AGRICULTURAL COLONIZATION, ENVIRONMENTAL CHANGES, AND PATTERNS OF MALARIA TRANSMISSION IN THE TROPICAL RAIN FOREST: THE CASE OF MACHADINHO D'OESTE, RONDÔNIA, BRAZIL

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SUMMARY

1. INTRODUCTION

In the last 30 years the pattern of occupation of the Amazon region in Brazil has changed. Traditionally it was carried out in a slow and progressive manner. The rivers were the routes of transportation. But the construction of highways and the incentives that derived from federal intervention, led to an intense occupation, especially in Rondônia State.

The Machadinho Settlement Project, located in the northeastern corner of Rondônia State, was officially created by INCRA (National Institute for Colonization and Agrarian Reform) in 1982, as part of the POLONOROESTE Program (Northwest Brazil Integrated Development Program) financed by the World Bank. Designed to be a model of colonization in the Amazon, the program would be an answer to Rondônia's problems with land use and to the country's need to design the right development strategy for the huge, unoccupied, fragile and priceless patrimony that is the Amazon region, which comprised 60% of the nation's territory but only 12% of its total population. The core of the program was the paving of the road BR-364, which would link Cuiabá (capital of Mato Grosso State) and Porto Velho (capital of Rondônia).

Fifty years ago the present area of the Machadinho Project was pure jungle inhabited by Indians, who were progressively displaced by rubber tappers and miners (Lourenço-de-Oliveira et al, 1989). Roads started to being built and settlement projects emerged. The results for the environment and the well being of settlers and local natives were drastic. Hundreds of thousands of migrants from other states, mostly with no immunity against malaria and with no knowledge of how to properly manage forest resources, came to the region searching for land, or employment in the construction of highways, hydroelectric plants, and mining. The forest was cut down in extensive areas, most of the times illegally, and with no concern about the consequences to the local ecology. The dependence on roads for transportation opened up corridors in the forest, but most of them remain unpaved. Malaria increased rapidly in the area becoming more than a public health concern. It became a serious threat to socioeconomic development of the area.

The purpose of this paper is to understand the linkages between frontier expansion, ecological transformation, land potential/use, and malaria transmission in the Brazilian Amazon. We focus the analysis on the Machadinho settlement project, implemented in Rondônia state as part of the POLONOROESTE program. Our findings show that poor soils, improperly utilized

for crop production, were the sites of crop failures that posed serious problems for the overall success of the project. The social, political and physical contexts of the area were major factors in understanding the linkages with malaria. We summarize the major lessons learned from this experience and propose some policies for malaria mitigation in the Amazon.

2. FRONTIER EXPANSION IN THE BRAZILIAN AMAZON

The Amazon Basin represents roughly half of the South American continent, and 60% of the Brazilian territory. The legal Brazilian Amazon is composed of the states of Acre, Amazonas, Rondônia, Roraima, Pará, Amapá, Maranhão, Tocantins and Mato Grosso (Figure 1). A classical boundary, largely used, follows the definition of the North region of Brazil.

