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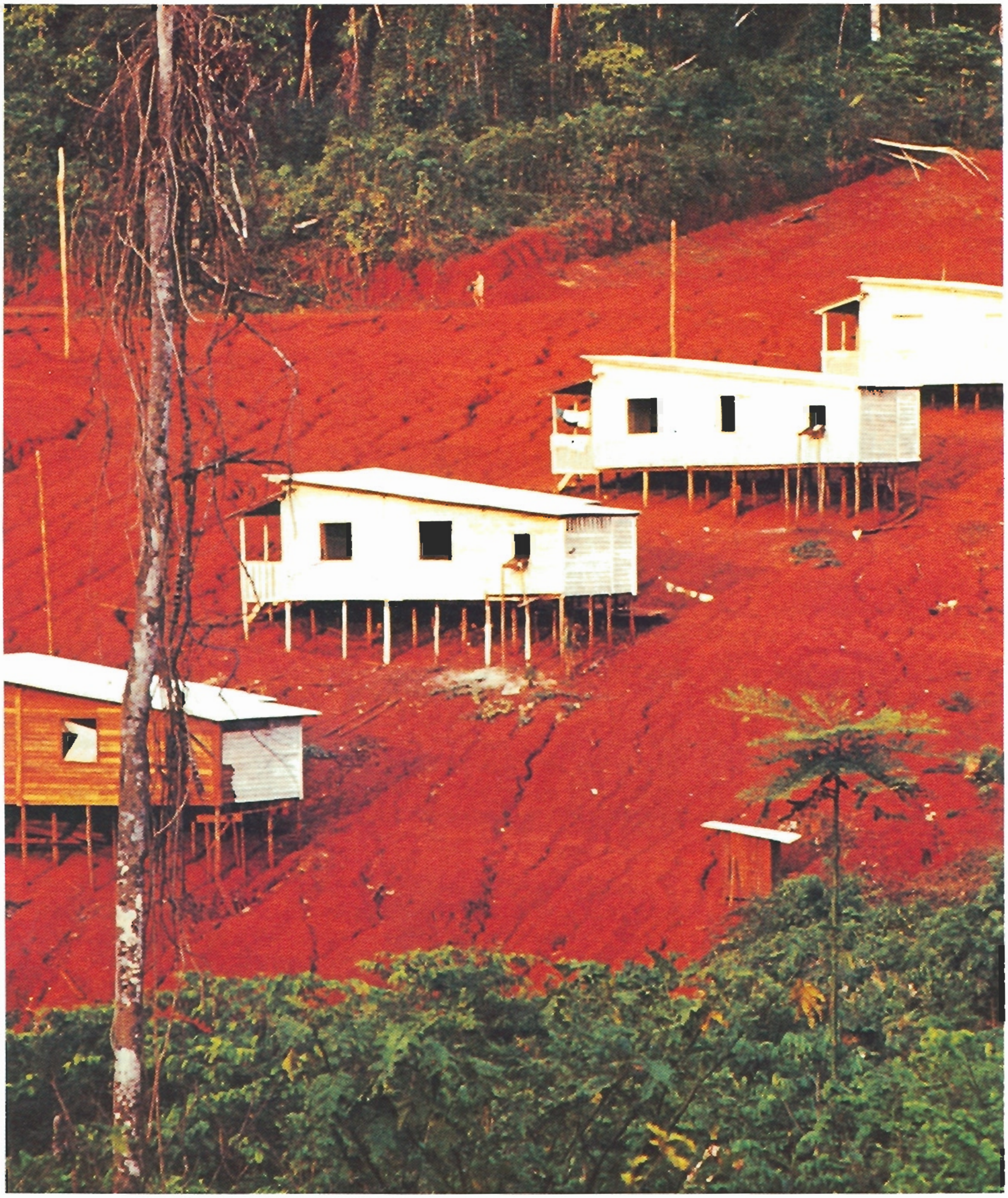

**COVER**

Severe soil erosion in a community along Brazil's Transamazon Highway. Because of the broken terrain and torrential rainfall, soil erosion is a major constraint on the agricultural development of the colonization scheme. Note the bright red earth which is derived from weathered basalt. See page 755. [Nigel J. H. Smith, University of Florida, Gainesville 32611]

# Colonization Lessons from a Tropical Forest

Nigel J. H. Smith

*Summary.* The decade-old Transamazon Highway provides a useful stage for examining some of the major issues related to frontier conquest and the impact of pioneer settlement on one of the world's richest biomes. The highway project is an ambitious colonization scheme and the lessons that can be drawn from it, ranging from the environmental effects of stripping back the tree cover to the spread of diseases, will be useful in guiding development policy in other tropical regions.

In 1970, the Brazilian government announced plans to integrate the Amazon region with the rest of the country. The forest-clad region was to be crisscrossed by a web of pioneer roads with the east-west Transamazon Highway serving as the backbone for the system. The 3300-kilometer Transamazon slices across the forest blanketing the southern interfluves of Amazonia, starting in Estreito on the Tocantins River and finishing in Cruzeiro do Sul near the Peruvian border (Fig. 1). The entire road was opened with bulldozers by 1975. Plans called for settling 1 million families on 100-hectare farms along the highway by 1980.

