"RORAIMA SAVANNAS" : CLIMAX SITUATION OR BOTANIC RELIC
(preliminary results)

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Résumé

Des mosaïques forêt- savane sont courants dans la zone de Roraïma (Amazonie brésilienne). L'occurrence et l'origine de ce type d'environnement ainsi que l'hypothèse d'une végétation "climax" sont ici discutées.

Les savanes sont très vraisemblablement un héritage des fluctuations climatiques quaternaires, comportant de phases "sèches" La remarquable composition botanique de ces savanes peut être interpretée comme le résultat d'un isolement relativement récent. Quant aux éléments communs de cette flore, ils indiqueraient que les processus de diversification de ces formations et les associations des nouvelles plantes sont l'expression de leur évolution actuelle.

Abstract

As in the other parts of South America, fores-savanna mosaics are common in the Roraïma area (Brazil) and cover quite extensive areas. Ocurrence and origin of this kind of environment remain debatable. The hypothesis of a "climw stage" is discussed.

These savanna areas can be considered as modern relic areas formed under Pleistocene and post-Pleistocene climatic fluctuations, during which drier vegetation formations penetrated the Amazon region. Their remarkable floristic and physiognomic similarities can be interpreted as a consequence of a relatively recent isolation; even more if we consider that for the Amazon savannas however, the constant presence of common elements in their flora may also indicate that such a diversification process and consequent formation of new plant associations is presently taking place.

Mots clés - Savanes. Roraïma. Amazonie Brésilienne. Evolution actuelle et quaternaire. Sols. Modelé. Variations paléoclimatiques.

Key-words - Sannas. Raraïma. Amazon's basin. Modern and Quaternary evolution. Soils. Morphology. Paleoclimatc environments.

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INTRODUCTION

The present research takes place in a kind of ecotone zone where forest changes almost abruptly into savanna vegetation. As in other parts of South America, forest-savanna mosaics are common in the Roraima area (Fig. 1), covering quite extensive areas though their complexity, distributional pattern and, composition and physiognomy of their components vary.

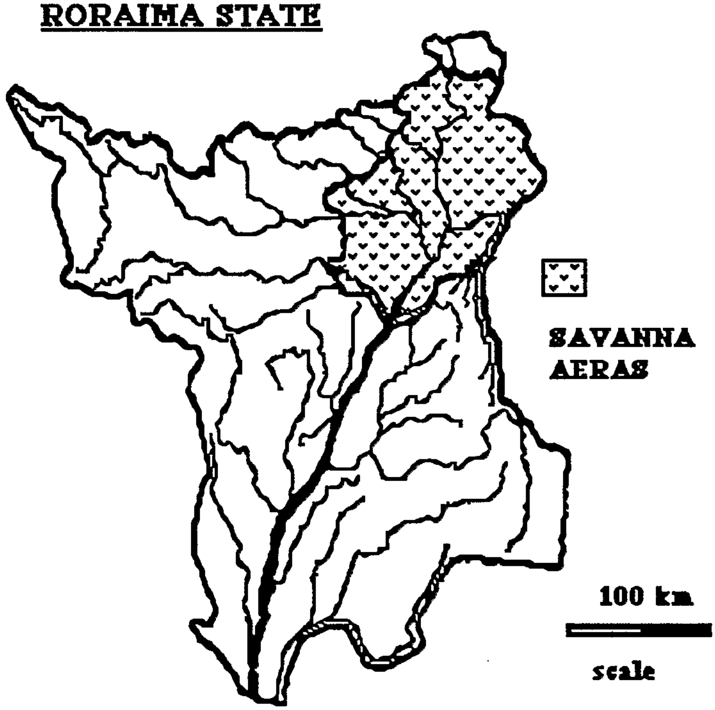

Fig. 1. Location map with forest and savanna areas.

Various uses have been given to the concept of "savanna" and literature is heavily encumbered by problems of terminology. The one adopted here is taken from Teunissen (1970) which says: *"savanna or a campo is an area with a xeromorphic vegetation comprising of an ecologically dominant ground layer consisting mainly of grasses, sometimes together with sedges, and with or without trees and/or shrubs either forming a more or less continuous layer, or occurring in groups, or isolated"*. In Brazil the dry savanna vegetation is called cerrado, cerradao or campo if it is shrub savanna, tree savanna or grass savanna respectively.

