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"OBSERVATIONS ON SAVANNA/FOREST BOUNDARIES IN TROPICAL AMERICA" *

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COMPENDIO

Este trabajo fue presentado originalmente en el "Simposio sobre la Ecología del Límite Selva/Sabana" convocado por la Unión Geográfica Internacional en Venezuela, en 1964 (Hills and Randall, 1968). Las cuestiones que se discuten reflejan la organización del Simposio: "Definiciones y Concepto", "El Límite Sabana/Selva en Equilibrio Debido a Características del Ambiente Físico", "El Límite Sabana/Selva en Equilibrio como Resultado de la Acción Humana", y "El Límite Sabana/Selva No en Equilibrio". En el trabajo se ha examinado la literatura sobre las sabanas en la América tropical, y se presentan datos del trabajo de investigación de campo del autor sobre la ecología sabanera en los Llanos de Mojos de Bolivia oriental, el "campo cerrado" de Brasil central, en Nicaragua y en Venezuela.

La ecología de las sabanas del Nuevo Mundo incluye el factor poco menos que universal de las quemas, y un número de factores variables, tanto antropogénicos como naturales. El autor concluye que la mayor parte de la sabana de la América tropical es natural, en notable contraste con lo que ocurre en Africa, donde muchas de las sabanas parecen ser debidas al hombre. La parte más extensa de las vastas sabanas de arbolado o "cerrados" (más de 1 y medio millones de Km^2), en el Planalto Cental del Brasil, es ahora generalmente considerada como el resultado de suelos extremadamente seniles y profundamente meteorizados, y la mayoría de las sabanas abiertas o herbosas de América del Sur (posiblemente 500.000 Km^2), pueden atribuírse a alternancia estacional de inundación y desecación del suelo. Por otra parte, hay áreas menos extensas de sabana-parque, lo mismo que sabanas herbosas y de arbolado, las cuales son sub-clímaces que han sido ocasionadas por las actividades humanas de desmonte y quema.

Ciertamente parece ser que la mayoría de los límites sabana/selva en la América tropical están asociados con una o más de las siguientes situaciones: 1) un cambio pronunciado de suelo; 2) un cambio de buen a mal avenamiento; o, 3) un límite producido por el fuego. Estas situaciones es-

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tán a menudo asociadas con cambios de relieve, aunque no siempre. En las sabanas que han sido claramente causadas por el hombre, los límites con la selva pueden reflejar tan solo desmonte y quema, o bien condiciones naturales del suelo relacionados con avenamiento, edad, o materiales parentales.

La experiencia del autor ha mostrado que la generalización es peligrosa y que la ecología del límite sabana/selva en cada caso debe considerarse independientemente, aún dentro de la misma región general.

Introduction.

The following comments are based on studies of the literature; on extensive geographical fieldwork in the Llanos de Mojos of northeastern Bolivia and in the campos cerrado of central Brazil; and on brief visits to other savannas in the Santa Cruz region of Bolivia, in eastern and western Nicaragua, in the Pantanal de Mato Grosso, on Marajó Island, and in the lower Orinoco llanos (Apure). These comments reflect the writer's current thinking on some of the topics under consideration in this Symposium, and it is hoped that they will stimulate discussion. I have also tried to briefly introduce some of the most recent literature containing material on New World Savannas.

(a) **Definitions and Concepts.-** In view of the wide range of usage of the term "savanna" for vegetation varying from pure grassland to partly open woodland, it is suggested that at least simple descriptive modifying terms be used with "savanna" as much as possible. The terms used above, for example, suggest amount of woody cover: **grassy savanna,** where there are few or no trees or shrubs; **orchard (or park) savanna,** where there are numerous but scattered trees; and **woodland savanna,** where there is a fairly continuous tree cover but with still a grassy ground cover.** Savannas can be further described by the type of herbaceous ground cover (tall bunch-grass savanna, sedge savanna,

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** The following comment on "woodland savanna", which I think has merit, was recently made by the botanist George Eiten (1963:186) in connection with a Brazilian campo cerrado study:

> "Despite the long list of authors... who consider the Brazilian cerrados in general as savannas, I cannot agree with this use of the term. 'Savanna' is a purely physiognomic term (whether or not one wishes to restrict its use to tropical vegetation). If its meaning is so extended that it includes everything from pure grassland, to open

etc.) and by the type of tree cover (palm savanna, pine savanna. thorn-scrub savanna, etc.).