The Transamazon Highway was designed to accomplish three main goals. First, this two-lane dirt road would provide a safety valve for the poverty-stricken Northeast, a region with 30 million inhabitants increasing by 1 million a year. The 1970 drought that seared the backlands of the region and uprooted some 3 million people triggered the government's decision to build the Transamazon. Second, the highway would help fill a demographic void in a region occupying half of Brazil's territory but containing only 4 percent of the nation's population. The Brazilian government was reluctant to leave such an immense space vulnerable to the covetous eyes of foreign concerns, and saw the Transamazon Highway as placing an indelible stamp of sovereignty on a land surrounded by an ever-increasing population and experiencing a growing scarcity of natural resources. Finally, the highway would create access to mineral and timber reserves that would fuel the country's spectacular 10 percent annual economic growth.

The Transamazon scheme has largely failed on all three counts. With the colonization phase of the highway now completed, only 8000 families have been settled by INCRA (Instituto Nacional de Colonização e Reforma Agrária), the federal agency responsible for administering the project. Even allowing for the estimated 1600 families that have settled spontaneously at the end of side roads and in forest reserves, the highway scheme has clearly not even come close to achieving the colonization target.

Although three-quarters of the colonists were supposed to be northeasterners, only 40 percent of the settlers have come from that parched region. The humid valleys of the Transamazon have accommodated 23,000 *nordestinos*, but since the highway was built, the population of the Northeast has grown by 6 million. The Transamazon has thus absorbed less than 1 percent of the region's population growth. The failure of the highway to relieve the demographic pressures and social strife in the North-

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east was highlighted in 1980 when drought once again struck the region. This time, the lives of 9 million people were disrupted, resulting in food riots in several towns of Paraíba (1). The drought has continued into 1981 and the incidence of ransacking stores for food has spread to other states.

A major objective of the highway scheme, that of unlocking resources, has only been partly realized. Neither lumber nor mineral operations provide significant income for the Transamazon settlers. Only eight sawmills operate along the highway, and all are small. The most commercially important woods, such as mahogany (*Swietenia macrophylla*) and cedar (*Cedrela odorata*), have been mostly cleared within a 15-km zone on either side of the highway. The high cost of transport fuel, and the enormous distances between sawmills, preclude the large-scale exploitation of other, less valuable tree species.

The highway has not led to the discovery of any sizable mineral deposits. Only one company, Mineração Taboca, extracts minerals along the Transamazon. The company has built a side road leading south from the Humaitá-Prainha stretch of the Transamazon to take out tin ore. The 1978 production from the mines totaled 1900 metric tons, representing a quarter of Amazonia's reported tin ore production for that year. The ore is trucked to São Paulo in the industrial heartland of Brazil. Mining activity thus occurs only along a short stretch of the Transamazon.

The sluggish colonization rate and disappointing economic performance of the scheme triggered a major policy shift in the Brazilian government (2). With the demise of a large number of the 100-ha homesteads, planners rethought their strategy for developing the Amazon with family-sized units. In 1973, the highway was opened for large-scale entrepreneurs, principally cattle ranchers. Plot sizes ranging from 500 to 66,000 ha were made available for wealthy individuals and for companies. These vast parcels of land, set further back from the highway than the 100-ha lots, are now being cleared. They total 2.7 million hectares, three and a half times the area zoned for small farms. In order to better assess the viability of the smallholder in the agricultural development of Amazonia, the major ecological, cultural, and institutional factors that have retarded the progress of settlement along the Transamazon need to be highlighted.

## The Ecological Setting

It is no accident that, historically, people have settled mostly along the margins of rivers in Amazonia (3). Silt-laden rivers, such as the Amazon, create generous floodplains with fertile soils, abundant fish, and the convenience of cheap water transportation. In contrast, the interfluvial forests of the basin generally mask poor soils, leached by millions of years of torrential rainfall. The Transamazon Highway was clearly not designed