Occurrence and origin of this kind of environment remain debatable. Fire adaptation, human influence, edaphic, climatic and hydrologic origins are some of the arguments used to explain such mosaic. Emmerich (1990) has speculated that the distribution of forest and savannas in Brazil depends on the landform.

The highest and oldest peneplains and their inselbergs are dominated by savanna. In contrast, younger lower peneplains and intermontane plains all over Brazil, in the Amazon basin as well as in the central west, are covered mainly by forest with spots of savanna.

LITERATURE REVIEW

In view of the agricultural methods used by Indians, the field preparation for food-growing includes slashing and burning forest plots as well as burning xeromorphic vegetation (savanna) for hunting in the renewed grazing fields. Based on this, some authors prefer to call the savanna vegetation as man-made vegetation (Aubreville, 1949; Rawitscher, 1950; and Budowski, 1985). Yet, Saldarriaga (1986), has supposed that the natural fires have occurred by the occasion of past dry phases recorded during the Holocene.

Many authors when studying different areas of savanna concludes that such vegetation is a kind of edaphic climax motivated or by the presence of infertile soils which are incapable of supporting a higher forest formation (Bleackley,1963); it means that the soils on which the forests first flourished were originally of considerably higher fertility, associated with a higher content of clay and organic compounds which has since been reduced by mechanical eluviation and chemical degradation. Folster (1986) collected substantial evidences that four processes (soil chemical or physical aspects, man-made deforestation and natural forest mortality) are jointly responsible for the present extent of forest and savanna.

Another possible explanation might be linked with past environmental conditions. More emphasis has given for paleoclimate as the main causal factor originating the present mosaic of forest and savanna. The foregoing factors would contribute at maintaining or modifying the savanna areas but not generating them.

If we just consider the position of the Roraima State by the time when continents were still linked together, this would suggest that paleoenvironmental features have been inherited since the continents started drifting. Some authors have tried to rebuild series of successive paleogeographical scenarios between the Jurassic and Quaternary in South America. From desert to humid tropical climate, there are several evidences of contrasting environments all along the natural history (Ab'Saber, 1956). Others have invested in finding out biological similarities remaining from the Pangea continent between Africa and South America (Delevoryas, 1973; Richards, 1973; Thorne, 1973). Moreover, Maguire (1970) has speculated that the savanna flora of Roraima highland became established around the Cretaceous.

Erhart (1961 and 1962) summarized in Brazilian journals the so called Bio-Rhexistatic theory focusing on ground cover types as important factors in the geochemical evolution of landscapes. Many geomorphologic effects were indicated as resulting of changes to other vegetation types that do not protect the landscape as forest does. Correlations between stratigraphical patterns and biogeographical distribution were inferred. Later, many authors working in Brazil increased this postulate with new observations; including new evidences (Barbosa, 1958 and 1959; Tricart,1959 and 1979; Cailleux, 1959; Ab'Saber, 1958; Bigarella, 1965 and 1982; Mousinho, 1971).

Palynological studies through pollen diagrams have detected changes in the vegetational cover (Hammen, 1966 and 1974; Absy, 1982; Labouriau, 1982), most of them in accordance with evidences from other fields. There is increasing evidence from pollen that areas which are now covered by forest were formerly occupied by savanna.

It is already well established that global climatic changes during the Quaternary played a role in stimulating ecological changes. The tropical belt has experienced a succession of wetter and drier periods concurrently with the interglacial and glacial periods occurring at higher latitudes and altitudes. Evidences of such past climatic shifting comes from different fields.

Sedimentological cores have been obtained from the prodelta of the Amazon. The prodelta stratigraphy contains feldspar, originating from erosional processes during the Pleistocene (Damuth & Fairbridge, 1970). These authors supposed that this large deposit of arkosic sands was originated from an arid period during the last part of the Wurm-Wisconsin glaciation. More recently Kronberg et al. (1986), also studying deep-sea fan sediments, concluded that the modern sediment compositions reflects the rapid weathering now occurring in the Andean source regions of the basin. This intense chemical weathering has controlled the chemistry of suspended sediments in the Amazon river since at least the Upper Pleistocene.

