coast. As striking elements of the landscape they are often dome-shaped whereas the so-called "kopje-type" (consisting of large boulders) is lacking. Lying amidst slightly undulating plains (mean sea level c. 300 m) the highest summit of Mt Niangbo reaches 643 m (altogether four separate summits can be distinguished) being nearly 340 m above the surrounding landscape. Due to its enormous size almost all morphological characteristics of inselbergs are present, e.g. the curved convex profiles of the slopes. Towards the periphery the inselberg is delimited by nearly vertical slopes.

Vegetation of Mt Niangbo

After GUILLAUMET & ADJANOHOON (1971) this inselberg is situated in the "secteur sub-soudanais", i.e. in a zone dominated by open forests ("forêt claire") and woodland ("savane boisée"). Although lying in a forest reserve the vegetation around the inselberg has been largely deforested except of tiny forest patches (so-called "bois-sacré") which were protected for religious reasons, small gallery forests and forest outliers associated with Mt Niangbo. Today several small villages are scattered around the mountain and different savanna types as well as farmland are dominating. Characteristic elements in the tree layer of the open forests are *Isoberlinia doka*, *Monotes kerstingii*, *Anogeissus leiocarpus* and *Manilkara multinervis*. Typical trees of the woodland are *Lophira lanceolata*, *Detarium*

senegalense, *Daniellia oliveri*, *Pterocarpus erinaceus*, *Terminalia glaucescens*, *Vitellaria paradoxa* and *Khaya senegalensis*. It can be supposed that the species composition of these communities is strongly influenced by regularly occurring fires during the dry season. Therefore many tree species have a thick bark capable of resisting fires. Another factor influencing the species composition is the selection and protection of useful trees around the villages and on the farmland. Highly appreciated trees are *Adansonia digitata* and *Parkia biglobosa*.

Being the dominant feature of the landscape Mt Niangbo is under anthropogenic impact. Most obvious effects are fires lit during the dry season and the existence of a radio station (built in 1972) which can be reached by a paved road.

Habitats types of mont Ngianbo

Based on own studies (POREMSKI & BARTHOLOTT, 1992) of more than 100 West African inselbergs it became obvious that several clearly delimited habitats can be distinguished. All these habitat types are present on Mt. Niangbo. A short description of the vegetation of Mt Niangbo is given by MIEGE (1955).

The following habitat types can be distinguished (Fig. 1.c, d, e):

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| 1 | Exposed rock surfaces covered by cryptogams (crustose lichens are dominating) |
| 2 | Drainage channels (covered by cyanobacteria and lichens) |
| 3 | Rock crevices and boulder-falls (offering growing sites to both herbs and woody plants) |
| 4 | Rock pools (seasonally water-filled, colonized by small ephemerals, fig. 4) |
| 5 | Flat depressions filled with young stony soil (harbouring seasonally inundated communities) |
| 6 | <i>Afrotrilepis pilosa</i> -mats (typical community of steeply sloping rock faces, fig. 5) |
| 7 | Ephemeral flush vegetation (occurring on moist peaty soil, develops during the rainy season) |
| 8 | Wet flush vegetation (develops on bare wet rocks during the rainy season, consisting of short-lived specialists) |
| 9 | Mesophytic forests adjacent to the inselberg (on deep weathered soils attaining a height of up to 20 m, rocks and boulders are abundant) |
| 10 | Semi-deciduous forests on the inselberg (often with xerophytic trees) |

Compared with the surrounding savannas and forest patches the vegetation cover of Mt Niangbo is floristically completely different. Most of the vegetation of Mt. Niangbo (Fig. 3, 4, 5) consists of a mosaic of rocks covered by cryptogams and *Afrotrilepis*-mats (about 65% of the surface). The rock faces are completely covered by dark brown and grey lichens (mainly *Peltula* spp.). On gently inclined slopes *Afrotrilepis*-mats nearly always occur as isolated patches with more or less circular outline. Irregularly shaped *Afrotrilepis*-mats develop on plain rock surfaces. Typically the lower edges of the mats are fringed by annuals and mosses (e.g. *Bryum arachnoideum*). *Afrotrilepis*-mats are floristically poor and homogeneous (low alpha- and beta-diversity).

An important determinant responsible for the distribution of habitat types on inselbergs is the degree of inclination of the rock faces. The correlation between inclination of slopes and distribution of habitats is demonstrated in the following for *Afrotrilepis*-mats and forests. The distribution of different slope classes is shown in Fig. 1.b.

