INSTITUTE OF CURRENT WORLD AFFAIRS

GSH-9: The International Amazon Project

Apartado 8-3870
San Jose, Costa Rica
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Dear Peter:

When I learned that the site of the Tropical Forest Refugia Symposium (GSH-8) had been changed from Manaus, Brazil, to Caracas, Venezuela, I arranged to visit the International Amazon Project in San Carlos de Río Negro in southern Venezuela. The project involves scientists from Venezuela, West Germany and the United States in an integrated interdisciplinary research effort to address critical questions concerning the natural functioning and potential uses of tropical ecosystems.

The project idea originated during a reconnaissance field trip to San Carlos de Río Negro in 1972 by Venezuelan scientists Ernesto Medina and Rafael Herrera, accompanied by Hans Klinge, a German ecologist with more than a decade of Amazonian experience. The following year Eberhard Brünig from Germany's World Forestry Institute and Carl Jordan from the University of Georgia's Institute of Ecology joined the discussions on project design and research proposal preparation.

The Venezuelan Institute for Scientific Research (IVIC) Ecology Center provides project leadership and coordination; financial support comes from the Venezuelan National Research Council (CONICIT), U. S. National Science Foundation (NSF), German Research Foundation (DFG), and the Organization of American States (OAS). The project was one of the first to be recognized by UNESCO as a Man and the Biosphere (MAB) pilot project under MAB-1: "Ecological effects of increasing human activities on tropical and subtropical forests."

The International Amazon Project site (Figure 1) is near the Venezuelan frontier town of San Carlos (1° 54' N Latitude) on the banks of the upper Río Negro (Black River) that eventually joins the Solimoes River near Manaus to form the mighty Amazon River. The Río Negro is the largest and best known "blackwater" river in the world draining a vast area of white sand soils (Figure 2a). The apparent incongruity of white sand and dark-colored water (Figure 2b) is due to an abundance of dissolved organic acids leached from the natural forest by rainwater that eventually reaches the streams, where the organic acids impart a characteristic dark, tea color.

Tropical white sand soils are probably the world's most nutrient-poor soils (very similar to the sterile sand used in hydroponic agriculture). Despite the extremely low level of nutrients in the soil, reasonably well-developed tropical forest (Figure 3) occurs in the Río Negro region. How the native forest is physically and chemically structured to minimize loss of nutrients and to optimize capture of nutrients entering the ecosystem is one of the fascinating stories being documented by researchers participating in the International Amazon Project.

After a 15 month hiatus Gary Hartshorn is back on board as a Forest and Man Fellow.