The most recent approach called "refuge theory" or the biological model (Salo, 1987) for diversification in the tropics, states that, during the arid cycles of the Pleistocene the Amazon forest was reduced to a number of isolated patches; "*plant and animal populations isolated in the more-or-less restricted* *forest and non-forest refuges during adverse climatic phases either became extinct, survived without much change, or differentiated to the taxonomic level of subspecies or species "*, (Haffer, 1969).

The theory which has been updated with new evidences by Haffer (1969); Brown (1979); Prance (1982); Ab'Saber (1982); Granville (1982); Vanzolini (1986), could be considered as the first attempt in determining areas formerly occupied by different vegetation types such as forest and savanna, in spite of the fragility of data already collected Nelson (1989). Ratter,Richards &Gifford (1971) have suggested that a boundary situation may be a dynamic rather than a static situation in which, perhaps, dry forest is expanding at the expense of savanna. In Africa, Peltre (1977), working at Ivory Coast, observed that the forest skirts are currently gaining ground over savannas at a rate of about one meter per year. Similar trend was observed by Foresta (1989) who studied ecotone zones in Congo and described several pioneer species occurring along the front of expansion.

Based on these assumptions it may be said that under different land cover types (forest or savanna) as well as during each climatic condition the landscape physiology works differently in terms of erosion processes, pedogenesis, drainage outlet and load river bed. Consequently at the areas which have served as scenario of past climatic changes, polycyclic landscapes like sequence of terraces and glacis can be expected. Polygenetic soil profiles like stone-lines, truncated topsoils and ironstone layers are expected as well.

The comparison of different soil-landscape evolution trends can give an important picture of previous environmental conditions. In this way, slope morphology as well as paleo-geopedological features such as sand surface deposits, ironstone outcrops and stone-lines will be used as evidences to rebuild past environments. Furthermore, if past climatic changes have been controlling the base level of denudation by shifting down-or-upstream the head-waters, some diagnostic features might still remain.

RESULTS AND DISCUSSION

Peneplain and hilland landscapes are the dominating features occurring in the whole study area, associated with the Cenozoic sediments of the Boa Vista Formation and the Proterozoic basement of the Guiana Shield, respectively. A relatively narrow valley built by the Rio Branco river crosses the area NNE-SSW direction (Figure 2).

- Peneplain

The dominant feature is the extensive glacis-terrace relief formed by flat (<1% slope), large interfluves (80-100m elevation). Shallow incisions of local streams (>3rd order catchment). While the smaller streams have a low inclination (<2%), the deep dissections can exhibit a kind of polycyclic evolution, with slopes of 2-5% and 5-10% respectively. With this relief type are often associated deep, well developed, porous, acid and mineral-poor soils. Sandy surface layers contrasts with loamy sand to sandy clay subsurface horizons. Colours are dark brown (10YR 4/3), grading to strong brown (7,5YR 5/6 or 5/8). The non structured or loose surface A horizons grade at a depth of about 30cm into very weakly structured, friable or loose subsurface B horizon which continue without any apparent changes to 2-3m. These soil classify as "Latossolo Amarelo distrofico" according to the Brazilian soils classification and "Typic Haplustox" according to the USDA system.