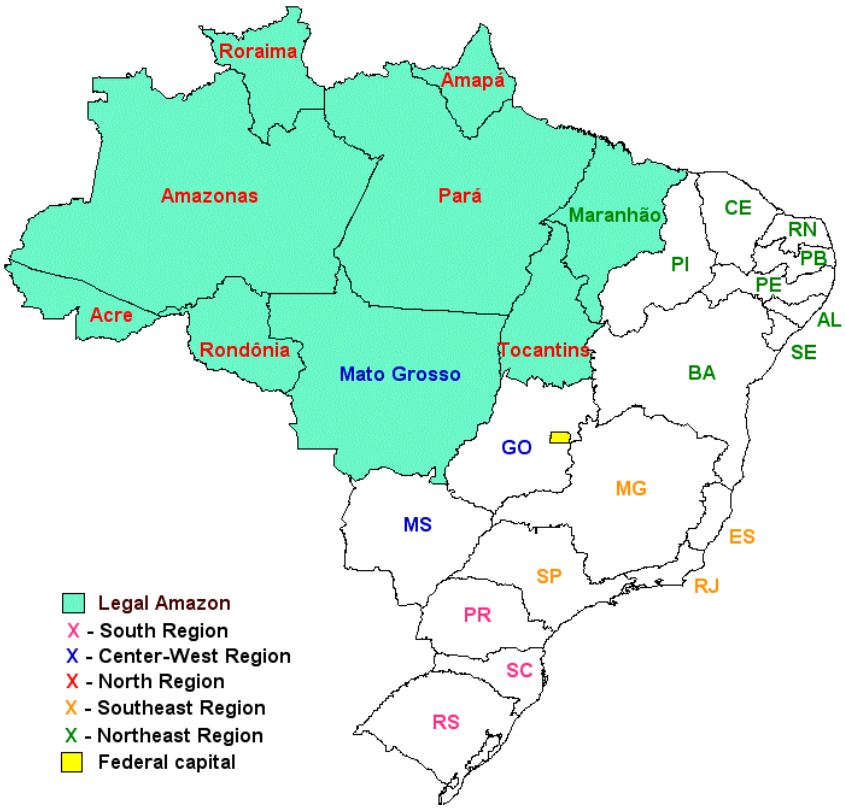

Figure 1 – Legal Amazon and regional definitions in Brazil

According to the last population count, made in 1996, the present population in the legal Brazilian Amazon is 18.7 million, or 12% of the country as a whole. In 1872 its population was roughly 300 thousand, and in 1980 had reached 11 million. This increase in the Amazonian population was not uniformly distributed over time. The demography of the Amazon basin can be divided into five periods (Benchimol, 1985)

- 1st Period → Pre-Orellana period (before 1542) – The area was inhabited basically by Amerindians.
- 2nd Period → Starts after 1542 (Orellana's expedition) – The starting point of Amazon conquest, and of the decimation of the indigenous population. Establishment of the colonists brought diseases like smallpox, measles, malaria and influenza. A period of depopulation is observed.
- 3rd Period → Starts in 1877 (severe drought in the Northeast region) – People from the Northeast of Brazil came as a response to two distinct factors: a push factor (severe drought) and a pull factor (the rubber boom in the Amazon).
- 4th Period → Depression of the '20s and '30s – The Amazon lost the rubber monopoly, its most important economic activity, to Asian countries. Another period of depopulation is observed, but now as consequence of migratory movements.
- 5th Period → Starts during World War II – The rubber activity regains importance during the war, bringing migrants from the Northeast. At the same time the government initiated its effort to *develop* the Amazon. During the '40s and '50s many agencies were founded. The '60s and '70s were marked by the construction of highways to achieve the goal of integrating the Amazon with the rest of the country, and the '80s brought a new phase of colonization programs.

This last period also brought a strong political issue. The first decade of the military regime (1964-1974) was characterized by what was called "integration programs". The large area, sparse population, and unpatrolled borders of the Amazon, shared with eight other countries - associated with the rubber boom and the mining rush - brought up military ideals of national security. Frontier expansion was seen as the solution to economic and social problems of the country. Drought victims of the Northeast and people without land would find in the Amazon the solution for their problems. However, state interventions were absent, irregular or uneven. On one side the government imposed rigid measures to control formal access to land by Indians and settlers. On the other, it provided credit subsidies, fiscal incentives and extensive land areas to corporate groups on the pretext of economic rationality.

The central point is that the fifth period was crucial. It brought the most dramatic changes to the area, both in demographic and ecological terms. Considering an equilibrium as defined by a point equidistant from the three vertices of a triangle - population, environment and health - we can say that, at that time, the balanced relationship was lost, and the equilibrium of the forest jeopardized.

2.1. Highways and colonization

The government intervention in the Amazon during the fifth period described above was basically based on the construction of highways and the promotion of colonization programs. But, usually, the real motivation behind these interventions was not social or agronomic. Political goals were dominant (Fearnside, 1990).

The consequences of these interventions are not limited to the areas where they were introduced. Once roads were opened, new landless migrants came and settled themselves voluntarily, even when the government tried to control the process. Mining areas were discovered and indigenous communities disturbed. Artificial dams were constructed, facilitating the spread of malaria. Small communities proliferated near the roads, with very poor infrastructure, and the deforestation rate assumed dramatic levels.

That period can be evaluated by the analysis of three major projects: The Belém-Brasília road, the Transamazon highway and the colonization programs in Rondônia, especially POLONOROESTE. Figure 2 gives an overview of the interventions and projects in the Amazon.