Slopes with inclinations of more than 20° are covered either by cryptogams or by small mats of *Afrotrilepis*. The percentage of cryptogams is increasing with the degree of inclination. Very steep slopes with degrees of inclination of more than 50° bear mats of *Afrotrilepis* only at localities like tiny crevices which allow long-term establishment. Gentle slopes and plain surfaces bear patches of forest or similar communities. However, it is striking that only a small amount of the potentially suitable area is covered by forests. This is probably the result of destructive human impacts in the past. On the other hand, mats of *Afrotrilepis* and related communities certainly have extended into former wooded areas. *Afrotrilepis*-mats on plain surfaces are occasionally invaded by woody colonists (e.g. *Terminalia glaucescens*) which might initiate a succession towards a reforestation.

Forest communities and savanna like habitats make up the remaining 35% of the vegetation cover. It is difficult to draw sharp boundaries between the different types of forests on inselbergs

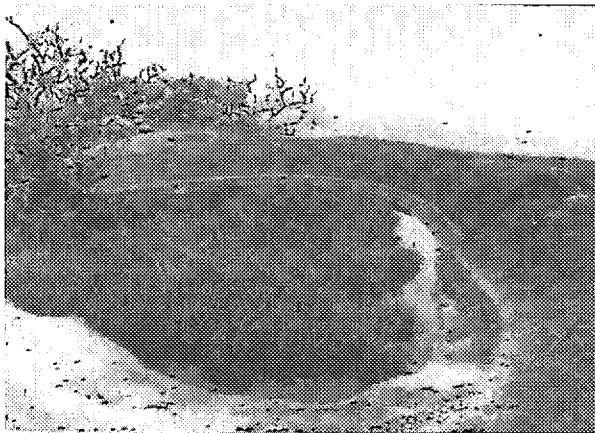


Figure 3 (up)

View of central portion of Mt Niangbo. The vegetation consists mostly of a mosaic of rocks covered by cryptogams and *Afrotrilepis*-mats. Forests are of minor importance.



Figure 4 (middle)

Seasonally water-filled rock pools (with *Cyanotis lanata* Benth.) can be found in large numbers on more or less plain rock faces.

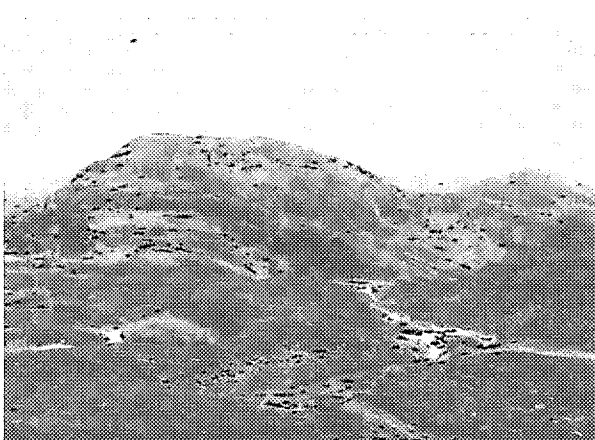


Figure 5 (low)

Mats of poikilohydric Cyperaceae *Afrotrilepis pilosa* 5Boeck. J. Raynal is a characteristic element of West African inselbergs.

because they often intergrade into each other. However it is possible to distinguish between mesophytic belt forests at the feet of the slopes and more xerophytic forest types on the slopes. The percentage of characteristic inselberg habitats like the ephemeral/wet flush vegetation lies below 1% of the area but contains a third of the flora. Short-lived ephemerals represent more than 50% of the flora of Mt Niangbo. Many of them are characteristic elements of the ephemeral flush vegetation (e.g. Lentibulariaceae, Eriocaulaceae). They possess remarkably short life-cycles and reach seed maturity in less than four weeks after germination.

The Rubiaceae are the largest family in the flora of Ivory Coast with about 300 species, followed by Poaceae, Fabaceae and Cyperaceae. The most species-rich families on Mt Niangbo are Poaceae (24 species), Cyperaceae (17 species), Scrophulariaceae (11 species) and Fabaceae (9 species). The largest genera are *Utricularia* (6 species) and *Panicum* as well as *Indigofera* with 5 species both.

