ECOLOGICAL, ANTHROPOLOGICAL, AND AGRONOMIC RESEARCH IN THE AMAZON BASIN

Emilio F. Moran
Indiana University

The Amazon was, until recently, one of those distant and unknown regions that excited the imagination but was largely irrelevant to the daily lives of scholars, policymakers, and the majority of Latin Americans. This is no longer the case. Developmentalists and disenfranchised people alike look to it as a vast resource area capable of yielding mineral, forestal, animal, and agrarian riches. Ecologists warn against the potential devastation of an environment that is still poorly understood. Agronomists are challenged by the variability encountered at every turn and the diverse responses of crops to standard management practices. Anthropologists and sociologists decry the lack of a social consciousness in the development of the Amazon and try to assess the human costs of this development paid by native and peasant populations. Many other specialists also have found the Amazon an important natural laboratory for their research skills. Yet much of this research remains inaccessible in specialized disciplinary or regional journals and unrelated to the central problems that are, fundamentally, multidisciplinary.

Despite the many investigators working in the Amazon[1] in the past two decades, their number is still small compared to scholars working in the Andes, Mesoamerica, or the Caribbean. Moreover, available research did not make its way into policy circles because of the inability of any Latin American nation to carry out a sustained effort in the area (Tambs 1974). That changed in 1971 when Brazil committed enormous human and capital resources to the construction of the Transamazon Highway, associated colonization projects, and a tax-incentive program to attract national and multinational capital to the Amazon.[2] Unlike past efforts, the Brazilians executed all of the above tasks and the region is changing rapidly: it is now possible to travel from Brasília to Caracas and from the Atlantic to the Peruvian frontier by road; bauxite, iron ore, and other minerals are being exported from the Amazon; and cattle ranches the size of European countries are being established to produce beef for export.

Researchers have found growing support for their investigations,

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easier physical access to previously inaccessible areas, and institutional bases out of which to publish their results. The Instituto Nacional de Pesquisas da Amazonia in Manaus studies the various life sciences and agricultural ecology; the Centro de Pesquisa Agropecuaria do Tropico Úmido (CPATU) in Belem does resource surveys and agricultural experimentation; the Núcleo de Altos Estudos Amazônicos (NAEA) at the Universidade Federal do Pará in Belem studies policymaking and sociological aspects of development; the Goeldi Museum in Belem continues the anthropological study of the aboriginal and peasant populations of the Amazon, as well as the biological sciences. The Centro de Desenvolvimento e Planejamento Regional (CEDEPLAR) at the Universidad Federal do Minas Gerais has carried out studies of internal migration in the Amazon, as have many other research centers throughout Brazil, for the Superintendencia do Desenvolvimento da Amazonia (SUDAM).[3]

Scholarly conferences have taken place with increased frequency—two Amazonian Biota Conferences, one in Belem (1966) and the other in Caquetá, Colombia (1969); the Man in the Amazon Conference in Gainesville, Florida (1973); two "Amazonia: Extinction or Survival?" Conferences at Madison, Wisconsin (1977, 1978); and the Conference on Colonization in Lowland Amazonia at Cambridge University (UK) in 1979.[4] Each of these has either already published proceedings or is currently preparing to do so, all of which reflects this increased pace in the development of Amazonian research (Lent 1967, Idrobo 1969, Wagley 1974, Scazzocchio 1980, MacDonald in press).

Popular courses on the Amazon have been taught regularly at the University of California at Berkeley, the University of Illinois at Urbana-Champaign, and the University of Florida at Gainesville. The latter was the recipient in 1980 of a five-year grant from the Mellon Foundation to stimulate research and teaching on the Amazon. A second international conference on the Amazon is planned for 1982 at the University of Florida.

This review focuses on the reevaluation of previously held assumptions about the societies and ecology of the Amazon.[5] It is organized around a set of questions that are of common concern to ecologists, agronomists, and anthropologists: What is the structure and function of the Amazonian forest? What is its capacity to support animal and human populations? What forms of resource use are capable of assuring the continuation of the environment and human societies depending upon it for survival? What contributions can the region make to the world food supply, national economic goals, and individual aspirations for land ownership? The impact of the political and world economic system will be alluded to whenever appropriate; such views recently have been the subject of several publications (Bourne 1978, Cardoso and Müller 1977, Davis 1977, Velho 1976).

THE STRUCTURE AND FUNCTION OF THE AMAZON RAIN FORESTS

Tropical rain forests are among the most extensive habitats on the earth, occupying over 700 million hectares (1 hectare = 2.47 acres) worldwide (see fig. 1).[6] Tropical rain forests are characterized by high ambient humidity and temperature and by diversity of complex life forms (Moran 1979a). Throughout this review, the term "rain forests" will be used interchangeably with "humid tropics." The concept of the humid tropics was a strictly climatic one, but UNESCO specialists, gathered to map and delimit the humid tropics, had to turn to vegetational criteria as well (Fosberg et al. 1961). Of all the rain forest regions, the Amazon Basin is the largest, with 557 million hectares (UNESCO 1978, p. 22). While it appears incomprehensible that this belt of equatorial green could ever be threatened, a number of ecologists have suggested that by the end of this century the Amazon rain forest may vanish (cf. Gómez-Pompa et al. 1972, Denevan 1973). Already 20 percent of the Amazon forest has been cut, and only about one-third of the African and Asian rain forests still stands (UNESCO 1978). As a timber resource, 40 percent of the remaining world forested land is to be found in the Amazon (UNESCO 1978, p. 37). Tropical forests differ from most other ecosystems in their high plant biomass, in the concentration of nutrients in the plant biomass rather than the soil, and in their rapid rates of nutrient cycling (Richards 1952; Klinge and Rodrigues 1968; Stark 1971; Jordan and Uhl 1978; UNESCO 1978, p. 283).[7]

Both plants and animals are affected profoundly by the region's climatic characteristics: warm temperatures, high humidity, high levels

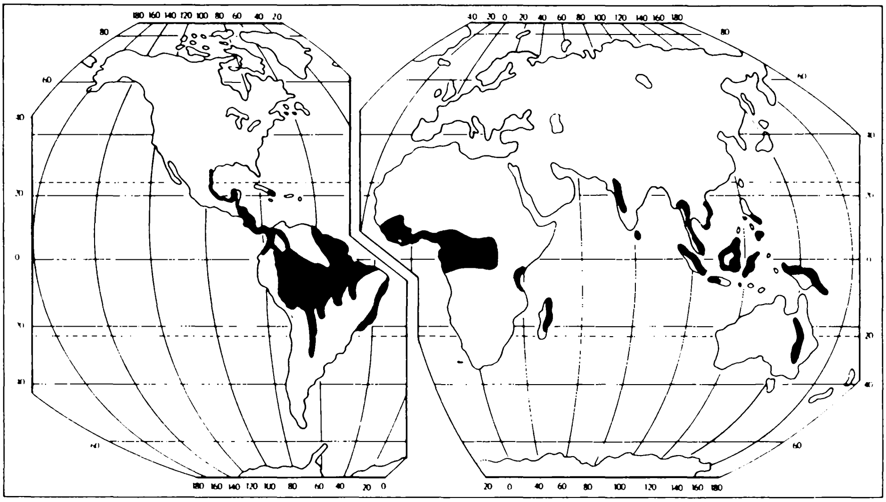

FIGURE 1 The Extent of Tropical Rain Forests

of rainfall year-round, and lack of a marked seasonality in most areas. The climatic regime, the paleoecological record, and human activities through time have brought about significant habitat differences from area to area in the Amazon Basin (Fittkau et al. 1975, Stark and Holley 1975, Moran 1981). These differences are just as important as the generally shared characteristics.

Tropical forests are important components of the global hydrologic cycle. The humid tropics contribute 58 percent of the total water vapor available on earth. A good portion of that moisture comes down as rain and runs along the huge tropical river networks, the largest of which is the Amazon's.[8] Twenty percent of the world's potable water each year enters the oceans from the mouth of the Amazon and about three percent from the Orinoco Basin (UNESCO 1978, p. 48).

Considerable annual variation has been noted in rainfall and in total solar insolation and net radiation, both of which accent the variability of rainfall (Salati et al. 1978; UNESCO 1978, p. 43). Unpredictable periods of water deficiency occur in the humid tropics in part resulting from the rapid water percolation found in some tropical soils, and in part due to the high rate of rainfall per hour (Reichardt et al. 1980). High levels of solar radiation may also be partly responsible for seasonal deficiencies in water supply to plants. Monthly temperature means in rain forests are relatively constant (usually hovering around 24° to 26° C) but daily temperatures can vary as much as 9° C in forested areas and as much as 15° C in open areas. Rainfall commonly exceeds 2000 mm annually with none of the months receiving less than 50 mm. Humidity hovers between 75 and 100 percent year round.