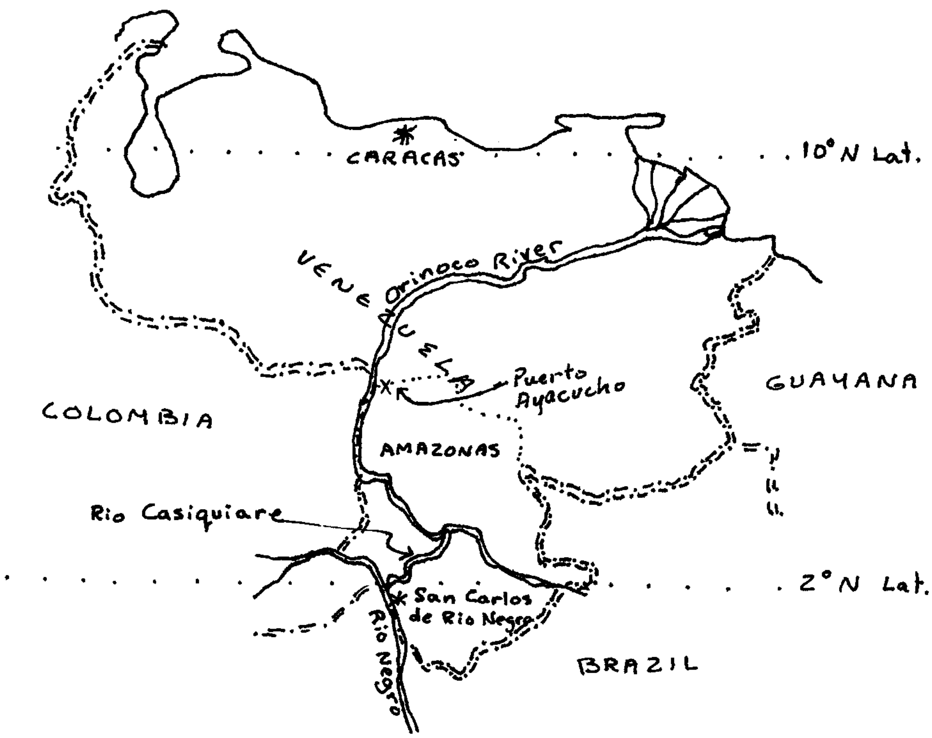

Figure 1.

Some additional background may contribute to a better understanding of the project's relevance. The white sand soils of the Río Negro region are developed from quartz sand sediments eroded from the geologically ancient Guiana Shield with its imposing flat-topped sandstone mesas or "tepuis". (The world's longest waterfall, Angel Falls, descends from a tepui.) In the San Carlos area the topography is rolling low hills of red lateritic soil in a patchwork of white sand.

The Federal Amazon Territory (Amazonas) occupies 19% of Venezuela, but it has extremely low population density. The presence of vast forests and considerable resources coupled with geopolitical interests prompted the Venezuelan government in the early 1970's to initiate major programs to "conquer" the Amazon Territory. Serious doubts about the suitability for traditional agriculture led Medina and his colleagues to push strongly for a major ecological research program in the Río Negro region. The direct relevance of the proposed project to Venezuelan development plans stimulated the early involvement and support of IVIC and CONICIT.

A riverfront sign suggests the town of San Carlos was founded in 1560. It was here more than a century ago that the British naturalist Alfred Russell Wallace walked from the Río Negro to the Orinoco River. Though Wallace walked between the two river systems, the Casiquiare River forms a natural channel connecting the two river systems (Figure 1). During high water, small boats can cross between the Río Negro and the Orinoco River. A lone Brazil nut tree in the center of town is said to be one of three trees in San Carlos commented upon by the German naturalist Alexander von Humboldt in his travels on the Amazon nearly two centuries ago.

Figure 2a. Hand-held aerial photo of the upper Río Negro in southern Venezuela. Note the abundance of white sand deposits on the inner curves of the meandering blackwater river; and the meander scars and oxbow lakes. Figure 2b (below). Low-level aerial photo approaching San Carlos de Río Negro in southern Venezuela. Note the striking color contrast between the blackwater river and the white sand bank.

Figures 3a-top, 3b-bottom: 3a. Two recent clearings for slash and burn agriculture in the vast forests of the upper Río Negro region of southern Venezuela. Note that the clearings were done in good forest, probably on lateritic soil; the lower vegetation in the upper left and lower center of this oblique aerial photo is probably "bana" vegetation on white sand soil. 3b. Profile of yevaro forest on lateritic soil north of the project study site, San Carlos de Río Negro. The tall yevaro trees in the center of the profile are Eperua falcata *(Caesalpiniaceae). The new clearing in the foreground was done by a local resident for planting his annual crop of mandioca.*

To get to San Carlos de Río Negro I took a regularly scheduled flight from Caracas to Puerto Ayacucho where I overnighted in anticipation of a charter flight by small plane to San Carlos. However, the promised flight did not occur due to a "shortage" of pilot(s). The flight postponement followed numerous small plane stories I had been told the previous week by Venezuelan and American friends familiar with the logistics of working in San Carlos. A pilot appeared the next morning for the uneventful, two-hour flight to San Carlos. Because of some earlier difficulties experienced by foreign scientists with Venezuelan national guardsmen protecting the border, Ernesto Medina gave me an official letter stating I worked for IVIC. Naturally, I was completely ignored by local officials --not even asked to show my passport.

No one ventured forth from the small crowd that always welcomes an arriving plane on a remote strip, so I shouldered my pack to search for the IVIC house. My arrival surprised Howard and Kate Clark, resident biologists for the project, because the radio connections with Caracas had been temporarily malfunctioning. Nevertheless, the Clarks welcomed my visit, showed me the research sites and contributed significantly to my productive and enjoyable five day visit to San Carlos de Río Negro.