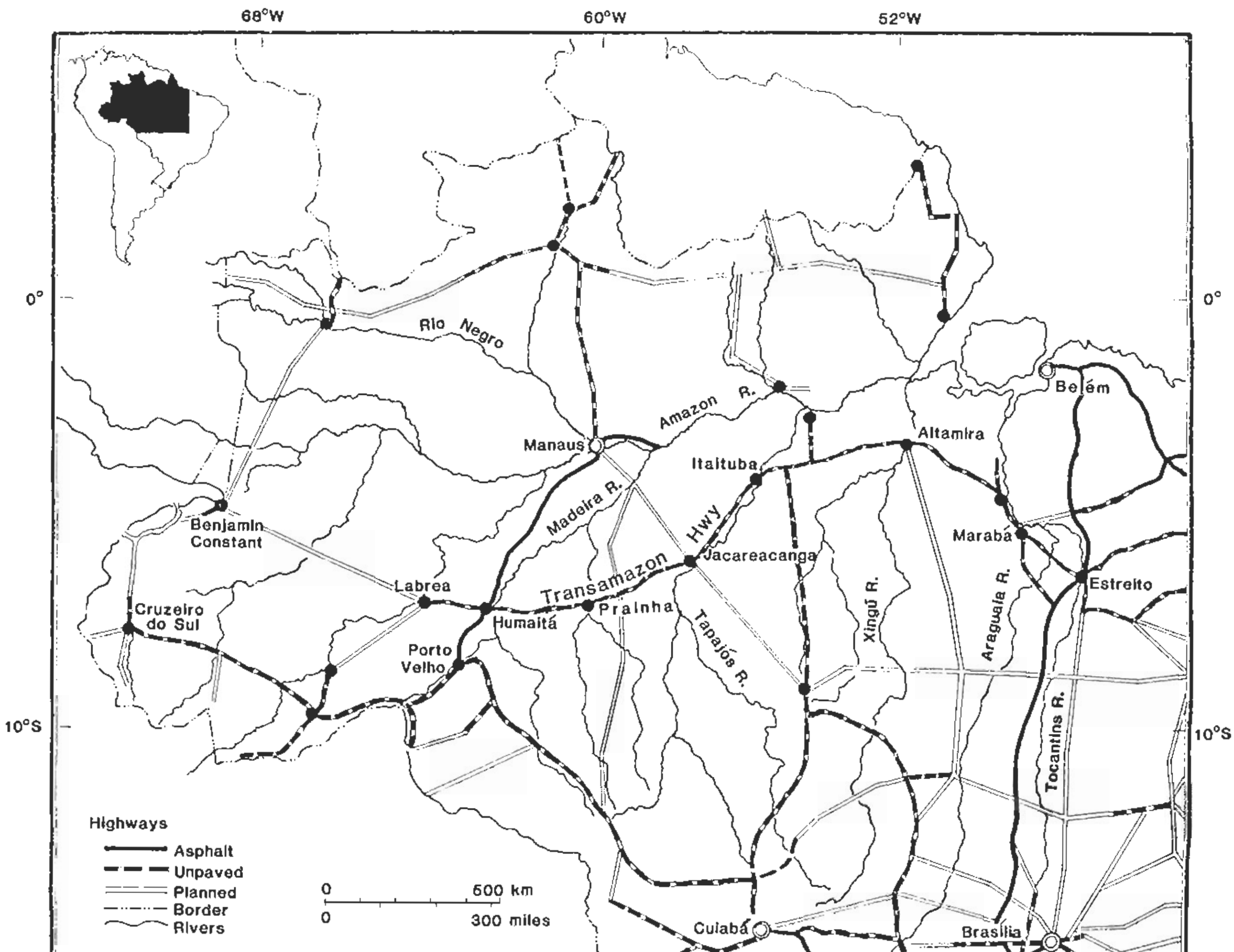


Fig. 1. The Brazilian Amazon highway network.

to provide access to the better soils of the region.

The highway transect vividly reveals this unfavorable base for agricultural colonization. Although soils vary considerably in texture, color, and drainage characteristics, most of them share one unfortunate quality: they contain few exchangeable bases. Oxisols and ultisols, which account for 80 percent of the earth along the Transamazon, are strongly acid with a low cation exchange capacity and high levels of toxic aluminum. Only 3 percent of the soils in the vicinity of the highway can be classified as naturally fertile; they are dominated by *terra roxa*, red clays derived from weathered basalt (*4*). Fertilizer prices are exceptionally high in Amazonia because the product must be imported from other regions. Consequently, farmers rely largely on nutrients that are captured in plants and released when the vegetation is burned in field preparation.

Fig. 2. Repairing the Transamazon Highway after the 1974 rainy season.

The thin layer of ash left on the ground after the annual burning is vulnerable to erosion and rapid leaching. Storms can be intense. In the Marabá area of the Transamazon, for example, 16 centimeters of rain fell within a few hours in February 1974. The onset of heavy rains coincides with the planting season when garden plots are bare and the soil surface is exposed. Up to 100 tons of topsoil per hectare can be lost within a year on 15° slopes planted to annual crops (*5*). The severe loss of topsoil recorded from some fields along the Transamazon is not unusual in the humid tropics. In a region near Ibadan in Nigeria, where the climate is similar to that of the Transamazon region, soil erosion on cleared 15° slopes has attained 120 tons per hectare annually (*6*).

The idea has been advanced that soil erosion in the tropics is not always detrimental to agricultural productivity. By stripping the highly leached mantle, it is argued, plant roots can penetrate closer to the weathering zone in the subsoil where nutrients are being liberated (*7*). But in the case of the Transamazon and other parts of the Amazon Basin, soil erosion clearly drains the nutrient reserves of the soils since most of the fertility is concentrated in the top 5 cm of soil (*8*).

Erosion of roads is at least as serious as topsoil losses in Transamazon fields. From jet-cruising altitude, the Amazon forest appears to be growing on a monotonously flat plain. But the canopy conceals a generally crumpled topography. The relief of the Precambrian Brazilian shield, where close to half of the Transamazon colonists have settled, varies from sharply to moderately undulating. Extremes of relief from trough to hillcrest attain 40 meters within 0.5 km in some areas. Relatively flat plateaus and terraces, generally rimmed by a protective edge of plinthite, are occasionally encountered along the Transamazon, particularly along the Estreito-Araguaia stretch of the highway, but most of the highway transect is a seemingly endless sea of hills. During the rainy season, some sections of the highway are cut by lateral erosion which must be repaired during the dry season (Fig. 2). Many of the side roads are cut off entirely for several months. Harvested rice, the principal cash crop along the highway, frequently rots in fields because the grain cannot be removed and sent to driers.