Traditionally, the hot/humid conditions were seen as producing generally poor soils. The commonly held view is that tropical soils are acidic, lack horizons, have been leached of important nutrients, and can be cultivated for only a couple of years before being abandoned (Gourou 1953, McNeil 1964). Recent agronomic research has shown that the soils of the Amazon are not uniform but highly diverse. Soils exhibit differential degrees of weathering due to the interaction of many environmental variables and the differential chemical composition of parent rocks from which soils are derived. Soils under tropical rain forests are much like those in the forested areas of the nonglaciated temperate zone (Sanchez et al. 1972; North Carolina State Univ. 1976, 1978; Sanchez and Buol 1975; Wambecke 1978). Where the parent materials are acidic the soils closely correspond to those of the southeastern United States and Southeast China, both areas now under highly productive intensive cultivation. Where soils are derived from basic rocks, they are frequently neutral in reaction and stand up well to intensive cultivation.

The most commonly mentioned and yet misunderstood aspect of the Amazonian environment is the presence of "laterite" in the soils

(Sanchez et al. 1972). Among soil scientists the term is being abandoned due to its lack of preciseness in the literature—which often included any reddish soil as a member of this category. The term *plinthite* has replaced it—to refer to the iron-rich, humus-poor soil material that hardens irreversibly after repeated wetting and drying once exposed to atmospheric oxygen. Plinthite probably occurs in less than 2 percent of the Amazon, according to Wambecke (1978, p. 235).

The scantiness of information on Amazonian soils creates problems in differentiating among them. Most available maps are at a scale of 1:100,000 to 1:500,000. These macroscale maps show the soils of the Amazon to be primarily low fertility oxisols (latosols) with a small area of inceptisols (alluvial soils) along the floodplain (Sombroek 1966, Nat. Acad. of Sci. 1972). However studies done elsewhere have noted that variability increases with movement toward the more micro-scale units in the sampling process. RADAM's (1974) maps, at a scale of 1:100,000, showed the dominant soil type in a subarea of Marabá in Brazil to be ultisols. A mapping effort at a scale of 1:10,000 reversed the results: oxisols constituted 65 percent, entisols 22 percent, and ultisols only 13 percent of the soils in question (Ranzani 1978).

The luxurious green vegetation of the Amazon was long taken as indicative of high soil fertility. However, it has been found that most of the nutrients in tropical rain forests are stored in the vegetation rather than in the soil. The trend of rain forests to accumulate a large proportion of the nutrients in the plant biomass (see table 1 and Herrera 1979) may make them more susceptible to disruption than ecosystems wherein a greater proportion of the total nutrients are stored in the soil (Klinge 1978). Despite this potential fragility, rain forests accumulate nutrients at a remarkably fast rate. They can attain 90 percent of plant biomass within eight to ten years after forest clearing (Sanchez 1976, p. 351) and nutrients are accumulated steadily, following a linear function (Bartholomew et al. 1953). Temperate forests, by contrast, take fifty to one hundred years to reach maximum biomass (Farnworth and Golley 1974, p. 76).

Most of the nutrients stored in the soil medium under rain forests are found in the top 30 centimeters. Studies have also shown that 65 to 80 percent of the vegetation's root system is found within that topsoil layer (Greenland and Kowal 1960, Jordan and Uhl 1978, Stark and Spratt 1977). The high gross productivity of rain forests is dependent on the contribution made by the vegetation to the nutrient pool (Klinge and Rodrigues 1968). Each year 10 to 20 percent of total biomass dies off and drops to the ground in the form of litterfall (see table 1). The nutrient composition of the litter is similar to that of the forest except for a higher nitrogen concentration (Klinge and Rodrigues 1968). Once the litter falls to the ground it is rapidly decomposed and mineralized. Approximately half of the dry matter is mineralized within the first eight to ten weeks (Sanchez et al. 1972, p. 49). Despite the high levels of rainfall there is no appreciable loss of nutrients due to leaching. Research in the Brazilian Amazon found the presence of tree-feeding rootlets at a depth of only 2 to 15 centimeters associated with mycorrhiza (root fungi) by means of which the trees were directly connected with the litter layer.[9] The trees can thus exploit the fungi to obtain their inorganic nutrients directly from the litter, instead of having to wait to have them become part of the soil layer itself. Stark (1969) estimated that 5.4 $g/m^2/day$ were mineralized, a figure that approached the gross primary production of the forest of 6.0 $g/m^2/day$.

As a result of recent research in the nutrient-poor Rio Negro Basin in southern Venezuela, it is now recognized that the structure and function of rain forests on nutrient-rich soils (e.g., some areas of Central America) is fundamentally different from that on nutrient-poor soils. Forests in impoverished areas act like gigantic filters that capture nutrients in rainfall and prevent them from escaping once they enter the system; a thick, above-ground root mat on top of the mineral soil acts as the major filter that prevents nutrients from being lost (Jordan et al. 1980). Other nutrient-conserving mechanisms are: the synthesis of alkaloids and polyphenols to reduce herbivory; sclerophylly (thick, leathery leaves); movement of nitrogen, phosphorus, and potassium to the twig before leaf shedding; and algae / mosses / lichens / bacteria filtering of rainwater nutrients (Herrera et al. 1978). Nutrient-rich environments dispense with such conservative ecological adaptations; instead, nutrients are able to enter the mineral soil or are cycled through the more significant herbivore population supported by this less protective type of rain forest. Despite the differences in nutrient-conserving mechanisms, net primary productivity, secondary successional rates, and other structural and functional characteristics remain fundamentally alike (Jordan 1979).

Whether in nutrient-rich or in nutrient-poor soils, the rain forest vegetation feeds on itself in what must be one of the most efficient closed nutrient cycles on earth. The vigor of secondary succession is

TABLE 1 Nutrient Levels in Mature Rain Forest Vegetation and Litterfall

Nutrient	*Biomass kg/ha*	*Litterfall kg/ha/yr*
Nitrogen	701–2044	74–199
Phosphorus	33–137	1–7
Potassium	600–1017	8–81
Calcium	653–2760	45–220
Magnesium	381–3890	10–94

Source: Adapted from Sanchez et al. 1972, pp. 48–49.

aided by the fact that only 40 to 50 percent of the total biomass normally is part of this cycling—mainly leaves, limbs, and roots. In addition, 20 percent of the total nutrient uptake is derived from the subsoil (Sanchez et al. 1972, p. 50), although this figure may be lower in nutrient-poor areas.

The most conspicuous feature of tropical rain forests is the large number of tree species and the presence of few individuals of a species in a given area. Although the flora of rain forests is still relatively unknown, the clear trend has been to increase earlier estimates of species diversity. The flora of the Amazon is the least known, although it appears to be, in species diversity, second only to the flora of Malaysia (UNESCO, 1978, p. 93). Species diversity in the humid tropics has been explained in terms of genetic drift (Federov 1966), variety of niches (Richards 1969), predator pressure on seeds and seedlings (Janzen 1970), and climatic fluctuations (Prance 1978). Studies suggest that sample plot size is a significant factor in predicting species diversity; whereas samples in 1 hectare plots yielded 60 to 79 species, the number of species rose to over 90 in 1.5 hectare plots and to over 173 in 2 hectare plots (Cain and Castro 1959, p. 60). Jordan (1979) found a marked and continuous increase in species number when sampling sites within a few kilometers of each other in the Venezuelan Amazon. Regional extrapolations are of doubtful reliability because of this diversity factor.

The notion that rain forests are "fragile ecosystems" has been contradicted in part by a classic experiment in which rain forest vegetation proved surprisingly able to withstand levels of gamma radiation that had devastated pine forests in North America (Odum and Pigeon 1970, 1:257). The reason for this resilience appears to lie in the diversity of species and the intense competition for light and nutrients. Some ecologists have suggested that three stories are recognizable in the forest (Steila 1976); however, these layers simply may reflect stages in succession brought about by forest openings (Uhl 1980, Pires 1978).[10]

Forest types vary depending on moisture regime, altitude, and soil factors. The differences resulting from these factors produce rain forests with different levels of productivity. Attention to the heterogeneity of the Amazon and the presence of diverse habitats is relatively recent. Denevan (1976) has noted correctly that the traditional ecological division of the Amazon into floodplain and upland is inadequate and shows that, historically, populations of the Amazon differed greatly in density as a response to the diverse resource base (see table 2 and fig. 2).[11] The coast, which probably offered the earliest habitat, as evidenced by the Marajó sites at the mouth of the Amazon (Meggers and Evans 1957), and the floodplain, which formed a natural extension of coastal adaptations, both were characterized by rich aquatic resources and high agricultural productivity resulting from the silt-enriched soils on the

TABLE 2 Population Estimates of Amazon Native Peoples per Habitat Type

Habitat	*Area in Kilometers*	*Estimated Density per km² in 1492*	*Estimated Total Population in 1492*
Coastal	105,000	9.5	997,500
Floodplain	102,814	14.6	1,501,084
Lowland Savannas			
Colombian & Venezuelan (Orinoco) Llanos	395,000	1.3	513,500
Llanos de Mojos	180,000	2.0	350,000
Upland Forest			
Eastern Peru & Northeastern Bolivia	216,000	2.1	259,200
Superhumid	56,000	0.1	5,600
Lowland Forest	5,037,886	0.2	1,007,577
Upland Savannas	2,178,000	0.5	1,089,000

Source: Adapted from Denevan (1976), pp. 213, 228, 230.

levees (Sternberg 1956, Meggers 1971, Roosevelt 1980). Thus, although relatively small in area compared to other habitats, their population density was far greater. Lowland savannas are semiaquatic, periodically inundated zones, with rich wildlife but somewhat poorer soil resources; nevertheless, they were cultivated by use of ridges, drainage ditches, and raised platforms (Denevan 1966, p. 210). Here, again, despite the smaller area involved, native population density was relatively high.