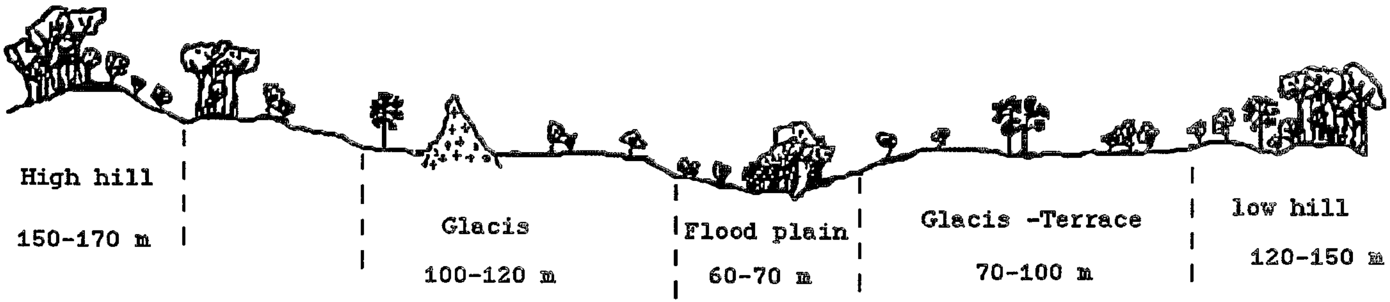

Figure 2 The general landscape patterns present in the study area

In some areas of the glacis-terrace, the headwaters areas are not well defined and patches of multidepressional drainage pattern occur confining hydromorphic soils. They consist of shallow depressions (2-3m deep), sometimes rounded and always surrounded by gentle slopes of about 1-2%. They function as perennial or seasonal dambo-like lakes, interconnected by small creeks. For the creeks, no clear evidences of abrupt particle size changes or other kinds of internal drainage blocking factor were noted. A textural range from sandy, loamy sand to sandy clay loam was observed. Colours varied from dark grey (10YR 4/1) to light grey or white (10YR 7/1 or 8/2) according the level of organic matter. Soils classified as "Gley Pouco Humico distrofico" according to the Brazilian system and "Haplustox" according the USDA system.

Ironstone layers were always found associated with valley sides of deep incised streams (>3rd order), with variable thickness (40-150cm) according to the degree of incision. Some of the features are as follows: fine to very coarse elements, usually quartz, around which sesquioxide are cemented; red matrix with black spots of manganese concentration; from gravel to crust; prismatic, massive or vesicular structure; and inclined disposition (Figure 2).

Conspicuous, domed inselbergs are loosely scattered over the whole area (in some instances 200-250m high); most of them are composed of granodiorite (Radambrasil, 1975) with steep slopes of bare rock descending towards a narrow piedmont rim. Ironstone is commonly present in the piedmont areas, both as massive crust or thin groundwater layer. The inselbergs should represent the exhumed summits of weathered and extremely lowered basal surfaces.

In the southern peneplain areas, the transition zone between forest and savanna is always a strip where patches of forest are scattered and mixed with savanna vegetation, over similar soils. It seems that forest is expanding through savanna areas. Moreover all inselbergs are accompanied by isolated spots of piedmont forest indicating possible forest refuge areas during the past dry climates. Several authors refer to such situation as altitude/orographic refuge (Prance, 1982; Ab'Saber, 1982; Granville, 1982; Foresta, 1989).

Hilland

In the crystalline hilland areas several remnants of erosion surfaces (hilltops) can be observed. These surface were intensely worn down in the course of the further episodes to which are due the shaping of slopes, terraces and sandy flat vales, as well as the hardening of the ferruginous remnants of the initial surfaces through improvement of the drainage during the erosion period.

The hill level corresponds to repeated sequences of convex summits and concave vale incisions. Slopes are short and steep (15-20%) on small streams (1st and 2nd order catchment). On more developed streams (>3rd order), a double step slope occurs with an intermediate erosional terrace level breaking the continuity of the vale sides. On this level only pediment-like material was found, mixing ironstone fragments with angular to sub-angular vein quartz, both having gravel size, within a sandy clay loam matrix. On the summits, the colluvium gives way to saprolite at a depth of 70cm. The vale incisions seem to have been filled in by sandy material, probably during one of the past dry phases. The embryonic vales are characterized by nicely selected coarse sands of alluvia-colluvial origin.

In the Roraima areas, the typical soils catena in the crystalline basement (hilland landscape) has the same characteristics under savanna, forest or even along the forest-savanna ecotone (Figure 3). The hill levels coincides with ecotone zones where the mosaic of forest-savanna has a peculiar distribution of forest on the summits ("tesos") and savanna vegetation on the slopes. Sometimes savanna is also covering the hills, without any apparent correlation between soil-relief-vegetation.

Three main ironstone levels can occur, each one being associated with vale sides or even surrounding lakes, dambo-like, induce to think in terms of groundwater ironstone, forming under the shifting of vegetation as a long term process of formation (Figure 4).