The project's primary study area is approximately 4 km east of town. The study area includes a 200 x 700 m (=35 acres) plot in undisturbed forest, bordered on two sides by experimental plots. The study area is predominantly on white sand soil; however, a low hillock of lateritic soil covers about one hectare (=2.5 acres) of the forested plot. The German and Venezuelan research effort that began in 1975 is focused primarily on the white sand soils. U. S. researchers began a year later, concentrating research on the lateritic soil.

Upon entering the forest I was immediately struck by how unusual this forest is. The forest soil is covered by a thick (20-30 cm), dense root mat (Figure 4a) that feels like you are walking on a foam mattress. Even more striking is the presence of a low conical "skirt" (Figure 4b) clasping each tree. The abundance of 50-150 cm tall "skirts" gives this forest an unusual appearance that bordered on the bizarre for my first encounter. Closer inspection revealed the basal cones are hollow and the "skirt" is formed by a network of small roots covered by green moss and fallen leaves. The "skirts" appear to be especially well-developed on the lateritic hillock in the study plot. I observed that "skirts" were much less frequent and lower in the forest on a lateritic ridge about 10 km east of town.

The lateritic soil supports a forest of rather typical (for tropical America) composition and structure--that is, if you look above the basal "skirts" and spongy root mat. The white sand soil supports a lower and more dense forest that varies considerably in height, apparently due to the variable depth of sand above an impermeable soil layer. At the local extreme (Figure 5), the low (about 2 m), scrubby "bana" vegetation has scattered emergent trees 5-7 m tall.

The forests on white sand soil in San Carlos are structurally similar to the "kerangas" forest I glimpsed in East Kalimantan, Indonesia (GSH-6). The forest type being converted to pine plantations by Jari Florestal (southwest of Monte Dourado) (GSH-12) is similar to the best-developed forest on white sand soil in the San Carlos area. In addition to Indonesian Borneo (Kalimantan) and central Amazonia, tropical white sand/ blackwater rivers occur in parts of Guatemala, Belize, the Guianas, coastal Brazil, the southern Amazon, eastern Peru, Nigeria, Congo Basin, Malaysia, and the East Indies.

Figure 4a-top, 4b-bottom: 4a. Profile of a 20 cm thick root mat on white sand soil in the project study site, San Carlos de Río Negro, Venezuela. 4b. Conical "skirt" around the base of the large, dark tree directly behind the small tree in the center of the photo. The hollow "skirt" is composed of small roots from neighboring trees and is covered with moss and fallen leaves. The basal trunks in the foreground are covered with feeder roots growing upwards from the root mat covering lateritic soil in the southwest corner of the project area, San Carlos de Río Negro.

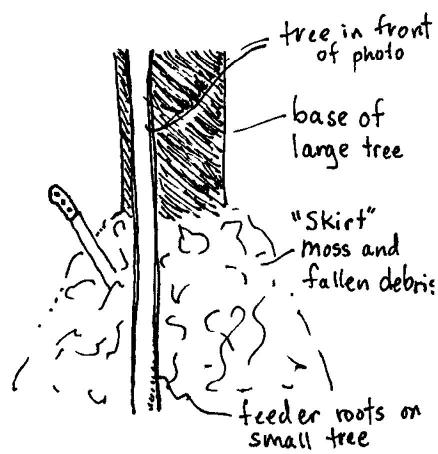

Figure 5. "Bana" vegetation dominated by shrubs with occasional emergent trees. The naturally low vegetation is thought to be caused by an impermeable soil layer that causes rainy-season flooding and dry-season drought of the shallow white sand. Howard Clark, resident biologist, is in this photo taken along the road about 8 km east of San Carlos de Rio Negro, Venezuela.

Interesting Research Findings

There is no way I can do justice in this brief newsletter to the scientific results and significance of the International Amazon Project. More than 100 scientific articles are based on research projects in San Carlos de Río Negro. Here, I will try to briefly highlight a few of the major findings and comment on their significance for tropical American forests and man. Many of the research efforts and major conclusions concern the remarkable nutrient conserving mechanisms that occur in the San Carlos forests.