The upland forests (*montaña*) should be distinguished from lowland forests, a distinction suggested only in the past decade.[12] Upland areas begin at about 700 meters or a mean annual temperature of 24° C. The cooler temperatures result in less soil leaching and, on sloping sites, depth to nutrient-rich parent rock is less, with the result that generally the soils are more fertile. In areas "where conditions are very wet or very dry, game other than birds is nearly impossible to find" (Denevan 1976, p. 220). Fishing is poor due to a lack of major streams and the absence of lagoons comparable to those in the floodplain and lowland savannas. The lowland interfluvial forest, the most extensive habitat, includes a wide range of characteristics. Rainfall varies between 1500 mm and 4000 mm and elevations vary between sea level and 600 meters; eastern areas are lower in rainfall (i.e., the moist forest) than western parts (i.e., the wet forest); soils are generally highly weathered, but

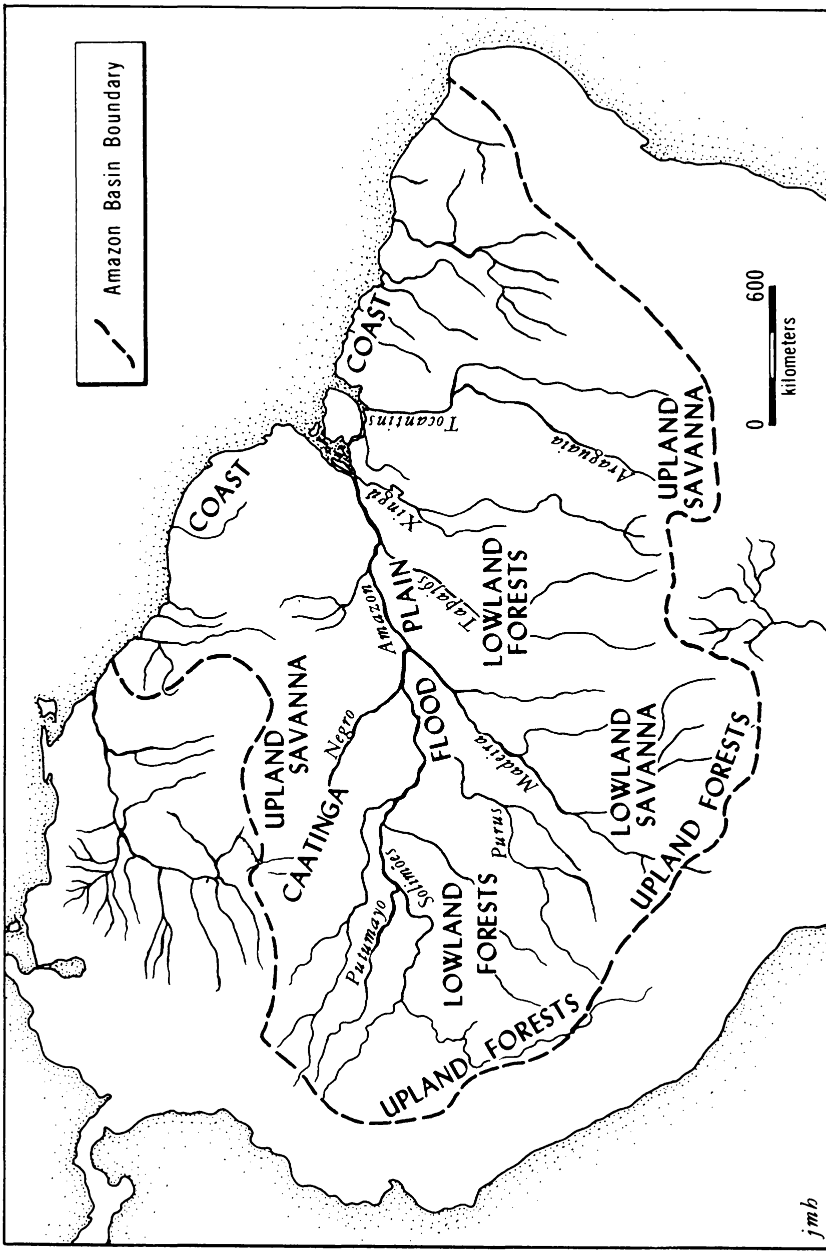

FIGURE 2 Amazon Basin Habitats

sizable areas of medium to high fertility (comprising 10 to 20 percent of the Basin) are present in dispersed form (Wambeke 1978). A portion of the Amazon Basin is upland savanna (*campos de terra firme*), covering areas in Central Brazil and the Guianas. Soils are leached and there is a prolonged dry season. Some native populations were nomadic hunter/gatherers, although most practiced agriculture in the adjacent gallery forests (Maybury-Lewis 1967).

The variation that has been noted in Amazonian habitats so far only begins to give an idea that the Amazon Basin is more differentiated than many writings would have us believe. To date we lack a systematic comparison of these habitats according to standard measures such as density, productivity, species diversity, soil-plant associations, etc.

FOREST PRODUCTIVITY AND ITS CONSEQUENCES

Undisturbed tropical rain forests show high rates of biomass productivity, whether they are found in nutrient-poor or nutrient-rich habitats (Jordan and Herrera 1981). When one compares the data for agricultural productivity, however, the differences are enormous. There is a clear association between the rate at which yields decline with cultivation and the initial pH of the soil. Soils with a pH of 6.0 and above take as much as fifteen years for yields to drop 50 percent below those of the first cropping season, but low pH soils often drop below 50 percent by the second year of cultivation (Sanchez 1976, pp. 375–76). The argument that soil fertility depletion is the chief cause of field abandonment remains undemonstrated. Very little correlation has been shown between declines in yield and measurable soil changes before and after cropping. The magnitude of changes in the better soils is too slow to permit definite assertions, although in the poorer soils it is clear that soil depletion and low yields may be responsible for abandonment of fields after one or two years.

The most important mechanisms that facilitate the cycling and conservation of nutrients in nutrient-poor habitats are located in the mat of roots and humus near the soil surface. With clearing, the root mat is destroyed along with the productive potential (Herrera et al. 1978, Stark and Jordan 1978).

In addition to the nutrient-conserving mechanisms discussed in the previous section, rain forest plants have evolved effective ways to repel and control the herbivore population. In Barro Colorado, Panama, numbers of animals are restricted through alternate seasons of fruit abundance and shortage. In the latter, mass starvation has been noted (Leigh, Jr. 1975, p. 82). Other trees reproduce by means of large, hard nuts. The hard endocarp protects the nuts from predators but the mesocarp tends to be rewarding, and some species of animals function as dispersal agents for it (Smith 1974b). Animals play important roles in processes such as pollination, fruiting, flowering, litter decomposition, consumption of green plants, and in mineral cycling (Fittkau and Klinge 1973). Animal consumption of plant tissue, and consequent excretion of feces, represents another effective short cut in nutrient cycling.

The richness of speciation is as true for animals as it is for plants. For example, in a six-square-mile area in Barro Colorado, Panama, there are twenty thousand identified insect species, as compared with a mere few hundred in all of France. Some scientists feel that the rate of evolution in the rain forest is particularly high and that many of the species presently occupying northern temperate environments evolved in tropical environments[13] (Bates 1960, pp. 109–10). Animals represent a small fraction of the rain forest's total biomass and are largely unobtrusive. A much larger proportion of animals live in the upper layers of vegetation than is the case in temperate forests; for example, 31 of 59 species of mammals in Guyana are arboreal, 5 are amphibious, and only 23 are ground dwellers. Fittkau and Klinge (1973) calculated that the living plant biomass was 900 metric tons/hectare while that of animals was only 0.2 tons.[14] A number of biogeographers and ecologists have indicated that the low net productivity of the rain forest biome provides little food for forest animals and that their biomass per unit area is quite small. While this argument is sound, it does not take into account the large area utilized by most indigenous hunting populations as well as the lack of adequate quantitative data.

Tropical rain forest fauna undergoes changes in population size and structure as a result of seasonal changes in precipitation (Brown and Sexton 1973), food availability (Janzen 1967), and weather periodicity. On the whole, however, animal populations in a complex biome exhibit greater longevity, have fewer offspring, and are more sedentary than their counterparts in temperate regions or in early successional phases (McArthur and Wilson 1967). Part of the stability of tropical forest animal populations results from intense inter- and intraspecific competition. Animals appear to partition resources in such a way that minimal niche overlap occurs (Moreau 1948), a situation that favors the development of interstitial, sequential, specialist, and hypercontingent species represented by few individuals (Colwell 1973). Predator-prey interactions are not well understood but mutualism has been extensively researched. Because of the abundance of insects and their impact on plants, mutualistic bonds are frequent between plants and insects, particularly in pollination processes.