(b) **Geographic Distribution in South America.-** A sketch map is attached showing the general locations of the major savannas in South America. Approximate boundaries are shown for savannas which are mostly subject to seasonal inundation. It is curious that despite the interest shown in the New World savannas, they have been mapped in only a few countries. There are, for example, sizable savannas in the Amazon Basin, such as those between the Río Beni and Río Madre de Díos, whose existence is scarcely knowm.

Savanna/Forest Boundary in Equilibrium Due to Characteristics of the Physical Environment.

(a) **Explained by Alternating Flooding and Desiccation: The example of Mojos.-** C. S. Beard (1953:203) has presented a strong case for most of the savannas of northern tropical America being a product of "unfavorable drainage conditions... with alternating periods of waterlogging and desiccation". He notes that "it seems that there are two classes of trees adapted to severe habitats at low elevations in the tropics: those adapted to withstand desiccation of the soil, which cannot tolerate flooding, and those adapted to flooding, which cannot tolerate desiccation". Very few, if any, woody species can tolerate extremes of both conditions. Many, but not all, of the savannas of northern tropical America are characterized by these conditions. P. W. Richards (1961: 19) points out that "more evidence is required before his (Beard's) conclusions can be accepted for the whole of the large areas discussed

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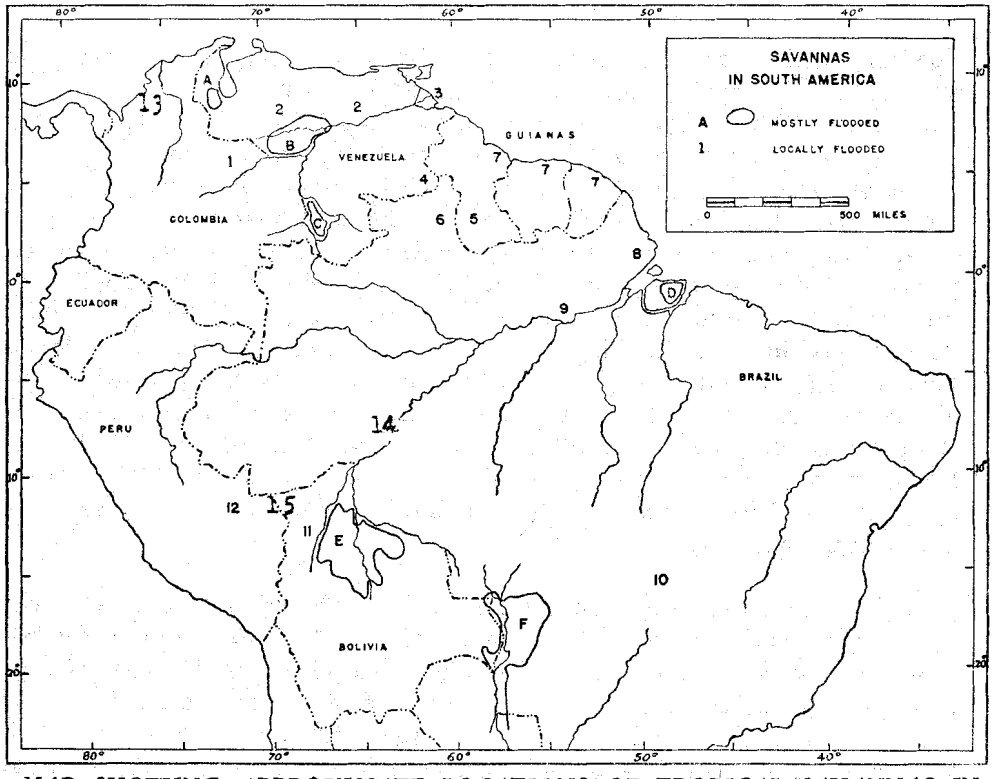
areas with scattered trees and shrubs, to tall closed woodlands, then it loses all meaning. Since there exist other terms for the other physiognomic forms, 'savanna' should be restricted to a physiognomy of tall shrubs and/or trees scattered individually or in small groves with open grass or herb-covered ground between them. The upper limit of the tree and tall shrub crown-cover may be set at about 25% if 'woodland' is used as a coordinate term, or at 50 or 60% if it is not used and 'forest' represents the next denser vegetation."