The root mat (Figures 4a, 6a) mentioned above forms the keystone of the complex mechanisms for minimizing nutrient loss from the forest ecosystems. Consisting of small to medium-size roots interspersed in organic matter in varying stages of decomposition, the sponge-like root mat effectively functions as a nutrient filter, recycling the sparse nutrients before rainwater leaches them through the root mat and sand and eventually to the blackwater streams. Because of the general sterility of the sand, the organic matter is extremely important as a nutrient adsorbing and exchanging medium. Project researchers have found that forest cutting and burning does not immediately destroy the root mat, hence the nutrient capital "stockpiled" in the root mat is the source of nutrients for the first crop of yuca (=manioc, mandioca, casava) or pineapple. Second or third crop yields, in the same field, drop off drastically as the decomposing root mat is consumed or is leached down through the soil.

Figure 6a. Profile of 25 cm thick root mat over lateritic soil in the project study plot, San Carlos de Río Negro, Venezuela.

Once the root mat is gone, the soil is worthless for agriculture or even tree crops. German researchers planted rubber trees in some of the experimental clearings; however, few trees survived in the nutrient-poor clearings. When told of the rubber "plantation", I had difficulty finding rubber trees in the clearings dominated by the pioneer *Cecropia* trees.

The fine roots in the mat often exhibit the unusual feature of growing upward as they colonize fallen leaves, fruits, twigs and trees (Figures 4b, 6b). Fallen branches that appear solid have been consumed internally by a network of feeder roots (Figure 7a). The shells of hollow branches, twigs, fruits, etc., contribute to the sponginess and fragility of the root mat. I noticed that the root mat is missing on the forest trails; even light foot traffic on minor trails appears to destroy the root mat.

Project researchers have experimentally demonstrated that the root mat adsorbs 99.9% of radioactive phosphorus and calcium sprayed on its surface. Apparently the nutrients are quickly adsorbed by organic matter in the root mat prior to uptake by tree roots. A mutually beneficial symbiosis between tree roots and fungi--called mycorrhizae--is a major factor in minimizing nutrient loss from these forests. Project researchers believe that rapid mycorrhizal uptake of nutrients permits direct cycling of nutrients on these nutrient-poor soils.

The basal "skirts" appear to be composed of roots from neighboring trees rather than from the live "center post". I noticed a few examples where the fine roots forming the "skirt" continue to grow up the center post--(terming it a waist-band may overstate the analogy). The upward growth of roots in the mat and "skirts" gives the distinct anthropomorphic impression that the feeder roots are competing for higher positions to catch falling nutrients.

On such nutrient-poor sands, essentially all the nutrients do come from above, not only as fallen plant parts, but also in the rainwater that passes through the system. Rainfall intercepted by the forest canopy evaporates, runs down the twigs, branches and stems (termed stemflow), or coalesces into huge drops that can soak you after several direct hits (termed throughfall). Stemflow (Figure 7b) and throughfall wash nutrients from leaf and bark surfaces. Nutrient-laden stemflow no doubt explains the "skirts" in the forest on lateritic soil. But it is unclear why "skirts" are virtually absent from the white sand forest. Perhaps the small trees, specifically the small individual tree crown, contribute negligibly to stemflow.

Figure 6b. Moss-covered feeder roots that are climbing a tree presumably to intercept nutrient-laden stemflow of rainwater. Photo taken in the project study plot, San Carlos de Rio Negro, Venezuela.

Figure 7a-top, 7b-bottom. 7a. Fallen branch that has been completely consumed by feeder roots. I removed the outer bark shell near the machete handle to expose the dense network of roots inside the fallen branch. Photo taken near the project study site, San Carlos de Río Negro, Venezuela. 7b. Adventitious feeder roots growing from a curve in the stem of a canopy liana (=woody vine). These feeder roots presumably extract nutrients from the rainwater that flows down the stem and drips from the curve.