Many anthropologists and ecologists have come to accept the culture and technology of tropical forest aborigines as the optimal approach to the management of the Amazonian tropical rain forest (Meggers 1971 and Goodland and Irwin 1975, to name several leading spokesmen). Indeed, Amazonians appear to have extensive knowledge of wild plants, familiarity with animal behavior, and varied uses for many components of the habitat. It is perhaps for this reason that explanations have tended in the direction of seeing the environment as the source of the limitations to human cultural and social development expressed in the form of small and isolated settlements, chronic warfare, lack of technological sophistication, and reliance on hunting. For a while the dominant argument was that the *soils* were unproductive (Gourou 1953; Meggers 1954, 1971). As noted in the earlier section, recent agronomic research has shown the variation in soil quality to have been great and that the problem is as much one of knowing how to identify soils as it is a problem of soil quality per se.

A currently heated debate in anthropology concerns the availability of animal protein in the Amazon Basin and its implications (Lathrap 1968; Holmberg 1969; Siskind 1973; Harris 1974, 1977; Gross 1975; Vickers 1975, 1979, 1980; Ross 1978; Beckerman 1979; Chagnon and Hames 1979; Hames 1979, 1980). Briefly put, the argument concerns whether protein availability is the major factor in the cultural processes of warfare, village fissioning, low population density, migration, male supremacy, and village-level political organization. At the time the connection was made, evidence was relatively scarce but its proposition has stimulated numerous quantitative studies that have tended to reject it on grounds that protein is not particularly scarce, and that the population's cultural practices promote dispersal and movement not so much due to scarcity of protein but to maintain the efficiency of hunting at a relatively high level (Vickers 1980). Hames (1980) has noted the rotation of hunting zones as a way of allowing for the recovery of hunted areas and reducing the need to move in response to decreased hunting productivity. The debate is far from resolved but the evidence is suggesting that the simplistic causal link between low faunal productivity and the structure and function of Amazonian human communities may have overlooked the complexities of the interaction between populations and resources.

Human populations dependent on hunting exploit the Amazonian fauna in ways that reflect local habitat characteristics, periodicity, seasonality, and previous patterns of exploitation in a given territory (Zarur 1979). The problems of obtaining protein reside more in its dispersed nature and the behavioral habits of the animals than in its absolute amount. Most of the statements concerning the lack of meat among native South Americans have been based not on personal observation and quantitative data gathering of game hunted and eaten, but on the acceptance of the natives' point of view. Indeed, among tropical forest peoples, "hunger for meat" is a constant concern (cf. Holmberg 1969, Siskind 1973). Verbally expressed concern over the lack of meat may not be based on a real dietary deficiency.[15]

The uncertainty associated with hunting is reduced in numerous aboriginal societies by elaborate symbolic systems; these reflect culturally sanctioned adjustments of populations to resources (Reichel-Dolmatoff 1971) and take the form of prohibitions. Some tribes taboo the eating of some or all game animals during puberty (Levi-Strauss 1948, Métraux 1948), menstruation, pregnancy (Nimuendajú 1948a), and post-partum (Métraux 1948; Nimuendajú 1948a, 1948b). Mura fathers may not hunt until their offspring can walk (Nimuendajú 1948c), a practice that may encourage conservation, intensify social exchange, and create close bonds between father and child. Ipurina fathers must refrain from eating tapir or peccary meat for a year after their child is born (Métraux 1948). Ross (1978) has argued that these taboos reflect ecological adaptations to the differential productivity of some species.[16]

Gathering forest products is also subject to the peculiar periodicities and seasonality of the tropical forest. During the dry season forest populations engage in concentrated gathering efforts because of the availability of game and greater ease of traveling. Forest plant products make important contributions to the diet and involve work by men, women, and children. While hunting, the men do not overlook the presence of plant resources and may collect or consume them on the spot. A wide variety of products is gathered but major contributors, by volume, are few in number. For ecological analysis, however, careful note should be taken to record even small amounts of food consumed since crucial trace elements may be provided thereby. Brazil nuts (*Bertholletia excelsa*), for example, contain large amounts of the amino acid methionine, mentioned by Spath (1971; see also Gross 1975, p. 534) as perhaps the most limiting nutritional element in Amazonian diets. Systematic measurement of Brazil-nut consumption by aboriginal populations in South America remains undocumented to this day. The same can be said for most other wild plant products. This is partly the result of a tendency by many populations to gather and eat, on the spot, any edible products they come across; accounts tend to mention only the plants that return to camp (Lyon 1974, p. 70). A problem too has been the lack of botanical knowledge on the part of many observers. The diversity of the tropical rain forest flora presents major problems to the ecologically minded scientist, even when properly trained. Sampling techniques also need to be modified since they developed in response to the characteristics of the temperate flora and fauna and yield inaccurate results if automatically applied in the humid tropics.

The species richness in rivers cutting through lowland regions has only begun to be studied carefully (Goulding 1981, Smith 1981). Junk notes that thirteen hundred to two thousand species have been identified in the Amazon rivers and that yearly harvests of 633,000 metric tons are theoretically possible on a sustained basis (1975, p. 109). Such potential has never been realized and the harvests of aboriginal peoples are miniscule by comparison with this theoretical figure. Unlike hunting, which is surrounded with ritual and taboo due to its insecurity, fishing is relatively free of restrictions due to the abundance of the resource relative to aboriginal capacity for its exploitation. In addition, fishing is not restricted to men as is the case with hunting.

Vickers (1976, p. 124) estimated the energy efficiency of fishing at 2.99 to 1, while that of hunting was 9.33 to 1 in a new village settlement and 2.48 to 1 in a long-occupied site. Since game depletion is a problem of greater immediacy than fish depletion, populations probably preferred riverine locations to those inland, where hunting would have to be relied on to supply the bulk of protein. The chronic state of warfare/raiding in tropical rain forest regions before contact, and since then, has been explained by some as a result of a constant effort to control riverine sites where subsistence efforts, particularly protein obtention, were more rewarding. Werner et al. (1979) have shown that the productivity of fishing is a function of location.

Agriculture in the lowland and upland forested areas of the Amazon followed a pattern emphasizing root crops and the technique known as slash-and-burn, swidden, or shifting cultivation found across all tropical rain forests.[17] In the past this agricultural technique was seen as both primitive and destructive, a view that has been shown to be erroneous (Conklin 1957; Nye and Greenland 1960; Popenoe 1960; Moran 1975a, 1976a, 1981). Swidden cultivation is an economical and agronomically appropriate management system when fallowing is adjusted to soil conditions and population densities are kept low (Lathrap 1970, 1976).

Shifting cultivation can be defined as an agricultural system in which fields are cropped for fewer years than they are allowed to remain fallow. In this system an area of land is cut, allowed to dry for a few months, and is then burned. Burning has been shown to kill parasites, insects, fungi, nematodes, and pathogenic bacteria. Weeds are destroyed and anaerobic nitrogen-fixing bacteria increase their activity. The heating of the soil during the burn leads to increased fertility due to the increased rate of nitrogen mineralization (Nye and Greenland 1960, p. 72). This allows more of the nitrogen to become available to plants for a period after the burn. The availability of nitrogen, phosphorus, and

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potassium, the three major macronutrients for plant growth, is increased by turning the vegetation into a nutrient-rich ash layer. The ash layer is not only fertilizer but also raises the pH of acid tropical soils. Rodents and other plant predators are driven out by the fire thereby giving the young crops a better chance at maturing (Popenoe 1960). Given the vigor of secondary succession, the strategy of burning also destroys the trunks of trees and thereby slows down regrowth. Burning by itself, however, cannot effectively cope with secondary succession and the reoccupation of the cleared area by pests and rodents.

Swidden systems also assume that the land will be periodically left fallow. Reasons for abandonment include weed invasion with every growing season, decline in the available nutrient pool, pest infestation, and consequent decline in yields. Crucial to the long-term productivity of swidden systems is the existence of mechanisms that encourage abandonment of fields at regular intervals so that forest can take over. In the Amazon, where land had traditionally not been in limited supply, populations appear to have shifted in response to the perception of decreased yields, pest and weed invasion and, less often, out of fear of sorcery and raids.

One of the important consequences of the introduction of a monetary economy into the Amazon has been the gradual erosion of the traditional strategies of diversified resource use (Galvão 1963). Hunting of a wide variety of game animals for subsistence gives way to hunting animals prized for their skins in trading posts (Smith 1976c); in the process the meat of the animals is misused or left unused as a protein source.[18] The diverse swidden plots of native horticulturalists were abandoned when the potential for wealth from tapping rubber or collecting Brazil nuts became alluring. Murphy and Murphy (1974) have shown that rubber tapping and a desire for trade goods led to the dispersion of the Mundurucú into single households, to a neglect of agriculture, and to debt/dependency on rubber traders. A comparable development has been studied in relation to the Brazil-nut trade (Laraia and da Matta 1967). On the other hand, Whitten (1976a, 1976b, 1978) has convincingly shown that the Canelos Quichua of Ecuador have been able to maintain themselves through the mediation of cosmological flexibility in the face of rapid economic change.

While it would be naive to suggest that all Amazon native peoples are in balance with nature, the evidence suggests that a wide spectrum of subsistence practices were applied to resource use. Because they lacked access to extraregional subsidies and lacked social and political organization above the village level, Amazon populations may have developed site-specific solutions that reflected the characteristic diversity of Amazon ecosystems. Native peoples were probably adjusted to the limitations of each zone; exploited, whenever possible, areas at the edge between habitats; and maintained strategies that adjusted resource use to resource availability in highly localized micro-environments.