2.1.1. Belém-Brasília Road – BR-010

In 1960 the Amazon had only 6,000 Km of roads, with roughly 300 Km paved. The Belém-Brasília highway was the first major road constructed into the Amazon, and ended the physical isolation of the region. Conceived in 1947, its definitive routing was carried out in 1956. Its construction concluded in rudimentary form in 1960; and its pavement concluded in the early '70s. The 1,900 Km of the highway would link the newly constructed capital of the country – Brasília - to the north region. Amazingly, an analysis of the economic feasibility of the Belém-Brasília highway was ready only eight years after it was in operation (Martine, 1981).

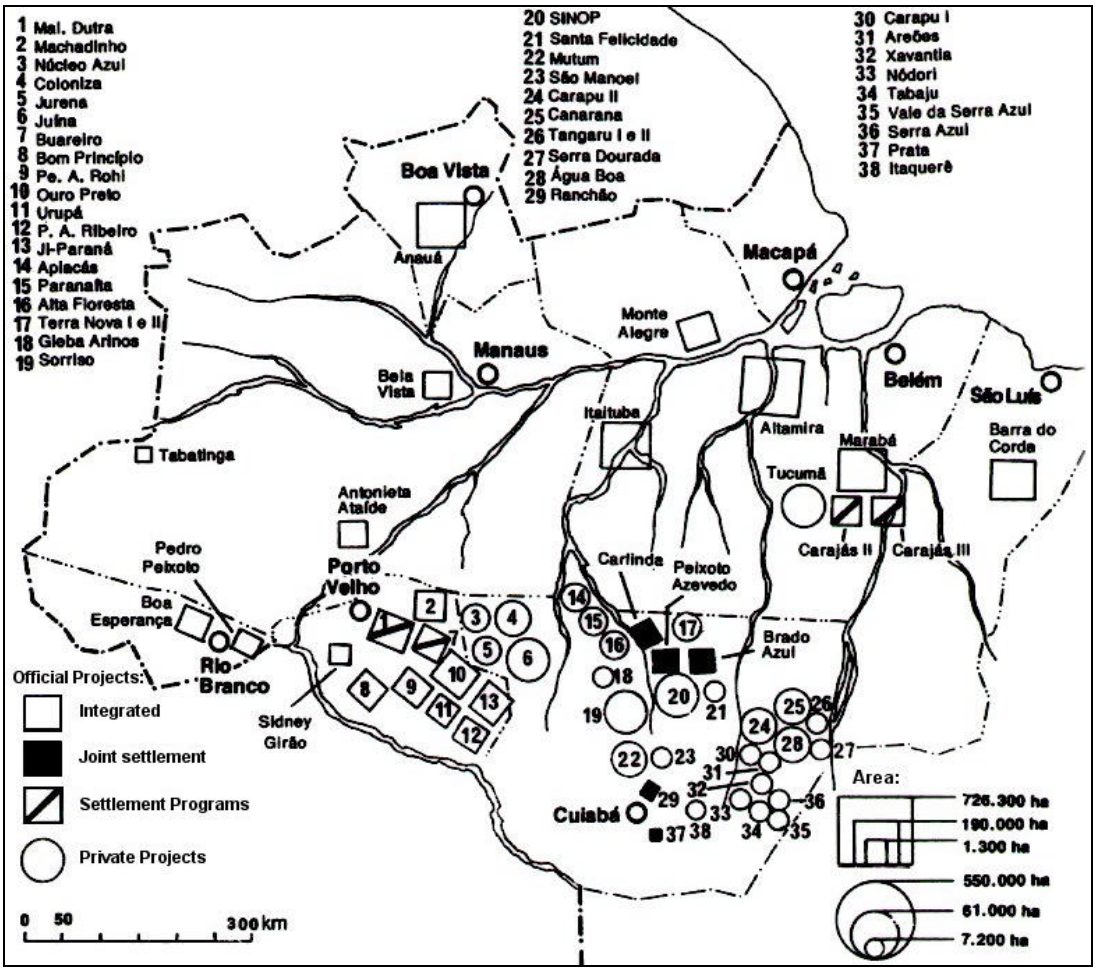

Figure 2 – Colonization Projects in the Amazon (Miranda, 1990:34)

In the first twenty years of occupation, more than 2 million people and 5 million head of cattle were brought along the highway, and the deforestation rates were increasing exponentially (Moran, 1993). Occupation along the road was mainly spontaneous, and government-oriented projects were of secondary importance. Migrants from other regions usually started their agricultural activities without technical assistance, and the natural process consisted of four phases: (a) select land; (b) cut and burn off the area; (c) plant subsistence-type crops; and (d) move on to another area as a consequence of the depletion of the soil or land speculation. This process clearly contributed to high rates of deforestation, and failed to absorb large number of people.