Much of the cerrado vegetation would therefore be classed as either woodland or forest and not as savanna. The same would apply to much that is called savanna in Africa and elsewhere.

in his paper," and that it would "be very unwise to attempt to apply his views uncritically to other parts of the tropics." Certainly the great African savannas are not generally subject to seasonal flooding. Locally, however, there are small areas, such as the dambos, toiches, vleis, esobes, and mbugas of central Africa, which are seasonally flooded, and these grasslands have been interpreted as products of drainage conditions in a number of studies, the most recent by D. F. Vesy-Fitzgerald (1963). The two largest areas of seasonally inundated savanna in all the tropics are found in South America; however, they are not in the regions described by Beard but rather in the west-central part of the continent: the Llanos de Mojos occupying most of the Beni Departament in northeastern Bolivia and the Pantanal de Mato Grosso in the upper Paraguay Basin (see map). The Pantanal has received some attention recently (Wilhelmy, 1957; Cole, 1960), so I would like to direct my remarks to the little known Llanos de Mojos, where I carried out research on physical and historical geography in 1961-62.

The Llanos de Mojos occupies an area of about 70.000 square miles in the Beni Basin, which is located between the Andes and the western hills of the Brazilian Highlands. The basin is filled with Quaternary sediments up to 15.000 feet deep overlying a basement of Pre-Cambrian gneiss. The elevation of the llanos ranges from about 1.000 feet in the south to 600 feet in the north, and the gradient is about one foot per mile. There are only a few natural relief features over 5 or 10 feet in height. The basin is drained by the Río Beni, Río Mamoré, and Rio Guaporé, which along with the Rio Madre de Dios join in an apex in the north to form the Rio Madeira, a major tributary of the Amazon. During high water these rivers and their tributaries overflow and combine with rain water to inundate as much as three-fourths of the llanos with up to several feet of standing water between December and June. Rainfall averages 60 to 75 inches and is concentrated in a six month period. Soils are mostly light brown or grey clay loams with hard pans very near the surface; however, on well drained ground there are often fine sandy loams with pans only at depth. Most of the Mojos savanna is burned every dry season.

About 80% of the region mapped as the Llanos de Mojos consists of tall-bunch-grass savanna with some orchard savanna, and about 20% consists of semi-evergreen seasonal forest and deciduos seasonal forest. There is a fairly clear-cut relationship between depth and length of



MAP SHOWING APPROXIMATE LOCATIONS OF TROPICAL SAVANNAS IN SOUTH AMERICA

WELL DRAINED OR LOCALLY FLOODED SAVANNAS

1.- Colombian Llanos
2.- Llanos Altos del Orinoco
3.- Orinoco Delta
4.- Gran Sabana
5.- Rupununi
6.- Río Branco
7.- Guiana Coast
8.- Amapá
9.- Lower Amazon Campos de Vareza
10.- Campos Cerrados of the Planalto Central
11.- Río Beni
12.- Gran Pajonal
13.- Bolívar Savannas
14.- Madeira Savannas
15.- Heath Savannas

SEASONALLY FLOODED SAVANNAS

A.- Maracaibo
B.- Llanos Bajos del Orinoco
C.- Casiquiare
D.- Marajó Island
E.- Llanos de Mojos
F.- Pantanal de Mato Grosso

flooding, which are determined by relief, and the type of vegetation present. The lowest depressions with water all or most of the year contain sedges **(Cyperaceae)**. Where flooding lasts from four or five to ten months each year, there is tall bunch-grass savanna **(Leersia, Paspalum, Panicum)** and arrow grass **(Gynerium)** with few or no trees. On higher ground with flooding for only a few weeks to a few months there is usually an open orchard savanna **(arboleda)**, with the most common trees being **Tabebuia suberosa, Curatella americana,** and the **Copernicia cerifera** palm, while the common grasses are species of **Paspalum, Panicum, Sporobolus, Anoxopus,** and **Trichachne.** Forest occurs on ground that is well drained and infrequently inundated: (1) the **galería** forests of the natural levees of rivers and embankments surrounding lakes and (2) the **isla** forests on natural and artificial mounds, on low divides between streams, and on remnants of former levees. Much of the forest, however, has been degraded into woodland savanna or orchard savanna by clearing and burning.