Up to the present, Amazonian environments have resisted the imposition of inappropriate management practices more successfully than have the human populations. Hemming (1978), Wagley (1977), and Denevan (1976) have documented the devastating demographic and cultural impact of post-Columbian contact on the aboriginal populations. The forest, however, has not yielded to human efforts to subdue it. Wave after wave of immigrants to the Amazon have had to adopt local patterns of resource use or they have left, defeated. The capacity of the forest to resist the penetration of resource users has been reduced by the scale of current exploitation. Estimates of deforestation range between 10 and 25 percent of the original forest, depending on what is considered Amazonia proper (Goodland 1980, p. 26). Mahar (1979) estimates that the wood wasted by cattle ranches in the past decade could have brought in an estimated $1 billion. Clearly, the capacity of industrializing Brazil and multinationals has reduced the ability of the forest to fend off human penetration through the vigor of secondary succession.

Anthropologists have also suggested that the reduction of the forests threatens the way of life and even the biological survival of the aboriginal population (Meggers 1971, Davis 1977, Ramos 1979). Negative consequences of Amazonian development projects have begun to manifest: according to Bourne (1978, p. 233), 45 percent of the Parakanã died in the first months after the Transamazon cut through their traditional territory. The decimation of the sixteenth and seventeenth centuries (Hemming 1978) is being repeated today as isolated groups fall ill to our diseases soon after contact (Wagley 1969, 1977); in this century alone, at least eighty-seven Indian groups have become extinct (Ribeiro 1970, p. 238).

As many observers have noted, the death of these peoples is a profound loss on many counts. The native peoples of the Amazon represent part of the variety of human societies and cultures that enriches our understanding of human possibilities. Relocation of groups in reservations provides temporary and necessary relief but rarely have such reservations been allowed to stand intact (Davis 1977) nor is life within them as rich as that before (MacDonald in press).

COLONIZATION IN THE AMAZON[19]

Poor distribution of land in some areas and its scarcity in others have led to the expansion of populations from their areas of origin to the Amazonian lowlands (Scazzocchio 1980). Colonization is normally of two general types: spontaneous or directed.[20] Studies have shown over the years that, of the two, spontaneous colonization is more cost-efficient

(Nelson 1973). In the Ecuadorian Oriente (see fig. 3), colonization has often progressed years in advance of road construction (Whitten 1976a; Bromley 1979), and economic well-being above the subsistence level has been hampered in these projects by elementary human and institutional malfunctioning (Crist and Nissly 1973, p. 81; Wesche 1967). The problems faced by planned colonization projects are different more in degree than in kind. Planned projects suffer from lack of credit, impassable roads, declining yields due to poor advice on soil selection, unrealistic loan repayment demands, inadequate markets to absorb produce, and naive advisors (Nelson 1973, Dozier 1969).

The recent thrust to develop the Amazon by means of a colonization program supported by massive capital inputs and government-directed colonization provides a telling example of the constraints and opportunities present in the Amazon Basin (Moran 1981). A prime instance is the Altamira Integrated Colonization Project in the Brazilian state of Pará (see fig. 4), in which serious efforts were made to carry out the plans;[21] it has also been the most thoroughly studied by fieldworkers (see Moran, N. Smith, Fearnside).

The colonists who came to the Transamazon Highway area were from all over Brazil and had a wide variety of backgrounds and resources. Their distribution, however, was not random—with clusters of colonists from one region here and from another there (Moran 1981). Government projections that 75 percent of the colonists would be impoverished Northeasterners did not materialize; only about 30 percent of those settled between 1971 and 1974 came from the Northeast, and comparable numbers from the Amazonian region and southern Brazil made their way to the new settlements. The best predictors of high income and farm productivity were not education and region of origin, as the government projected, but, rather, previous farm management/ ownership experience, residential stability, experience with credit, and liquid assets (Moran 1975a, 1976a, 1979c). Fearnside, in his study of another colonization zone of Altamira, confirmed the importance of these factors (1979, p. 6).

The colonization plans had ignored the peasant population of the Amazon (*caboclos*), but these people were an important element in the new communities (Moran 1974). The highest yields in the area studied were obtained by caboclos—an average of twice that of outsiders and as high as four times the mean in some exceptional cases. Such yields reflect the more judicious choice of soils, knowledge of the peculiarities of the local weather, and better use of plants, animals, and available labor. Unlike the non-Amazonian immigrants, the caboclos combined production for consumption with cash crops; this went against pressures from the bank, which gave financing only for the cultivation of cereals. Their production of manioc flour, home-cured tobacco, milk,