The broken terrain slows traffic and boosts transportation costs. Trucks and buses cannot climb certain rain-soaked hills, and tractors have to pull the vehicles over the crests. Accidents due to the slippery road surface are frequent. Highway engineers employ certain formulas to decide which roads warrant a hard surface, but their calculations need to be tailored to local conditions. In the case of Amazonia, the undulating topography and heavy rainfall probably justify asphalting major highways at the outset.

## Agricultural Yields

A major factor in the slowdown of the colonization rate has been the disappointing agricultural yields. Poor soils and erosion have already been mentioned as two important constraints to agricultural productivity. But a host of other ecological and sociological factors have led to low crop yields.

A poor selection of crops by planners is partly responsible for the generally depressed crop performance along the Transamazon. INCRA envisaged upland rice (*Oryza sativa*) as the main cash and subsistence crop for Transamazon colonists. Favored by fiscal incentives, rice accounted for 30 percent of the 1978 income of 155 settlers sampled by the author. But heavy dependence on one crop for food and cash income is a risky policy, particularly in the tropics where weeds and pests proliferate all year. Most Transamazon farmers cannot afford to buy insecticides, fungicides, or herbicides.

Rice yields along the Transamazon average only 1593 ± 679 kilograms per hectare (mean ± standard deviation, $N = 97$). A typical farmer plants 8 ha of the cereal every year, but only grosses about $1900 from the sale of the crop, a meager income if one considers the inflated prices of manufactured goods and wages that must be paid to laborers. One of the reasons that rice yields are so low is that inappropriate varieties have been promoted by INCRA and EMATER (Empresa de Assistência Técnica e Extensão Rural), the agricultural extension service. The most commonly planted variety, IAC 101, was developed in Campinas in southern Brazil, barely within the tropics. The IAC 101 strain is unsuited to the climatic conditions of the Amazon Basin because the long stems lodge during storms at harvest time. A flattened crop takes longer to harvest, rots in contact with the humid earth, and is

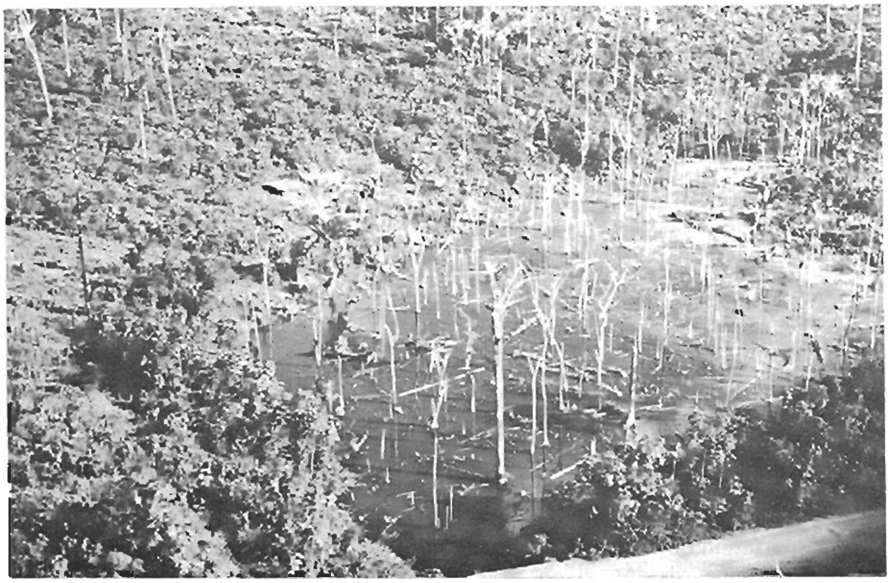

Fig. 3. A stream that was dammed by the Transamazon Highway.

eaten by rats and ground doves (*Columbina talpacoti*). For the 1973 planting season, INCRA distributed *barbalha*, a rice variety from the northeastern state of Pernambuco. *Barbalha* yields were well below expectations, averaging only 445 kg/ha (*9*). In an effort to introduce more advanced agricultural techniques, planners overlooked local varieties of rice traditionally used by peasants.

Manioc (*Manihot esculenta*), a basic staple of the Amazon region, was relegated to a minor role in the agricultural strategy of the colonization project. The root crop was perceived as a primitive cultivar with little economic potential. Nevertheless, manioc has several crucial advantages over rice as a catalyst for agricultural development, especially during the start-up phase of a settlement scheme in Amazonia.

The myth that manioc is an economically unattractive crop has been dispelled by the Transamazon experience. On first-year plots, yields of the root crop easily attain 20 tons per hectare, in part because of the light pest damage (*10*). Most of the crop is converted to flour for domestic consumption and sale. An average of $3.3 \pm 0.4$ kg ($N = 4$) of tubers is required to make 1 kg of flour, so 1 ha of manioc can easily yield 4240 kg of flour. A family of six can comfortably harvest 3 ha of the tubers within a year and earn $3000 from the sale of flour. Although the relative financial advantage of manioc cultivation will vary according to such factors as market conditions and variety planted, in most cases cropping the tuber is more profitable than rice cultivation.

Manioc enjoys several other advantages over rice as a cash and subsistence crop in the uplands (*terra firme*) of Amazonia. Since the roots can be harvested from 6 months to 3 years after planting, farmers do not compete with each other for labor or machinery at harvest time, as in the case of rice. Rather, manioc cultivation fosters mutual assistance, because neighboring families often help each other to process the crop. The roots can stay in the ground until roads are passable, and the flour can be stored for months with little deterioration. Finally, the tubers are a far more productive and reliable source of carbohydrates, providing three times more calories per hectare than rice.