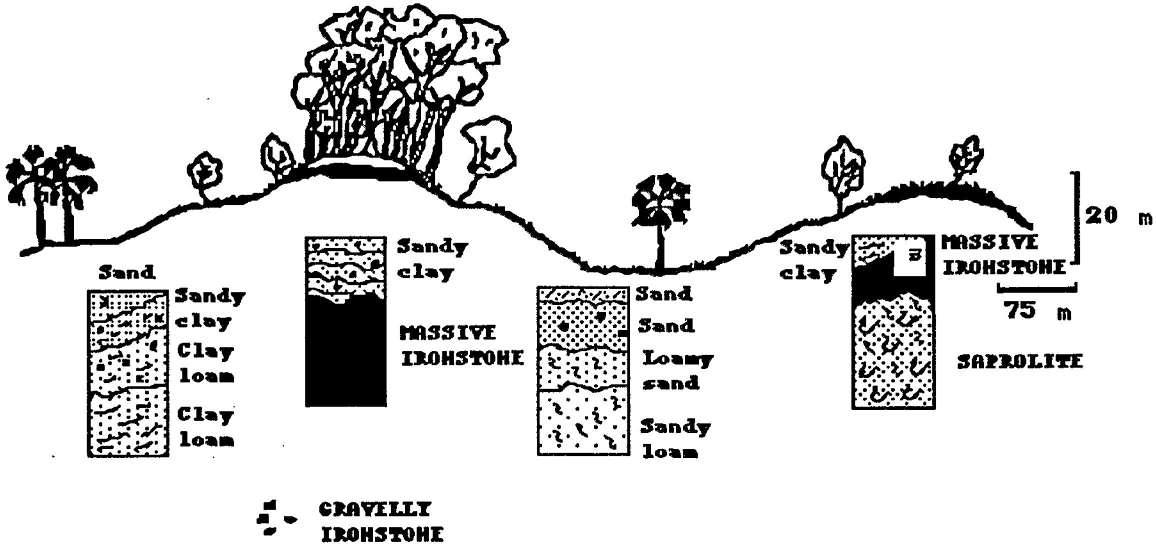

Figure 3 Presence of forest and savanna on similar relief and soil

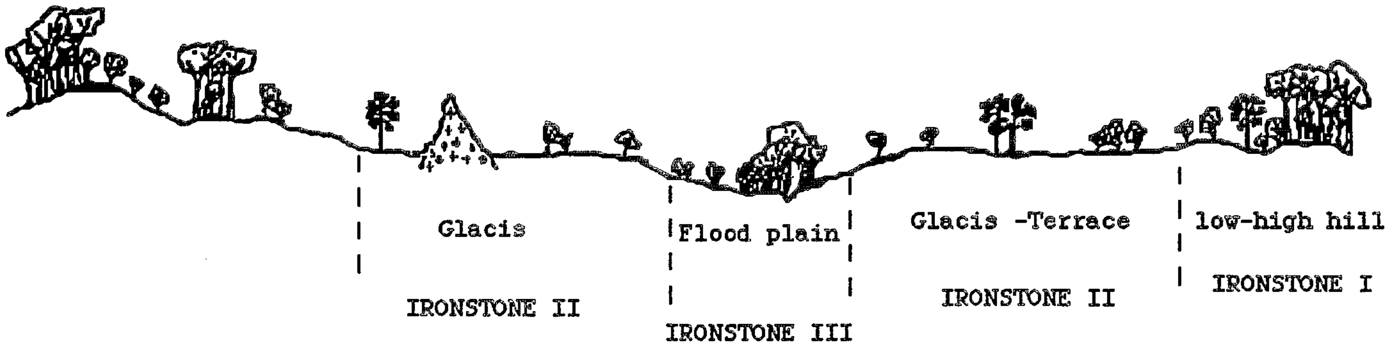

Figure 4 Association of different ironstone levels and relief types

The shifting of vegetation could be connected with the ironstone formation as a long term process. The occurrence of these levels can involves, first, a biostasic phase (Erhart, 1961/2), when a thick lateritic mantle is formed under forest, including an iron segregation zone with plinthite, and second, a climate change into a more rhesistasic phase, when savanna replaces forest, land is degraded according to a new erosional level, profiles are decapitated and plinthite, since come up is converted in a massive and hard ironstone level. Ironstone levels can therefore be used as a important key to understand past environmental conditions and changes affecting vegetation.