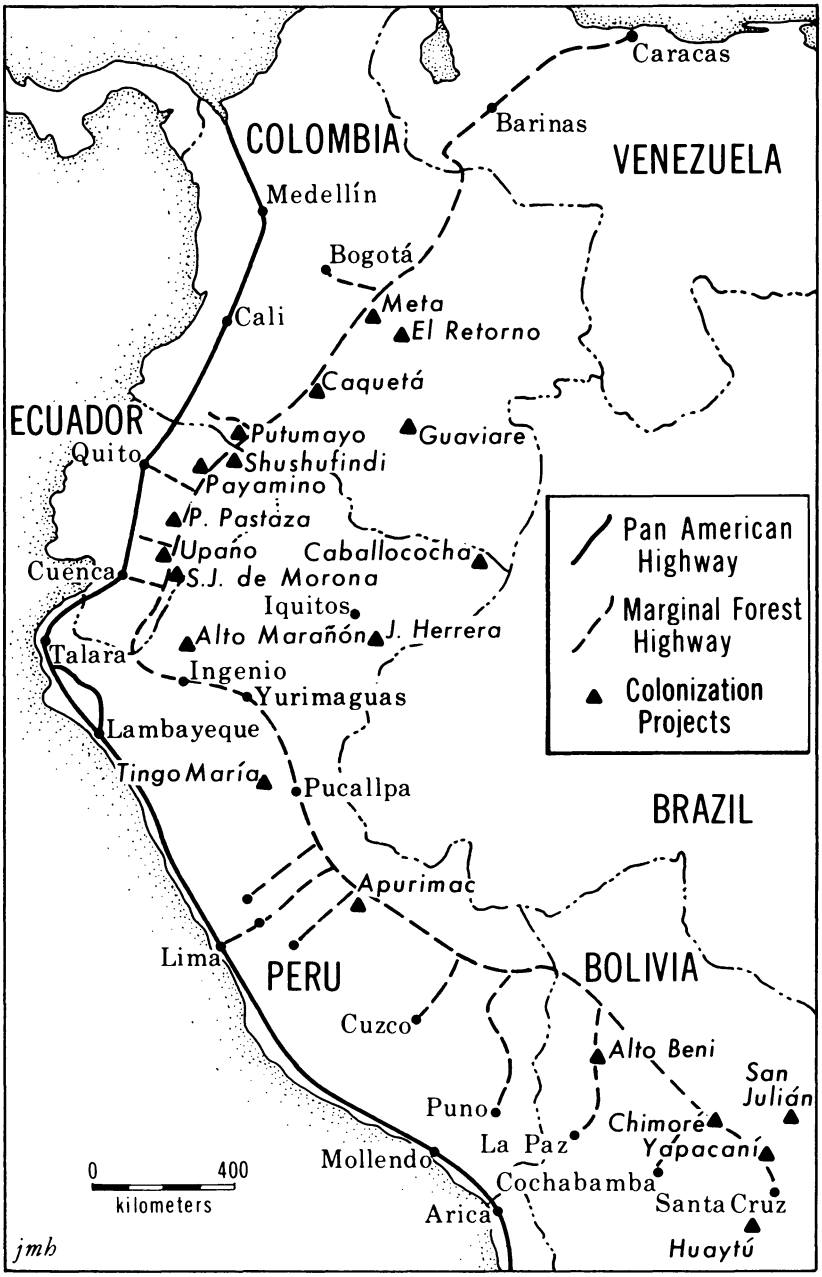

FIGURE 3 Andean Highways and Amazon Colonization

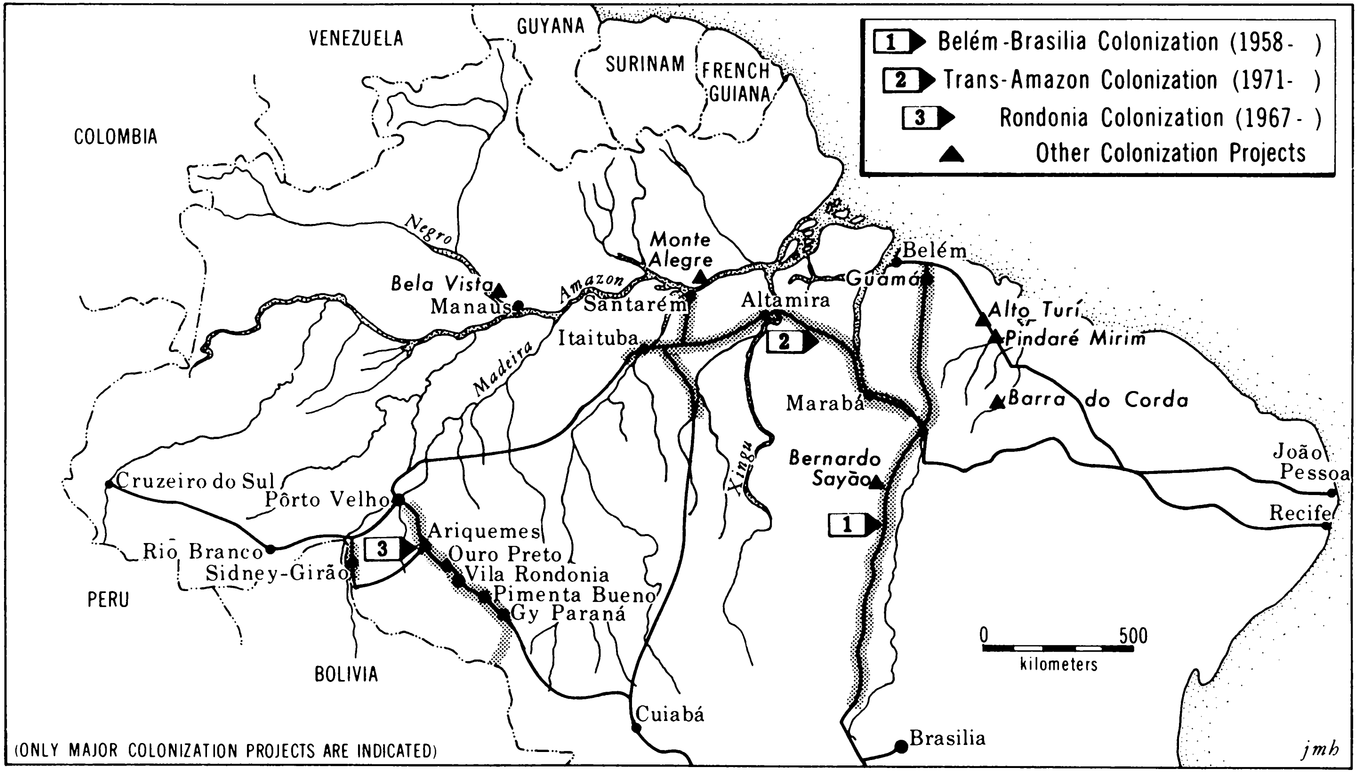

FIGURE 4 Roads and Colonization in the Brazilian Amazon

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eggs, pigs, and chickens provided income and supplies needed locally (Moran 1976a, 1979b, 1981). The presence of caboclos in the colonization area turned out to be beneficial; they became disseminators of information about local plants and animals, and of ways to reduce the adverse effects of seasonal isolation, lack of information, and defective production systems advocated by government agents.

The constraints on the agricultural development of the Transamazon were more often structural and institutional than environmental. Despite numerous studies that discussed the need to guarantee year-round road quality, the timely release of credit for agricultural activities, and the extension of appropriate technical knowledge for specific agricultural uses and sites (e.g., Hegen 1966, Dozier 1969, Nelson 1973, Crist and Nissly 1973), these perennial problems were allowed to recur. Inappropriate criteria in colonist selection led to inappropriate soil selection and poor farm management (Moran 1977, 1979c). Road construction priorities neglected access roads to farms and rainy season maintenance. Credit was released late and in a pattern that reduced the benefits that might be derived from the low interest rates.[22] Technical assistants were generally unfamiliar with Amazonian production systems, or held them in low esteem; as a result they promoted inappropriate crops and farm management practices for the prevalent conditions (Moran 1975, Smith 1976a, Fearnside 1978, Bunker 1978, Wood and Schmink 1979).

The bulk of the field-based research on colonization along the Transamazonian Highway has found that many factors militated against the performance of the migrants; they were ecological (Smith 1976a, 1977; Fearnside 1978; Moran 1979b), ethnoecological (Moran 1975a, 1976a, 1981), interactional (Fleming-Moran and Moran 1978, Moran, n.d.), structural (Cardoso and Müller 1977, Pompermeyer 1979, Wood and Schmink 1979, Moran, n.d.), and economic (Moran 1975a, Mahar 1979). Such factors form a complex web of constraints, one acting upon the other and in turn upon the actors. They need to be included in any effort to resolve how to integrate the Amazon region into national production goals, how to achieve social equity, and how to protect the environment against potential devastation (Scazzochio 1980).

Frontiers provide an opportunity to reproduce the social and economic system of the region or nation that promotes frontier growth (Forman 1975, Fleming-Moran and Moran 1978). Political economists have noted the expansion of the Brazilian state and its peculiar form of state capitalism into the Amazonian frontier (Velho 1976, Cardoso and Müller 1977, Pompermayer 1979). Whereas in the past the frontier was developed by private enterprise, with sporadic and usually inefficient government intervention, the modern state seeks to extend control over the Amazon by recreating the conditions that assure its own predominance. On the one hand, the regime seeks legitimation through the execution of socially beneficial schemes, and on the other hand, it yields to pressures from the dominant capitalist sector which supports its continued existence. These internal contradictions negate the possible benefits that might be derived from its socially oriented projects.

I have suggested elsewhere (Moran 1981) that the decision made by the Brazilian government in 1974 to turn from small-farmer colonization to large-scale development took place because of the structure of the Brazilian bureaucracy and the aggregate inputs that serve to formulate its policies. Hirschman (1967, pp. 39–44) has pointed out that planners anywhere tend to be biased against programs that involve technological uncertainties and prefer to avoid projects that involve dealing with large numbers of people. The problem is thus general to all bureaucratic structures and affects any government effort to direct colonization of frontiers. In Brazil's case, that structure is remarkably centralized (i.e., authoritarian) and is unable to process complex information incorporating the variability present in any areally extensive system. The result is a structure of decision-making insensitive to micro-level variability and with a tendency to homogenization of both environmental and social variables (Moran 1981).

SUSTAINED YIELD PRODUCTION SYSTEMS

It is generally acknowledged that the use of Amazonian resources has been dominated by either "subsistence" or by inappropriate intensive systems imported from the temperate zones. One of the important thrusts of research in the past decade has been the study of sustained yield agroecosystems (Janzen 1975) that use some combination of pasture, root crops, tree farming, and silviculture.

The favorable and massive financial and tax incentives that have been provided to cattle ranchers will have resulted in over $1 thousand million being invested between 1965 and 1978 in SUDAM-promoted cattle ranching (Mahar 1979). Such high capitalization produces few jobs and destroys enormous areas of forest (Goodland 1980; Kleinpenning 1978, 1975). Ecologists argue that, in a short time, overgrazing, trampling, and compaction of soils lead to reduced pasture productivity and, eventually, to abandonment of the deteriorated pastures in favor of new areas of forest wherein the process starts anew. The findings of Falesi (1976), however, seem to contradict this bleak picture. Falesi found that pastures actually improved soil fertility when properly managed: soils under *Panicum maximum* for twelve years have shown very satisfactory nutrient stability; organic matter levels stabilize and even increase due to the rapid turnover of the root system of grasses; and the pH is stable over time, as are the levels of exchangeable bases (Falesi 1976).

Hecht (n.d.) has noted that 85 percent of the cattle ranches in the

Paragominas area of the state of Pará, Brazil, have been abandoned. She attributes this to the invasion of noxious weeds into the pastures. A great deal more research is needed into this question but, when properly managed, pastures should be able to provide a relatively stable production system. However, with cheap and easily available land in forest, it is unlikely that most managers would opt for an intensive management system capable of sustained yields through time. This is particularly the case when tax incentives encourage clearing of new land rather than intensive use of existing clearings (Fearnside 1979a).

Agricultural production in the Amazon has been thought to be possible chiefly by swidden cultivation. Amerindians produced sufficient food for their needs, but population was kept low per unit area. Studies undertaken by research institutes on small farmer production systems have shown that traditional combinations of root crops, legumes, and squashes provide a stable and highly efficient agricultural system. However, studies of caboclo communities suggest that periodic deficiencies in food supply occurred, and it is unclear if the deficiencies were a result of poor soils, poor management, or the demands of an extractive economy (Wagley 1953, Moran 1974). One realistic solution is to plant new varieties that reduce labor input and are disease-resistant but do not sacrifice yields (Sanchez 1976, p. 381). Special deficiencies may be overcome and the land improved by selecting trees for the successional cycle that accumulate needed nutrients. The planting of *Heliconia* and *Gynerium* spp. to accumulate phosphorus can be important in areas where that element is in short supply. *Acioa barteri* accumulates calcium and magnesium, while *Cassuarina* pine trees fix nitrogen symbiotically (Sanchez 1976, pp. 384–85).

Increase in population density in the Amazon makes it increasingly difficult to maintain the integrity of shifting agriculture. More continuous cultivation of rain forest soils seems almost inevitable, but this need not spell the creation of deserts (Goodland and Irwin 1975), nor an end to hope for populations seeking new lives in the lowland tropics (Moran 1975a, 1976a, 1981; Smith 1976a; Nelson 1973). The change from shifting to permanent cultivation invariably involves the use of either organic or inorganic fertilization; a move from communal to private land ownership; and higher labor inputs, particularly into weeding.