The savanna/forest boundaries in the Llanos de Mojos are generally very sharply delimited. Invariably, the abrupt boundaries between grassy savanna and forest are associated with a fairly rapid change in relief amounting to several feet. This is easily seen during the flood period when patches and ribbons of forested high ground rise up out of the water. At times the savanna/forest boundary is a remarkably straight line, usually with a NE-SE orientation. The same alignements occur with straigth-sided lakes and in river meanders and have been attributed to several feet of subsidence of sediment over fractures or fault blocks in the basement rock. There is little doubt that many of the savanna/forest boundaries in Mojos are drainage controlled through differences in micro relief. However, where boundaries are not sharp and slopes are gentle, either clearing and burning or drainage could be the critical factor in determining the actual location of the boundary. Although the soils under poorly drained grassland and the better drained forest do differ, particularly in depth to hardpans, neither the structure nor the fertility of the savanna soils seem capable of permanently preventing tree growth.

Drainage controlled savannas such as those of Mojos are generally designated "edaphic" savannas. Possibly a more meaningful term would be "hydrologic" or some other expression which places the emphasis on water conditions as distinct from physical and chemical conditions of the soil, as is partly implied by the word "edaphic". Another, but not too

suitable, term that has been suggested by A. H. Bunting (1962) is "topographical savannas", since topography is the main control of drainage conditions including the development of impermeable soil layers. G. M. Roseveare (1948:130) and others contrast "dry" savannas with "wet" or "flooded" savannas in reference to rainy season conditions.

(b) **Explained by Extremely Infertile Soils: The Example of the Campos Cerrados.-** It is now generally agreed that the low nutrient status of most of the plateau soils of central Brazil is the main limiting factor favoring campo cerrado (scrub-woodland savanna) over forest, although other factors, especially clearing and burning, may be more important in some areas. This is the conclusion reached by M. G. Ferri (1963), a leading cerrado scholar, in his survey of the history of research on the campo cerrado vegetation presented at the 1962 Cerrado Symposium in Sao Paulo, and it is supported by the word of a number of people (e. g. Alvim, 1952; Arens, 1963; Feuer, 1956; Hardy, 1959). This low nutrients status may be a result of the destruction of the surface humus layer by cultivation and erosión, but it is most extreme in deep, senile, highly leached latosols from which soluble nutrients have been completely removed. The latter seems to be the situation on the older erosion surfaces (Jurassic, Cretaceous) in the Planalto Central, where are found some of the oldest soils in the world.

In the tropics the level of natural soil fertility is largely determined by the stage of weathering and leaching of the parent rock material. Nutrient bases are removed at an early stage and rapidly if drainage is free and rainfall heavy. The order of loss by leaching according to Frederick Hardy (1959, p. 21) is Cl - $S0^4$ - Ca - Na - Mg - K - $Si0^2$ Fe^20^3 - Al^20^3.After the $S0^4$ stage the soil is base saturated; after the K stage the soil is highly acid and kaolinitic; after the $Si0^2$ stage the soil is gibbsitic and then hematitic. The best tropical soils haven't yet reached the kaolinitic stage, and are generally derived from basic rocks to start with. As weathering continues the type of parent material involved becomes less and less important. Fertility rapidly diminishes after the kaolinitic stage. The younger erosion surface (Cretaceous, Tertiary) soils of the Planalto are into or beyond the kaolinitic stage, and older erosion surface soils are way beyond it, with nearly all bases and minor plant elements removed.