Project researchers have found that throughfall dripping from the canopy has lower quantities of most nutrients than is found in the above-canopy rainfall. Mosses, algae, lichens and bacteria growing on leaves (as epiphylls) or in the tree crowns (as epiphytes) are apparently scavenging nutrients from the incoming rainwater. It is unclear if the host tree directly benefits from the nutrient scavenging by its "guests". Evidence is now accumulating that leaves hosting blue-green algae do benefit from the nitrogen-fixing capability of the algae.

The characteristic leaf in forests on white sand is thick and leathery, often persisting on the tree for a lengthy period. Leaf structure and the evergreenness of most of the trees are thought to assist in nutrient conservation because thick leaves may be more resistant to leaching and key elements such as nitrogen, phosphorus and potassium are translocated back into the twigs before old leaves are gradually shed. The lengthy life of leaves in these forests permits longer development for the epiphyllous organisms that colonize the upper surfaces of most leaves. Because tough, thick leaves do not easily compact (Figure 7a), the geometric arrangement of fallen leaves apparently contributes to the porous structure of the root mat.

Thick, evergreen leaves ought to be attractive food sources to herbivorous insects and animals, yet there are unusually few insects and animals in white sand habitats. Numerous tropical naturalists and biologists have consistently remarked on the paucity of wildlife in these forests. Even the blackwater streams draining white sand areas are notoriously poor in fish, turtles, insects, etc. Peter, if those voracious New England mosquitoes bother you during pleasant summer evenings, you will appreciate the fact there are no mosquitoes in tropical forests on white sand soil. In Surinam where the Indians practice shifting cultivation on lateritic soils, they consistently locate their villages on white sand sites. In the San Carlos forests I became cognizant of the paucity of flying insects by not walking into a single spider web in some 20 km of meanderings off-trail or on infrequently used trails. In tropical forests of the western Amazon or in Central America, you may bump into several webs in a single kilometer.

There is a general consensus that plants growing in nutrient-poor habitats synthesize relatively large quantities of secondary chemical compounds, such as alkaloids, tannins and other phenolics. The tremendous array of secondary compounds effectively minimizes animal consumption of plant parts such as leaves, wood, roots, fruit, etc. of the natural vegetation. Secondary compounds retard decomposition of dead plant material as well; the famous greenheart logs from Guyana used for marine pilings is a classic example. Thus, noxious secondary compounds protect plant parts and function as nutrient conserving mechanisms.

In the past year, concern about acid rain has reached the popular press (see Natural History, vol.90(2), February 1981). Acid rain is blamed for fish kills in Scandinavian and North American lakes, and Canada objects to acid rain drifting in from the U.S.A. Sulfur and nitrogen oxides emissions from fossil fuel burning combine with atmospheric hydrogen to form sulfuric and nitric acids that acidify rainwater. Research by project scientists in San Carlos de Río Negro indicates fossil fuel burning is not the only source of acid rain. Deep in the Amazon Basin you would not expect atmospheric pollution to exist nor to find acid rain, yet project researchers have found San Carlos de Río Negro rainfall to have a pH of 4.7--sufficiently low to qualify as acid rain. (Project researchers had found preliminary evidence of acid rain just prior to my visit, hence part of the delay in this newsletter has allowed time for verification.) The surprise finding of acid rain in the Amazon Basin has prompted additional research to determine the sources of tropical acid rain. Initial efforts are focusing on sulfur volatization from tropical soils into the atmosphere and cycled back to earth as acid rain.

In summary, the International Amazon Project in San Carlos de Río Negro, Venezuela, is demonstrating the intricate and effective nutrient conserving mechanisms of tropical forests on nutrient poor soils. Destruction of the thick root mat by forest clearing and burning prevents sustained use of the land for agriculture or even tree plantations. Research results from San Carlos de Río Negro are certainly applicable to the poor soils of the Río Negro region of southern Venezuela and central Amazonia. However, the San Carlos de Río Negro site has such nutrient-deficient soils and such bizarre forest (e.g. the basal "skirts") that I feel it is not representative of many tropical regions, such as the western Amazon Basin.

Sincerely,

Gary

Gary S. Hartshorn
Forest and Man Fellow

Received in Hanover 7/20/81