Nearly one third of the species occurring on Mt Niangbo is to be found chiefly on inselbergs, i.e. they are characteristic elements of the inselberg vegetation (e.g. *Afrotrilepis pilosa*, *Cyanotis lanata*). These inselberg characteristics are not strictly restricted to inselbergs and can be found elsewhere under similar ecological conditions. In West Africa the vegetation of inselbergs shows close floristic affinities to the vegetation over ironstone outcrops (locally known as "bowal"), to communities on thin, rocky soils at higher elevations (e.g. highlands of Guinea) and to the vegetation of coastal savannas on poor leached soils ("savanes littorales"). Concerning the number of species Mt Niangbo can be considered as a local center of diversity. Compared to the flora of Ivory Coast (3660 species of vascular plants after AKÉ ASSI, 1984) 5,3% of all species occurring in this country can be

found on Mt. Niangbo. With an area of 7,13 km² this inselberg covers only 0,002% of the area of Ivory Coast (322,463 km² DAVIS *et al.*, 1986). It is therefore to conclude that inselbergs like Mt Niangbo are important components of biodiversity concerning the number of species.

Phytogeographical affinities

The chorology of the species found on Mt. Niangbo has been evaluated by using floras of tropical Africa (most of all "Flora of West Tropical Africa" HUTCHINSON & DALZIEL, 1954-1973). Regarding the delimitation of phytogeographical divisions we follow TAKHTAJAN (1986). The 194 species found on Mt Niangbo show the following phytogeographical relationship:

25,8%	TROPICAL AFRICAN
23,7%	SUDANO-ZAMBEZIAN ELEMENTS
22,1%	GUINEO-CONGOLIAN ELEMENTS
10,5%	PALEOTROPICAL ELEMENTS
8,9%	PANTROPICAL ELEMENTS
7,4%	ENDEMIC IN THE UPPER GUINEA PROVINCE
1,6%	OCCUR BOTH IN TROPICAL AMERICA AND TROPICAL AFRICA

Tropical African species make up the largest part of the inventory. However the term "tropical African" is phytogeographical weakly defined. The category Sudano-Zambeian includes in particular species with a very extended distribution: many are annual weeds. This group also includes *Cyanotis lanata*, a characteristic species of tropical African inselbergs. The percentage of Sudano-Zambeian elements is decreasing towards the rainforest zone whereas Guineo-Congolian elements become more frequent. In the rainforest zone the forests are barriers which prevent easy access of Sudano-Zambeian species which are dispersed by "island hopping". The vegetation of inselbergs in the rainforest zone shows nevertheless a considerable percentage of Sudano-Zambeian species. Lying in the rainforest zone these species may be remnants of drier vegetation types which were dominating during drier periods in the Pleistocene (VAN ZINDEREN *et al.*, 1972).

Guineo-Congolian elements are dominating the physiognomy of typical inselberg habitats, e.g. *Afrotrilepis pilosa*. Relatively high is the amount of Guineo-Congolianelements in the belt forests adjacent to the inselberg (also in the gallery forests in the same region). Tree species like *Chlorophora excelsa* and *Sterculia tragacantha* have their northern outposts in Ivory Coast in these forest types which are benefiting from the run-off water.

Most of the paleotropical species are weedy annuals. Similar ecological tendencies are characteristic for the pantropical elements, e.g. *Chamaecrista mimosoides*. Endemic to Upper Guinea are 7,4% of the species. A striking representative of this category is the orchid *Polystachya microbam-busa* which is restricted to tufts of *Afrotrilepis pilosa*. Only 1,6% of the species show an amphi-atlantic distribution, e.g. the Gentianaceae, *Neurotheca loeseliodes*. Mt Niangbo has no endemics. However species occur (e.g. *Aeschynomene lateritia* and *Microcharis welwitschii* var. *remotiflora*) which are known from only a few localities in Ivory Coast. Probably due to the frequent fog-covering of the summits some cryptogams occur (e.g. the lichen *Toninia bumamma*) which are otherwise absent from the savanna region.

Vegetation of dynamics on Mt Niangbo

In Ivory Coast analysis of vegetation dynamics in a forest-savanna mosaic using aerial surveys has been conducted in order to answer the question whether forests or savannas are increasing in area (GAUTIER, 1989, 1990). Inselbergs however have never been investigated in this way. Judging from aerial photographs and field work it can be stated that anthropogenic influences lead to changes in the vegetation cover but that most habitats which are characteristic of inselbergs did not vary in large

extent in their area over almost 40 years. Therefore it can be supposed that most inselberg habitats are relatively stable and may act as refuges for certain species.

Highly sensitive to human impacts (fire, logging) are forests on the summit of Mt. Niangbo respectively in the surrounding area. According to the analysis of aerial surveys and field work it became obvious that forests on Mt Niangbo were decreasing whereas fire-resistant *Afrotrilepis*-mats and related communities have enlarged their area. In the surroundings the forest surface was considerably decreasing from 1956 up to 1992 due to the large-scale extension of farmland.

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