The most impressive feature found there is a dune-like relief type, formed by a NE-SW oriented sequence of long, parallel, convex ridges of fine sand (60-77%) and silt material (100-120m high), alternating with shallow streams or creeks having the same NE-SW orientation. These fields were covered by sparse grass savanna mainly, having cactaceae scattered throughout. The presence of such paleodunes in Roraima, should also be correlated with a drier episode as described in other parts of South-America (Tricart, 1974; Khobzi, 1981).

Slope deposits as stone-lines were found in the glacis and hilland zone and they shall also be related with these dry episodes. They are mainly formed by dismantled ironstone and milky vein quartz, which outcrop at the hilltops. The autochthonous lateritic cover on the hilltops may have been one possible source of such transported material. In this case, parts of it were eroded, transported by slope wash and sedimented on the next younger relief level. The presence of stone-lines in the Amazon is considered as an important evidence, in addition to biogeographical data,supporting the refuge theory. The depositional origin of the stone-lines can be explained as the result of a phase of increased morphodynamics, caused by more aridity which led to a thinning out of the vegetation (Ab,Saber, 1977; Soubies, 1979/80; Lichte, 1990).

FINAL COMMENTS

The hypothesis which states that the present stage of vegetation cover is a "climax stage" or, in other words, a mature vegetation in a steady state of equilibrium with prevailing environmental conditions, seems to be insufficient to explain the present mosaic distribution of forest-savanna in Roraima State and it cannot be explained entirely in terms of now-existing biogeographic factors.

Current patterns of vegetation distribution may be the result of an interplay of paleoclimates and the present ecological factors. To better understand the problem, we should consider the present biogeography as just a matter of "time and space" or, lets say, paleoenvironments have been responsible for controlling the distribution of these vegetational types and what we actually see is just one step in akind of dynamic equilibrium where forest and savanna are already answering to the present ecologic situation. We shall remember the suggestion given by Mayr and O'Hara (1986) who said: " *the work of evolutionary biologists sug-gests that biogeographers must be very specific, both taxonomically and geogra-phically, when they are proposing explanations for present day distributional patterns.*".

Considering these ideas and including the suggestions that such situations are homologous with those evolved under a strictly arid savanna climate (Tricart, 1974; Brown & Ab'Saber, 1979; Ab'Saber 1982), we can generalize the present Roraima landscape features as resulting of morphoclimatic work which includes shrinkage and expansion of forest-savanna vegetation. In the hilland zone, severe climatic desiccation with causing the surface wash under sparse vegetation cover took place in the late Pleistocene on the hillslopes of the eastern and western part of the study area. The wash deposits can be presently recognized as thin angular gravel layers on slopes and as sandy materials on the vale floors.

The various levels levels of ironstone recognized can also be related to a sequence of dry episodes, as hardening phases derived from changes in the phreatic level as well as the regional erosional level, forming hardpan and planation surfaces on the hills and glacis-terraces.

From the foregoing that there are several evidences of the previous presence of: a) forest in the present savanna area and, b) savanna in the forest area. Perhaps some drier phases also occurred in the past. Moreover, the landform and soils (formations superficielles) still show traces of several dry Quaternary pulsations of rhesistasic type occurred in the past and represented as gravelly surface pavements, ironstone levels, stone-lines, sand colluvium, paleodunes and inselbergs.

In agreement with Prance (1982), Ab'Saber (1982), and Granville (1982) these savanna areas can be considered as modern relic areas formed under Pleistocene and post-Pleistocene climatic fluctuations, during which drier vegetation formations penetrated the Amazon region. Their remarkable floristic and physiognomic similarities can be interpreted as a consequence of a relatively recent isolation, which has not yet been differentiated into more diversified communities; even more if we consider that for the Amazon savannas however, the constant presence of common elements in their flora may also indicate that such a diversification process and consequent formation of new plant associations is presently taking place.

Two main issues should be further tackled. First, the fragmentation of the forest and savanna in Roraima needs to be better documented by biologists. Secondly, the absence of radiometric leaves so far little chance for reconstructing the late Pleistocene and Holocene history of the area.

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