Efforts to introduce cereals as a substitute for the traditional root crops have foundered in many cases. Smith documented the superiority of manioc over rice production among Transamazon farmers in three communities (1977, 1978). Under conditions of minimal inputs, root crops are better adapted to conditions of low fertility, acid pH, and pest infestation (Moran 1973, 1976a). Their growth pattern also tends to shadow out sun-loving weeds and reduces their competition. Use of vigorous tropical legumes to increase the organic matter of soils has been tested and found to work well. Mulching and minimum tillage (i.e., tilling the row only and mulching the rest) can be integral parts of tropical agriculture since they decrease soil temperature, conserve moisture, prevent erosion, and reincorporate nutrients to the soil.

As production systems, tree crops have a long history in the humid tropics; thus perennial crops such as rubber, coconuts, Brazil nuts, guaraná, black pepper, cacao, and oil palm have been proposed as an ideal solution to the problems of coping with low fertility soils and potential loss of humus in the topsoil. Improvements have been made in recent decades by combining groundcover legumes with the tree crops so as to improve the nitrogen condition of the soils. By creating mixed rather than monocrop plantations, the problems of pest or pathogen devastation may be reduced significantly (Sioli 1973).[23] The major problems of perennial crops are economic and social. Demand for these products is relatively inelastic, unless they include basic commodities such as cooking oil. Socially, plantations are associated with colonialism and/or extractivism. Large holdings have been associated in many cases with economic exploitation and dependency-creating environments that disenfranchise workers from the managerial skills required for economic independence.

Plantation forestry is touted as another panacea for the creation of sustained yield systems (SUDAM 1974). Few cases exist to support this hope. The world demand for paper has created an interest in the forestry potential of the Amazon.[24] So far most efforts have substituted native vegetation with exotics such as *Gmelina* or *Pinus* spp., well-known for their growth rates. Plantation forests can be up to twenty times as productive as native forests (Goodland 1980). However, as with perennial crops, management is best directed by large operators using wage-laborers. The Jari plantation in Brazil has about one hundred thousand hectares planted and employs about thirteen thousand workers (Goodland 1980, p. 17). Surprisingly, there have been few attacks from pests and pathogens to date although it is well-known that the corporation employed some of the best talent in forestry to set up its operations. Whether operations at a smaller scale can be as successful remains to be demonstrated.

The Amazon's contribution to human society need not come only in the form of food and fiber: aluminum, manganese, tin, iron, kaolin, gold, and diamonds are among the minerals that offer a potentially important source of revenues for Brazil and Brazilians. Goodland (1980) believes that environmental precautions are being integrated into mining projects in Amazonia, making this an attractive alternative to resource use. The bauxite project on the Trombetas River contains an estimated six hundred million tons of high grade ore extractable by opencase mining from a relatively small area of 72 hectares per year. The iron ore deposits at Serra dos Carajás contain an estimated 15.7 thousand million tons of high grade ore. Unlike the bauxite, which will leave the Amazon by boat, the iron ore will go to port via a 876 km railroad specially constructed for the purpose. Although Goodland feels that such projects are more desirable than agropastoral projects on environmental grounds, there is little doubt that all these projects can be operated best by large-scale national and multinational corporations. They will tend to follow a capital-intensive rather than labor-intensive approach, and, in the isolated condition of the Amazon, will create modern versions of company towns with little room for competition and mobility. The Jari project has a town on the opposite shore of the river due to the prohibition by the company, Bulk Carriers, against individual entrepreneurs operating within the landholdings of the corporation. Davis (1977) has shown the potentially devastating consequences of opening up the Amazon to multinationals in alliance with national elites. The rights of Brazilian Indians and peasants alike are generally ignored by these powerful groups (Davis and Matthews 1976).

CONCLUSION

Latin American nations have always looked to the Amazon as a land of great promise and as a basis to justify their aspirations to greatness. The lush forest was intepreted to be filled with vast wealth—first as the legendary El Dorado, later as a land of great fertility, more recently as a land capable of absorbing the unemployed laborers teeming in the crowded cities and holding forestry, mining, and cattle potential. Some still consider it capable of making a contribution to the world food supply, although this hope has been mellowed by the results of recent research. Others have looked to it as an area capable of adding an important element to national economic growth goals: Peru and Ecuador have found petroleum in the Amazonian lowlands; Brazil has found minerals and enormous hydroelectric potential. For the individual Latin American, the Amazon offers the last hope of owning land and achieving the aspirations of independence, security, and, possibly, wealth. The current state of research would suggest that there are some serious conflicts among these various goals.

Only about 30 percent of the Amazon Basin is of sufficient soil fertility to justify establishing agricultural production of annual crops. This area does not occur in well-defined homogeneous regions but is patchy and dispersed throughout the basin (Moran 1981). Such areas cannot be identified by sideways-looking radar nor by Landstat satellite images. Large-scale maps betray the variation that exists on the ground and cannot be used for land-use planning without a high probability of error (Moran 1981, Wambecke 1978, Ranzani 1978, Furley 1979). The only sensible strategy for agricultural development of the Amazon Basin would appear to be a slow and systematic sampling of areas with a view to identifying the most appropriate location for potential projects.

It would seem that more information is still needed before nations with Amazonian territories embark on projects on the scale of the Transamazon Highway, or the vast plantations, cattle ranches, and mining enterprises that are being initiated (Sternberg 1973, Meggers 1971). The planning process appears to precede rather than follow the availability of information on the options and potential impact of various activities; governments appear to brush aside the established use of feasibility studies for a mixture of geopolitical, economic, social, and political reasons. Without clear evaluations of the impact of Amazonian development interventions, nations may be giving away what they are trying to protect. An example of how this can happen is the subsidization of Venezuelan communities bordering Brazil. The high levels of subsidy in the form of wages was meant to make it attractive to settle in these communities and guarantee the presence of Venezuelans along the frontier. What has, in fact, happened is that after a short period in these towns, Venezuelans proceed to larger cities and eventually to Caracas. The subsidization of frontier communities has in fact depopulated the Venezuelan Amazon and created a vacuum into which the Brazilians are moving (Moran, n.d.).

At least for the next decade, the Amazonian forest should probably be protected from large-scale deforestation. Researchers from all over the world have now achieved a sufficient critical mass to be able to generate policy-relevant research; for instance, Mahar (1979) has shown the exorbitant and wasteful costs over the past decade of promoting cattle ranching by tax incentives. The social and economic cost of promoting production systems incapable of sustained yields cannot be borne by any nation, whether developing or developed. Mining projects appear to present fewer environmental problems, but the social impact of this type of economic unit needs to be studied carefully. In the past, plantations were the only areas in the Amazon where malnutrition was noted; it would be a sad commentary if to protect the environment systems of resource use associated with malnourishment were promoted. The choice of crop for plantations has been generally unimaginative, which may explain partially the inelastic nature of demand for such crops. The Amazon is full of exotic plants that might receive national and international attention if proper integration between marketing and production was achieved. Promotion of these exotic tree fruits would also permit the maintenance of diversified tree agriculture with all its advantages in terms of crop protection, soil cover, and better use of labor on a year-round basis.

There has been a serious gap between good intentions and execution; there has been more patriotic spirit than adequate knowledge in the current thrust to conquer the Amazon. These gaps have given authors reason to predict the conversion of this "green hell" or "counterfeit paradise" into a "red desert" (Meggers 1971, Goodland and Irwin 1975). The effect of these dire forecasts has been to attract worldwide interest and stimulate scientific investigations.

This review has addressed some of the central questions that have brought together ecologists, geographers, anthropologists, and agronomists. Fear of ecologically irreversible damage, loss of species not yet known, ethnic decimation of aboriginal peoples due to contact and disease, and conflict over the available resources in the frontier areas are among the relevant concerns of biological and social scientists. After a decade of uncontrolled development activities, Brazil has begun to assess what it has cost and to heed the advice of those who have questioned the wisdom of development-at-any-cost. In June 1978, Brazil signed a treaty with the other seven countries with Amazonian territories (Medina 1979) that aims at promoting cooperation in the provision of health services, telecommunications, tourism, river traffic, frontier trade, and scientific knowledge about conservation and development of the region; 1979 was declared the Year of the Amazon in Brazil and the whole nation was invited to help formulate a new policy for the Amazon.

Brazil enters the 1980s having paid a costly price for its recent Amazonian ventures: much forest has been unprofitably cut for the benefit of a very few; the costs of highway construction were three times the projected figures—and road maintenance even higher; whereas the accomplishments of a Transamazonian Highway are undeniable, the cost of transporting goods across distances of three to five thousand kilometers at current gasoline prices reduces the benefits of lower labor costs; industrial development in Manaus benefitted the city but not the region (Mahar 1976a, 1976b). Very few of the lessons learned before the 1970s were taken into consideration as planners instituted projects that overlooked Amazonian realities. The recent policy moves toward regional cooperation, open policy forums, and reduced incentives to cattle ranches and clear cutting of forests provides guarded optimism that the gap between research and policy can be bridged. In the balance hangs the future of an exquisitely complex environment and of millions of people who can benefit from its continued existence.