As tropical weathering progresses on nearly level sites without erosion continually re-exposing fresh mineral soil, the forest vegetation becomes more and more dependent upon mineral nutrients accumulated in the surface organic layer. On senile soils with great depth to weathering parent rock material these nutrientes are no longer brought up from below by plant roots, but are passed from foliage to soil to roots to foliage and back again in a closed cycle. In this situation the humus is important not just for supplying nitrogen but also for most other plant nutrients. The cycle is broken once the forest is cleared, and recovery on very senile soils may be long and difficult, if not impossible.

On the campo cerrado soils the closed nutrient cycle may have been broken and forest terminated by clearing and repeated burning by Indians in pre-conquest times. However, since extreme soil senility was already attained millions of years ago on the higher erosion surfaces, it seems not unlikely that the nutrient cycle, once relatively self contained, slowly played out from gradual losses of nutrients from miscellaneous causes, and the vegetation deteriorated from forest to the present campo cerrado (which may have evolved concurrently) having species adapted to present low nutrient conditions. If campo cerrado on senile soils is protected from fire, clearing, and grazing, the vegetation still remains campo cerrado. The "deficiency of nutrients is apparently chiefly, if not solely, the prime cause of the failure of the forest vegetation to re-establish itself" (Hardy 1959: 26). However, on younger soils where surface fertility has been destroyed by human activities and campo cerrado has taken over, forest may well recover in time if protected.

The savanna (cerrado)/forest boundaries in the Planato Central of Brazil are usually soil boundaries. As has been pointed out by Monica Cole (1960), the campos occur on the senile soils of the plateaus, while forest grows where streams are dissecting the plateaus and exposing fresh parent material, as well as changing drainage, burning, and other conditions. On a survey of some 5.000 miles through the Planato Central, not once did I observe forest growing on senile latosols of the plateau surfaces. On the other hand, and Cole fails to mention this, where forest is advancing onto young soils of newly dissected surfaces, cerrado may actually take over because of human disturbances which inhibit forest growth and favor the cerrado.

Actually, the natural vegetation on the senile soils of central Brazil may have been neither campo cerrado nor forest but, as suggested by S. R. Ehre (1963:247), the transitional cerradao which contains species of both cerrado and forest and is best described as closed woodland savanna.

Only small, scattered depressions in central Brazil have "hydrologic" savannas. Beard (1949) attempted to apply his theory of waterlogging to the campo cerrado on the assumption that the plateau surfaces were underlain by lateritic horizons that impeded drainage. It is now known, however, thanks to R. Feuer (1956) and others, that laterite only occurs on slope exposures with lateral water drainage, while the soils of the plateau sufaces are generally well drained internally.

Savanna/Forest Boundary in Equilibrium as a Result of Human Action in Combination with Edaphic Conditions.

Savannas which have apparently been created by man's clearing and burning activities sometimes have fairly stable boundaries with forest. However, the actual boundary may be determined by a change in parent material, especially a change from acidic (silicious) rocks such as granite to basic rocks such as basalt. Tropical soils derived from acidic rocks, while capable of supporting forest, have a relatively low fertility and often a thin topsoil which is quickly destroyed by erosion once a forest cover is removed. Forest has a difficult time re-establishing itself, especially if there is frequent burning, while vegetation that is tolerant of poor soils and fire readily takes over. Such a situation exists in highland Nicaragua and other parts of Central America where open pine forest has invaded slopes with thin soils derived from acidic rocks following clearing of the original forest (Denevan 1961). Also in Nicaragua, on the east coast, there is a fairly consistent and sharp boundary between tropical forest on basaltic soils and pine savanna on granitic gravels. This pine savanna is a "fire-caused disclimax" according to B. W. Taylor (1963:48). On more fertile tropical soils derived from basic parent materials, forest vegetation is capable of quickly recovering after clearing and cropping, and savanna and woodland fire climaxes are not common except where there is severe pressure.

In the Planalto Central of Brazil on slopes with young soils, the relation between vegetation and parent materials is fairly clear. Cam-

po cerrado species have taken over many, but not all, slopes with siliceous parent materials, such as quartzite, while dissected uplands with basic parent materials generally have mixed hardwood forests (Mato Grosso de Goias, Mata da Corda, parts of the Minas Triangle). The pressures of human activities on the vegetation on different parent materials here as well as in Nicaragua have at least been comparable and have probably been greater on basic parent materials since they produce more fertile soils.