What crops are planted is determined largely by bank policy. Farmers can obtain bank loans, arranged through EMATER, to plant rice, but not for manioc or other root crops. Most of the colonists are poor, so they depend heavily on loan installments to purchase equipment and to hire workers.

The credit system operating along the highway has worked against the interest of settlers in other ways. The processing of loans takes considerable time and farmers must make several financially onerous trips to town to expedite paper work and to pick up installments (*11*). Sometimes a loan payment is released after the dry season has begun and when newly planted crops will wither. Furthermore, the state-owned Bank of Brazil provides more generous loans for farmers willing to grow crops in fields cleared from mature forest since yields are usually higher than in garden plots opened in second growth. Consequently, the bank policy encourages a wasteful destruction of forest; settlers often clear far more space than they can use.

As a long-term solution to the cash crop problem, EMATER and INCRA have encouraged the planting of perennial crops. A perennial vegetative cover is far preferable to annual cropping for most of the *terra firme* of Amazonia (*12*). Pepper (*Piper nigrum*), bananas (*Musa* spp.), cacao (*Theobroma cacao*), and cattle pasture have been especially promoted along the Transamazon. Although these crops provide better soil cover than annuals, in most situations they still require fertilization to maintain productivity over the long term. Costs of maintaining yields of the perennial crops are likely to increase because of a buildup of pests and plant diseases.

The Transamazon was envisaged as a fresh beginning for tropical crops. For the most part, the highway slices through wilderness containing few species-specific crop pests and diseases. But it did not take long for fungi and agricultural insect pests to disperse along the corridor of disturbance created by the highway. By 1975, for example, a disease caused by the fungus *Fusarium solanum piperi*, resistant to chemical control, was severely damaging pepper plantations along the Transamazon (*13*). The fungus probably penetrated the colonization zone with infected cuttings or stakes. The useful life of a pepper plantation has been reduced from an expected 15 years to an average of 7 years, and now the crop is marginally profitable.

Banana growers have also felt the destructive impact of introduced plant diseases. Initially, bananas were produced in abundance along the highway, and much of the crop during the first few years of settlement rotted on the ground because the local markets were too small to absorb the output. After 1974, the prospects for banana growers along the Transamazon improved markedly when the Belém-Brasília highway was paved. Truckers were able to buy bananas from Transamazon colonists and transport the fruits to markets in Belo Horizonte, Rio de Janeiro, and São Paulo before they spoiled. As marketing opportunities improved for banana growers along the highway, disease struck. Several fungi, especially species of *Fusarium*, now severely attack banana groves, often before a lucrative harvest can be cut.

Although most of the agricultural pests and diseases have seemingly spread along the Transamazon Highway in the wake of settlement, some crop damage undoubtedly occurs from insects that were already present in the forest before the highway was built and from insects and other potentially damaging organisms that flourish in light gaps created by tree falls. Some crops are at risk because their wild relatives in the forest act as reservoirs of disease; for example, cupuaçu (*Theobroma grandiflorum*) and cacau bravo (*Theobroma speciosum*) are hosts of witches'-broom (*Crinipella perniciosa*), a debilitating fungal disease of cacao.

As of 1979 some 6000 ha of cacao have been planted along the Transamazon, and plans call for increasing the area under the crop to 40,000 ha by 1985 (*14*). The Amazon region is slated to play a key role in propelling Brazil into the leading position as a supplier of chocolate beans on the world market. But witches'-broom and black pod (*Phytophthora palmivora*) are poised to disperse rapidly through cacao groves along the Transamazon and other areas of the Amazon Basin.

**Public Health Problems**

Diseases in humans have also played an important role in depressing agricultural yields. As in the case of crop diseases, the forest serves as a pool for some pathogens potentially transmissible to settlers. The forest shelters parasites and vectors, and human modification of the landscape favors disease transmission. However, the most important public health problems have been introduced by colonists.

The popular image of the rain forest teeming with tropical diseases that enervate settlers has not proved to be the case along the Transamazon. Few of the zoonoses in the forest have actually infected settlers. As of 1977, for example, only two cases of yellow fever had been confirmed along the Transamazon, one of them fatal (*15*). Even though yellow fever is endemic in certain monkey species in the Amazon region, less than half of the settlers along the Transamazon have been vaccinated against the virus. One reason that the disease rarely infects colonists is that the forest is cleared during the dry season when populations of the canopy vectors are probably at their lowest.

Table 1. Patients from the Transamazon Highway region admitted to the public hospitals of Altamira and Marabá in 1973. The sample did not include maternity cases or patients from Altamira and Marabá. The highway population served by the hospitals during 1973 is estimated at 31,300 (*16*).

| Disease or injury | Cases | | |
|---|---|---|---|
| | Number | Percent | Deaths |
| Malaria | 1285 | 53 | 26 |
| Gastrointestinal | 218 | 9 | 32 |
| Injury | 200 | 8 | 8 |
| Respiratory | 199 | 8 | 13 |
| Miscellaneous | 135 | 6 | 6 |
| Helminthiasis | 87 | 4 | |
| Genital | 57 | 2 | |
| Liver | 55 | 2 | 6 |
| Hemorrhagic syndrome | 52 | 2 | 2 |
| Malnutrition | 31 | 1 | |
| Measles | 29 | 1 | 1 |
| Hernia | 27 | 1 | |
| Snakebite | 21 | 1 | |
| Kidney | 19 | 1 | 1 |
| Cardiovascular | 17 | 1 | 3 |
| Scorpion sting | 6 | | |
| Total | 2438 | 100 | 98 |