NOTES

1. Considerable confusion exists among the terms used to describe the Amazon, and they are not interchangeable. The term "Amazon Basin" refers to the drainage area of the Amazon River and its affluents. "Amazonia" refers to the extensive lowlands bounded by the Guiana shield, the Brazilian shield, and the Andean chain compris-

ing an area substantially larger than the Amazon Basin proper (cf. Meggers 1971; Denevan 1976, p. 205). The term "Amazonia Legal" is used in contemporary Brazil to refer to the area within which the Superintendencia do Desenvolvimento da Amazônia (SUDAM) acts, and includes large areas of the central plateau. The term "Amazon" refers to the river itself in most cases. In using the term Amazon in this review, I will usually mean the drainage area covered mostly by tropical rain or moist forest.

2. The tax-incentive program was established in 1966, under Law No. 5.174, following the reorganization of the Superintendência do Plano de Valorização Económica da Amazônia into SUDAM. Likewise, limited multinational operations began as early as 1957 in Amapá, associated with the exploitation and exportation of manganese. After 1971, however, the pace of investment increased rapidly. Details of the evolution of Brazilian policy toward the Amazon is discussed in Moran (1981).

3. As the emphasis given in the paragraph would suggest, this review will focus on the Brazilian experience. A full complement of institutions in Hispanic America are also engaged in Amazonian studies: Instituto Venezolano de Investigaciones Científicas in Venezuela, Centro de Investigaciones para la Amazonia in Peru, Instituto de Colonización y Reforma Agraria de Ecuador in Ecuador, and Instituto Codazzi in Colombia, to name only the most visible ones. I will emphasize the Brazilian research effort because of its larger scope and the Brazilians' dominance over most of the region.

4. I wish to thank the organizers of the University of Cambridge (UK) conference for inviting me to participate. The stimulus from that conference, in no small part, led me to write this review. I also wish to thank the Indiana University Overseas Conference Fund that made the trip to Cambridge possible. My earlier work in the Amazon was supported by SSRC, NIMH, Fulbright-Hays, and Tropical South America Program (University of Florida) fellowships and grants. None of the above organizations should be held responsible for the views expressed herein. I also wish to thank Carl Jordan, Ernesto Medina, Rafael Herrera, Haydee Seijas and others connected with the MAB/UNESCO Rain Forest Ecosystem study at San Carlos de Rio Negro, Venezuela. I have benefitted from my association with these scholars and their openness to anthropological inputs into their ecosystem research.

5. This review is perforce selective and relies heavily on the literature published in English, Spanish, and Portuguese; the French and German literature is not thoroughly covered, although authors from these countries are cited whenever their research has been part of international conferences on the Amazon. Readers may wish to pay particular note to the recent conference volume published by the Swiss Ethnological Society, which is the result of a cooperative program between the Centre National de la Recherche Scientifique de France and the Fonds National Swisse de la Recherche Scientifique (Centlivres et al. 1975).

6. The major compilation of knowledge on rain forests is found in UNESCO (1978). The collected articles in Meggers et al. (1973) have an excellent coverage of data on floral and faunal aspects of tropical rain forests of Africa and South America. Numerous articles in the journals *Biotropica*, *Amazoniana*, and *Acta Amazonica* treat plant/animal interactions with occasional discussions of human populations. The classic work is still Richards (1952).

7. Biomass measurements are still relatively scarce and have been conducted in areas of less than 0.25 hectares (Fittkau and Klinge 1973, Klinge 1978). Since biomass measurements are strongly correlated with uncorrected volumes, biomass variability is great; two hundred to five hundred tons per hectare have been estimated. At this time one can cite only biomass for specific areas without any confidence as to its general representativeness (UNESCO 1978, p. 128).

8. The precise impact of the removal of forests as vast as the Amazon's on large-scale atmospheric circulation is simply not known. Water vapor transport patterns, horizontal heat and momentum transport, and convergence/divergence of all these transport systems might be expected to change with reductions in forest cover and reduced rates of evapotranspiration, but there is a lack of data on upper air flows over tropical continents. The need for studies of atmospheric circulation are critically needed as the process of deforestation gets underway (Newell 1971, Molion 1976). I have omitted reviewing the extensive research on limnology and geomorphology car-

ried out predominantly by German and North American scientists. Sternberg (1975) has reviewed the state of knowledge on the Amazon river's geomorphology. *Acta Amazonica* (published by the Manaus-based National Institute of Amazonian Research) and *Amazoniana* (published by the Max Planck Institute in Plön, W. Germany) regularly publish such materials that are really beyond the scope of this review.

9. In a radioactive isotope study, 99.9 percent of the phosphorus and calcium moved from leaves to roots without contacting the mineral soil (Stark and Jordan 1978).
10. It is difficult to judge the age of the trees since annual rings are not present, but estimates put them at 150 to 250 years. Much of the vegetation lacks deep roots and the trees achieve support by developing plank buttresses which reach as high as 9 m up the tree. The presence of these buttresses has led to the nearly universal use among indigenous peoples of platforms in order to cut the giant trees above the planks. It should be noted that the Amazon rain forest contains fewer large trees and fewer buttressed trees than the forests of Africa.
11. The literature before the 1930s treated the Amazon as a broad habitat type across which homogeneous populations could move, transferring their knowledge and systems of production with ease and familiarity. This level of generality was reduced somewhat when scholars began to make use of the distinction between the upland (*terra firme*) and the floodplain (*varzea*) habitats (Sioli 1951; Wagley 1953; Sternberg 1956; Denevan 1966; Lathrap 1968, 1970; Meggers 1971). Unlike the homogeneous descriptions of the tropical forest and its culture, this distinction helped make it clear that populations along the floodplain had achieved higher population densities, larger and relatively permanent settlements, and greater control over neighboring groups than did terra firme groups. However, the rapid depopulation of the varzea by warfare and disease after 1492 has made the study of such populations impossible. It is only recently that attention has begun to be given to the heterogeneity of the Amazon and the presence of many more habitats than the simple terra firme/varzea distinction.
12. In English, "upland forests" have often served to identify everything beyond the varzea. Denevan's and my usage differ from such broad usage. Montaña is a term commonly used to refer to the high forests of eastern Peru. The equivalent term in Bolivia is the "yungas" and "oriente" in Ecuador. I thank one of the manuscript reviewers for making this clarification.
13. Baker (1970) reviews the theories that attempt to explain evolutionary rates.
14. Eisenberg and Thorington (1973) give a considerably higher estimate based upon their research in Barro Colorado, Panama. However, the island is protected and probably represents unusual conditions.
15. Among the Siona-Secoya inhabiting an upland forest area of Ecuador, even the least successful hunter managed a mean of 13.08 kg of butchered meat per hunt—with an average for all hunters of 21.35 kgs. This translated into 80.7 grams of protein per person per day, an amount well above protein needs. Even in the area inhabited for thirty-two years continuously, the mean kill was 5.67 kgs per hunter (Vickers 1975, 1976, 1979). Chagnon and Hames (1979) show that the Yanomamo and the Yecuana obtain a more than sufficient amount of animal protein. The mean consumption per adult was 88 grams of protein per day, an amount higher than in many contemporary developed societies. Of course, even if the hunters are successful, given the nocturnal habits of much of the game, the high canopy habits of most of the birds and monkeys, and the aggressiveness of the peccaries, it is not surprising to see a great deal of cultural attention given to hunter/animal relations. Of all the subsistence activities, hunting is the least secure of all. In addition, many aboriginal populations practiced entomophagy (insect-eating) and thereby obtained a rich and abundant source of protein (Ruddle 1973).
16. Kiltie (1980) has pointed out that white-lipped peccaries are of uncertain availability but almost never tabooed—unlike tapir and deer. Ross has responded by noting the herd behavior of white-lippeds which makes them "movable feasts," unlike the more isolated behavior of deer and tapir.
17. Recent evidence suggests that complex cultures with high population densities based

on the cultivation of corn and beans existed in pre-Columbian times along the floodplain's rich alluvial land (Roosevelt 1980).

18. Smith (1974a; 1979) and Mittermeier (1975) have shown the devastating effect of Portuguese demand for turtle oil on the giant river turtle, now near extinction. The demand for alligator skins also led to the wholesale slaughter of these animals; because of the scale of operations only the skins were used, the rest was wasted.
19. This review of the colonization literature will be briefer than might be expected since T. Lynn Smith (1969) wrote an excellent overview of colonization (directed and semidirected) and settlement (spontaneous) in this journal. I will simply update and focus on Amazonian colonization.
20. Obviously these two types represent ideal extremes. Most often they represent a mix of government intervention and of colonist responses. Anderson (1976) deals with colonization in the 1758 to 1930 period in Pará and, together with Sweet (1974), is among the few recent historical studies available on the Amazon.
21. Readers will want to consult the review of earlier colonization efforts in the Brazilian Amazon in Tavares et al. (1972), Staniford (1973) and Moran (1975b).
22. In fact, I have shown that interest climbed from 7 percent per annum to 50 percent when costs incurred from labor lost in getting credit during the critical harvest period was accounted for (Moran 1975a, 1976a). Bunker's (1978) data for another area confirmed these findings.
23. The fungus *Cripinellis perniciosa* of cocoa, the *Fusarium* wilt of black pepper, and the leaf blight *Dothidella ulei* of rubber have in the past devastated well-established plantations. Whereas resistant varieties now exist, new pathogens are likely to emerge.
24. In 1979 Brazil took in $180 million from exports of 600,000 tons of pulp, twice their earnings from the previous year (*The Economist*, 13 May 1980, p. 96).

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