In traveling through the universally fire-swept savannas of tropical America I have been particulary impressed by examples of fairly dense scrub-woodland savanna and woodland savanna which are regularly subject to burning but do not degrade into grassy or even orchard savanna. Both the campo cerrado and cerrado of Brazil, for example, are regularly burned without being significantly opened up unless there is also clearing. The same is true of much of the isla forest of the Llanos de Mojos which has been converted to woodland savanna by man's activities. The question also arises as to why the fire-tolerant trees of orchard savannas do not grow more closely spaced than they ordinarily do. The critical question that needs to be asked about any given savanna, in addition to why it exists and why its boundaires are where they are, is why there is a certain density of woody vegetation. The answer, of course, may be largely anthropic (frequency, time, coverage, intensity of burning; grazing pattern; degree of clearing) or largely natural (slope, drainage, smooth vs. broken terrain, soil condition, type of herbaceous cover). Actually, it is impossible to completely isolate anthropic and natural factors because they influence one another. The effects of fire, for example, may depend more on the severity of drought or brokenness of terrain than on the frequency or time of burning.

The point that I have been trying to make, then, is that both the physiognomic form of a savanna and the location of its boundary with forest quite often reflect a combination of anthropic and natural factors.

Whether or not there are savannas which are irreversible anthropic climaxes is, I believe, questionable and needs discussion and further investigation. It has been pointed out that certain savannas which have been protected from fire and grazing for long periods of time have not regrown in forest, and this has often been attributed to the development

of clay or iron pans after forest clearing. However, it has not always been satisfactorily demonstrated that the sites concerned ever supported true forest or, if they did once support forest, that they won't revert back to forest if given enough time.

Savanna/Forest Boundary not in Equilibrium.

(a) **Advancing Savanna Due to Change in Drainage.-** In northeastern Bolivia I observed several small areas from the air where recent changes in river morphology has resulted in seasonal flooding of sections of forest which had formerly been well drained. The trees on these sites were dead and leafless, and were being replaced by open grassland. The transitions to grassland were taking place over a period of only a few years and seemed unrelated to human factors or changes in soil conditions.

(b) **Advancing Forest Due to Change in Drainage.-** In some of the seasonally inundated portions of the Pantanal de Mato Grosso, scrub forest is now advancing on the edges of grassy savannas. Herbert Wilhelmy (1957:67) believes that this advance is due to the replacement of tall, native bunch grasses by introduced short grasses. As a result, flood waters seem to drain off the upper margins of shallow depressions several weeks faster than previously, and woody vegetation is thus able to occupy lower positions on gentle slopes. In parts of the Mojos savannas where cattle numbers have been greatly reduced, ranchers say that just the opposite has happened. Water now remains longer in depressions due to the presence of tall grasses which have not been grazed nor burned.

(c) **Advancing Forest Due to Grazing Conditions.-** In many portions of the New World savannas today, wood scrub growth is invading. Grassy savannas are becoming orchard savannas and orchard savannas are becoming scrub or woodland savannas. There is generally no advancing forest front but rather increased woody growth within the savannas. I have observed such invasión in the Llanos de Mojos and in Apure in the Orinoco llanos, and it has been described and studied in detail in Honduras by Carl Johannessen (1963). Johannessen relates such invasión to overgrazing which thins the grass cover and reduces the intensity of fires, but also suggests that it may result from undergrazing and reduction of browsing pressure on scrub seedings. In the Llanos de Mojos in

the last 15 years there very definitely has been a marked reduction of cattle and at the same time scrub invasión in some areas. In Apure some of the invasion is on ranches which protect pastures from burning, but ranchers also claim that there has been less flooding in recent years than previously.

(d) **Advancing Forest Due to Fire Protection and Land Abandonment.** The best example of forest invasion as a result of fire protection that I have seen was in the Miskito pine savanna of Nicaragua. On a site protected from fire since 1944, open pine savanna had been replaced by a dense pine forest. The understory consisted entirely of mixed hardwoods, and with continued fire protection these would probably replace the pines eventually (see also Taylor, 1963:48).