The most serious public health problems along the Transamazon are caused by the importation of pathogens by people. For example, in any given year, from 5 to 25 percent of the highway population contracts malaria, which can debilitate a person for a month or more. In a 100 percent sample of patients from the Transamazon region admitted to the Marabá and Altamira hospitals in 1973, malaria accounted for 53 percent of the admissions, exclusive of maternity patients (Table 1). In 1978, the disease still accounted for 44 percent of admissions from the Transamazon region (Table 2) (*16, 17*).

Although much remains to be learned about the epidemiology of malaria in the Amazon Basin, it is clear that incoming settlers and migrant workers, especially from the northeastern state of Maranhão, are responsible for bringing the etiological agents *Plasmodium falciparum, P. vivax,* and *P. malariae* to the Transamazon region. No nonhuman reservoirs have been found in the wild for these parasites; however, alterations of drainage conditions have favored the buildup of potential vector populations that already existed in the forest prior to settlement.

The identity of the vector, or vectors, of malaria along the Transamazon has not been established with certainty, but *Anopheles darlingi* is the most common vector for the disease in most of the Brazilian Amazon and is implicated as a major vector along the Transamazon. The mosquito prefers partially shaded, neutral, unpolluted, and relatively still water for breeding (*18*), conditions rarely found in the rain forest where streams are generally strongly acid and heavily shaded. However, water culverts under the Transamazon were often installed above the gradients of streams crossed by the road; consequently, hundreds of water courses have backed up forming small lakes which vary in surface area from 0.5 to 10 ha (Fig. 3). The artificially created ponds allow sunlight to penetrate the water, while soil erosion from cleared banks introduces nutrients and reduces the acidity of the water, thereby creating more favorable breeding conditions for anopheline mosquitoes. Since settlers often build their homes close to the ponds they are easily exposed to malaria vectors.

Although Transamazon settlers may be infected with malaria all year round, two main peaks of transmission coincide with critical phases of the agricultural calendar. The major peak usually occurs at the beginning of the rainy season in December or January when farmers are putting in their crops. The impact of malaria at that time can be devastating; if an entire family is sick with the disease, crops cannot be planted. When planting is postponed for more than a month, yields are considerably reduced.

The second peak of malaria transmission occurs during the rice harvesting season, and when new fields are being cleared. A delay in reaping the cereal adversely affects yields because of predation. If a family is confined to the home because of malaria, the next year's garden plot cannot be cleared; when the task of cutting forest or second growth is postponed too long the slash does not have sufficient time to dry for a thorough burn. The effective planting area is thus

Table 2. Patients from the Transamazon admitted to the public hospitals of Altamira and Marabá in 1978. The sample did not include maternity cases or patients from Altamira and Marabá. The highway population served by the hospitals during 1978 is estimated at 53,300 (*16*).

| Disease or injury | Cases | | |
|---|---|---|---|
| | Number | Percent | Deaths |
| Malaria | 664 | 44 | 11 |
| Injury | 165 | 11 | 5 |
| Respiratory | 143 | 9 | 12 |
| Gastrointestinal | 132 | 9 | 19 |
| Miscellaneous | 120 | 8 | 4 |
| Genital | 52 | 3 | |
| Cardiovascular | 29 | 2 | 4 |
| Infectious hepatitis | 28 | 2 | 2 |
| Anemia | 27 | 2 | 1 |
| Poisoning | 19 | 1 | |
| Hemorrhagic syndrome | 17 | 1 | 1 |
| Scorpion sting | 15 | 1 | |
| Snakebite | 15 | 1 | 1 |
| Toxic hepatitis | 14 | 1 | |
| Malnutrition | 12 | 1 | 1 |
| Appendicitis | 11 | 1 | 1 |
| Kidney | 11 | 1 | 2 |
| Nervous disorders | 10 | 1 | |
| Helminthiasis | 10 | 1 | 1 |
| Total | 1494 | 100 | 65 |

reduced, a problem also noted in parts of Paraguay (*19*).

Malaria is likely to persist as a major public health problem along the Transamazon. Control efforts have had little success. The inside walls of buildings along the highway are sprayed with DDT every 6 months under the assumption that malaria vectors alight on walls after taking a blood meal. Whereas in several tropical countries malaria vectors have acquired a physiological resistance to insecticides (*20*), in Amazonia, vector behavior has changed in response to DDT applications. Along the recently opened Manaus–Boa Vista Highway, for example, *A. darlingi* avoids DDT-coated walls and digests blood meals outside of homes on nearby vegetation (*21*). A similar situation probably prevails along the Transamazon since malaria continues to menace public health even after a decade of DDT spraying.

Other major public health problems along the highway, such as gastroenteritis and helminthiasis, are related to poor standards of hygiene. Contaminated drinking water is a primary source of gastrointestinal disease among all age groups along the Transamazon. Less than 10 percent of the highway population has access to piped water; most people obtain their drinking water from streams, ponds, and poorly covered wells. Less than 5 percent of the Transamazon settlers use latrines on a regular basis; most of the colonists take care of physiological necessities in a nearby patch of vegetation. Although less than 1 percent of the highway settlers require hospital treatment for intestinal problems in any given year, the entire population probably suffers from some form of gastroenteritis during a 12-month period. Diarrheal diseases, as in other regions where hygiene standards are low, are a leading cause of infant mortality (*22*). Gastroenteritis was responsible for 48 and 51 percent of the hospital deaths of children under 5 years old in 1973 and 1978, respectively.

## Lessons

It is not enough to open up frontier areas with highways, divide the land into parcels, provide credit, and expect largely illiterate farmers with few capital resources to flourish. This approach has led to disappointing results in other tropical regions, such as Indonesia's outer islands (*23*). Along the Transamazon, many settlers soon fell victim to a biased and inefficient credit system, a poor selection of crops, infertile soils, and isolation from large markets (*24*). Planners need to pay closer attention to ecological factors, such as the suitability of soils and proposed cultivars. State colonization projects in Malaysia have generally been more successful than those in Amazonia, partly because the soils of settlement zones are more fertile and because there has been an emphasis on tree crops that protect the soil surface and discourage weeds (*25*).

The failure of the Transamazon scheme is also due to an inadequate screening procedure. Some colonists arrived with land speculation in mind and little or no prior experience with agriculture. The colonization scheme not only failed to absorb a significant portion of the landless in the Northeast, it did not provide a seçure environment for the few thousand families it did accept. Close to half of the Transamazon lots have been sold at least once.

It is an unwise policy to regard Amazonia as a convenient depository for the landless from other regions. In most instances the incoming settlers contribute little to the development of the Amazon Basin (*26*). On the contrary, massive forest destruction, degradation of soils, and the loss of genetic stocks for future agricultural experimentation and drug plants ensue (*27*). The forces responsible for driving the itinerant folk need to be dealt with in order to slow the flow of migrants to manageable proportions. In the Northeast, for example, the government-subsidized strategy of industrialization and irrigation has created few jobs while displacing more farmers than have been settled (*28*). More effective attempts at land reform, easier access to birth control methods, and increased attention to rural development engaging small-scale farmers would alleviate some of the demographic pressure in the region. In southern Brazil, diminishing plot sizes, steeply rising land prices, and severe frosts in recent years are forcing many families to migrate north, particularly into Rondônia (*29*).

Political expediency and the buffer of an immense, sparsely settled region will inevitably result in a continued stream of settlers into Amazonia. In order to better accommodate the influx of land seekers, future colonization schemes could be located along the floodplains of silty rivers such as the Amazon, Madeira, and Purus. In this manner, colonists could take advantage of fertile alluvial soils which are annually rejuvenated, abundant fish supplies, and cheap water transportation. Most major towns and cities in Amazonia are located along rivers, so large markets would be more accessible to floodplain farmers. While the alluvial soils are flooded during the 4- to 7-month high-water seasons, colonists could attend to perennial crops, such as cacao and rubber, on nearby uplands. Unrestricted settlement of floodplains could nevertheless trigger serious ecological effects. Many of the fishes important in subsistence and commerce depend heavily on floodplain forests for shelter and food; large-scale disruption of their habitat would considerably reduce their numbers, thus restricting supplies of a major source of dietary protein in the basin (*30*).

The Brazilian government has spent close to $500 million on the Transamazon project. Few Third World countries, Brazil now included, can afford to invest such sums in schemes that produce limited social and economic benefits. The Transamazon Highway was conceived when the cost of petroleum was only $2 a barrel on the world market; Brazil currently pays close to $36 a barrel for the product. In 1980, Brazil spent $11 billion, half of her export earnings, to import petroleum. Considering Brazil's mounting external debt, now approaching $60 billion, it would be wise to concentrate scarce public funds on consolidating the gains of earlier colonization efforts in the Amazon region, and to focus any new settlement propects on floodplains where settlers can benefit from the world's largest network of rivers.

The Transamazon project fits a pattern of the repeated failure of government-directed settlement schemes in South America (*31*). Blueprints are usually drawn up with little or no understanding of the ecological and cultural conditions of settlement areas. Bureaucratic controls often hamper the development of colonization zones. Spontaneous migrants, already highly motivated, should be given land titles relatively quickly and access to an efficient credit system. It is unrealistic, though, to expect pioneer zones to foster the blossoming of egalitarian communities. The great diversity of soil types and the different cultural values of settlers will usually lead to social stratification.

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## Transamazon Highway: Impact on Indians

While reading Nigel J. H. Smith's article "Colonization lessons from a tropical forest" (13 Nov., p. 755), I was troubled to note that the discussion of the social, economic, and ecological impact of the Transamazon Highway project does not include mention of the cultural and physical destruction of the Amazonian Indians.

At the inception of the Transamazon project, the recognition of the danger to the indigenous population prompted the Brazilian government to establish the National Indian Foundation (FUNAI). This government bureau was given the responsibility for the protection of the Amazonian Indians and is a successor to previous, maladroit efforts meant to protect the indigenous population.

Public statements by Brazilian bureaucrats notwithstanding, FUNAI has failed to prevent, and in some cases has abetted, the seizure of Indian land. Since the mid-1970's, prospectors primarily seeking gold have invaded Indian territory; laws later enacted to stop those seizures were rescinded in a government decree of 15 January 1980 that allowed prospectors working for government enterprises to enter Indian lands. Furthermore, the introduction of diseases such as malaria, whooping cough, and hepatitis against which the Indians have no resistance, has decimated their ranks in the same manner that the expeditions accompanying Columbus all but eliminated by disease the original population of the islands of the Caribbean.