(e) **Fluctuating Savanna/Forest Boundaries Due to Settlement and Desettlement.-** There are a number of areas in the New World where man-made savannas have been invaded by forest following aboriginal depopulation and then later became savannas again as result of new settlement activities. One of the best historical studies of large-scale fluctuating changes in savanna/forest boundaries due to changes in population presure is that of the Sinú (Bolívar) savannas of northern Colombia by Le Roy Gordon (1957:57-70). In the region between the Río Magdalena and the Caribbean Coast, Gordon shows an area in the southern portion which was savanna in the 16th century but had become reforested by the 18th century, by which time much of the northern portion had become savanna. By the mid-20th century nearly the entire region had been converted to savanna.

(f) **Methods of Studying Past Changes or Stability of Savanna/Forest Boundaries.-** Undoubtedly much more can be done using historical documents to demonstrate the stability or lack of stability of different types of savanna during the European period in tropical America. On the other hand, significant new work is already being carried out on the stability of savannas in pre-Colombian times utilizing pollen analysis and other techniques: see, for example, the work of T. Van der Hammen (1963) in the Colombian llanos and the study by Cowgill and Hutchinson (1963), who have concluded that the savannas around Tikal in Petén were in existence before and at the time a dense Mayan population developed rather than being a result of Mayan settlement.

For the Llanos de Mojos there are partial sets of air photographs taken in 1948 and 1958, thus making possible comparisons of changes in vegetation boundaries. While there has been some scrub invasion on ground of intermediate height and while some small savanna patches within forest have been engulfed by the forest, the general pattern is one of considerable stability of the savanna/forest boundaries. Undoubtedly comparisons of boundary change or lack of change could be made for other savanna regions for which there are two or more sets of air photos taken at different dates.

Conclusion.

The ecology of New World savannas involves the one nearly universal factor of burning and a number of variable factors, both anthropic and natural. I find myself in agreement with C. S. Beard (1953) that most of the savanna of tropical America is natural, in marked contrast with the situation in Africa where much of the savanna seems to be man made. The greater part of the vast (over 1½ million sq. kil.) woodland savannas or "cerrados" of the Planalto Central of Brazil are now generally believed to be the result of extremely senile and deeply weathered soils, and most of the open or grassy savannas of South America (possibly 500.000 sq. kil.) can be attributed to seasonal alternation of soil flooding and soil desiccation. On the other hand, there are less extensive areas of orchard savanna, as well as grassy and woodland savannas, which are sub-climaxes resulting from man's clearing and burning activities.

Most savanna/forest boundaries in tropical America do seem to be associated with one or more of the following situations: 1) a marked soil change; 2) a change from good to poor drainage; or 3) a fire boundary. These situations are often but not always associated with changes in relief. Of the savannas which are clearly man made, the boundaries with forest may reflect clearing and burning alone, or natural soil conditions related to drainage, age, and parent materials.

My own experience has shown that generalization is hazardous and that the ecology of each savanna/forest boundary must be considered independently, even within the same general region.

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INVESTIGACIONES SOBRE CONTAMINACION AMBIENTAL EN LA UNIVERSIDAD DE LOS ANDES

En la Universidad de los Andes (Bogotá) ha sido organizado el **Grupo Interdisciplinario de Investigaciones Ambientales,** en el cual están vinculados inicialmente Néstor Miranda, Segundo Bernal, Carlos Morales, Arturo Infante, Jacques Mosseri, Ulpiano Ayala, Elizabeth Grose, Roberto Galán, Víctor Contreras, Rodolfo Heredia, Ignacio Vélez, Germán García y H. F. Rucinque.

Los objetivos inmediatos de este distinguido grupo investigativo son los de adelantar estudios sobre contaminación atmosférica en Bogotá, y la realización de un inventario sobre la situación ambiental en todo el país. Se ha informado que el Grupo Uni-Andes tiene la intención de promover todo tipo de estudios e inquietudes científicas que se relacionen con el problema de la conservación y sanidad ambiental. La iniciativa, que merece todo respaldo, tiende a conjurar una amenaza latente —y ya patente en algunas ciudades— contra las condiciones de habitabilidad y estética de las diversas regiones colombianas.

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