FUNAI has been pressured for years to create a national park for the protection of the Indians; all of FUNAI's proposals, including one which called for the creation of 21 small, disconnected Indian reserves, have been soundly rejected by those concerned about the survival of the native population. A proposal for one undivided park that was advanced by the Committee for the Creation of Yanomami Park was rejected by FUNAI. At the present time, while FUNAI considers and rejects proposals, the destruction of the native population continues.

One can only hope that in the future the Brazilian government will show as much concern for the survival of its native population as it does for technocratically defined economic development.

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tion that the customary safeguards will continue to operate as the video screen starts to replace the printed page: committees of experts will evaluate and editors will exercise judgment.

To be truly attuned to the potential of microprocessor-based technology, an electronic journal must be more than printed pages on a screen. The full potential of data-base techniques must be realized if this expensive, still-clumsy system is to be recognized as an improvement over the print medium that has served us so splendidly for more than 500 years and is far from being superseded.

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Editors are rightfully concerned about the quality of manuscripts published in electronic journals without appropriate peer review and evaluation. Their fear that the speed of publication may entice scientists away from traditional journals is also not unfounded. Whether traditional editors are happy or not, the electronic journal, in one form or another, will become a reality. Given this simple fact, it behooves those concerned about the future quality of scientific and technical publications to establish a suitable peer review process for these journals.

The technology itself contains the seeds of a potentially powerful "quality filter for information" (*1*) in the form of electronic "letters to the editor." If, while the manuscript is on-line, every reader could immediately enter his or her comments, then, upon editorial approval, those comments could be seen by every subsequent viewer of the manuscript. What better quality filter than the combined (and edited) comments of the readers? It can also be foreseen that hardcopy compendia of the best on-line manuscripts would be published.

While it is true that scientists may opt for quick publication to establish priority for what they may deem to be original ideas, results, and so forth, the same scientists will not want to read everything but will continue to favor manuscripts published in high-quality journals, electronic or otherwise. To meet the competition of speed of publication, traditional journals may opt to publish, in electronic form, editor-approved, but otherwise unrefereed articles, including tabular data. After publication of a refereed article, the corresponding unrefereed publication may be removed, but the tabular data could, nonetheless, remain in electronic form.

As is often the case when new technology has an impact on traditional activities, perceived problems can be resolved by other applications of the same technology.

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## Health Problems of Colonists

I would like to comment on some of the observations on the public health problems among colonist populations along the Transamazon Highway presented by N. J. H. Smith in "Colonization lessons from a tropical forest" (13 Nov., p. 755). In reference to the colonization program, Smith states, ". . . human modification of the landscape favors disease transmission." In fact, the deforested areas served as protective barriers to the colonists from vectors of many tropical diseases, for example, leishmaniasis (*1*). Smith also writes that, ". . . the most important public health problems have been introduced by colonists" and that "Few of the zoonoses in the forest have actually infected settlers." There is no evidence that pathogens introduced by the colonists became a significant public health problem, while serological surveys and epidemiological studies provided conclusive evidence that colonists were subjected to a wide variety of endemic health hazards, including Altamira hemorrhagic fever, leishmaniasis, Mayaro fever, Mucambo virus, Guaroa virus, and Oropouche fever, with hunters and forest workers at greatest risk (*2*).

Since malaria was a significant problem in the Transamazon region before the colonization program, Smith's statement that it was imported into the area by the colonists is not correct (*3*). Smith also states that *Anopheles darlingi* was implicated as a major vector of malaria along the highway and implies that alterations of drainage systems along the highway resulted in a proliferation of *A. darlingi* breeding sites. In fact, actual field data from 2 years of entomological surveillance in the areas discussed by Smith revealed *A. darlingi* populations at only two isolated sites (one near the Aratú river and one at Gleba 3/5, near the Xingú river) (*1, 4*). At all other sites sampled along approximately 800 kilometers of highway road-front, representing predominantly upland forest ecology, there was no evidence of *A. darlingi* (*1*). Furthermore, the age-sex distribution of malaria cases within the colonist population was compatible with exophilic transmission, that is, malaria generally was transmitted out-of-doors by secondary vector species (*5*).

Smith speculates that the DDT spray applied to colonists' houses was ineffective as a malaria control measure along the Transamazon Highway and cites as support two published works, neither of which includes data on the impact of DDT on the indoor biting activity of the malaria vectors. Evidence that colonists became infected with malaria does not demonstrate that the DDT spray program was ineffective. In this respect, one should consider what the malaria problem might have been had there been no malaria control effort. Ironically, after Smith criticizes the Transamazon colonization program, he proposes that future colonization take place along the river systems. Since the principal vector (*A. darlingi*) is a riverine species, such a colonization scheme might well take place under high-risk circumstances for malaria transmission.

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## Correction

In the briefing "OSHA's new thoughts on cancer policy" (News and Comment, 2 July, p. 35), Philip Landrigan was incorrectly identified. Landrigan is director of the Division of Surveillance, Hazard Evaluations, and Field Studies at the National Institute for Occupational Safety and Health.



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