The spontaneous, disorderly, uncontrolled and itinerant form of occupation, associated with the absence of government support, led to land speculation, concentration and violent conflicts. In the state of Pará, between 1959 and 1963, about 5.4 million hectares of land were transferred to private hands (Browder and Godfrey, 1997).

The Belém-Brasília highway was just the start. The following years would bring the Transamazon highway and other roads linking these two highways. The PA-150 road, linking the Belém-Brasília road to Marabá brought spectacular transformations in the environment, given the role of private companies and the discovery of timber, iron and gold. Figure 3 gives an example of how fast deforestation developed near the roads.

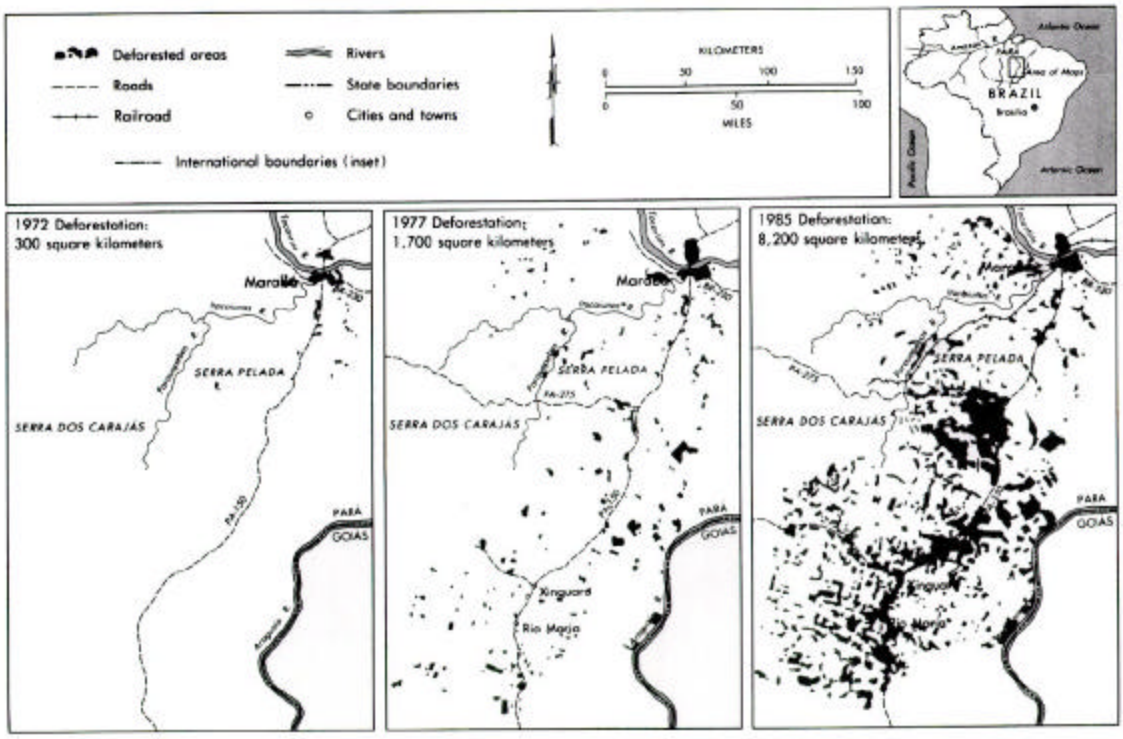

Figure 3 – Deforestation in Southeast Para (Mahar, 1989:14)

2.1.2. Transamazon Highway – BR-230

The Transamazon highway was one of the pharaonic constructions projected during the Brazilian military regime, designed to link Recife (in the Northeast region of Brazil) to the Peruvian border, in more than five thousand kilometers cut through an unknown territory. As part of the Plan for National Integration (PIN) the highway was publicized as a chance to populate the almost uninhabited area and to alleviate the suffering of the northeasterners caused by the 1970 severe drought[3]. However, its plans were ready months before the government linked its construction to the drought in the Northeast. Furthermore, huge deposits of mineral

[3] Military president E. G. Médici, after visiting the Northeast, tried to attach a social goal for the PIN, and his most popular words at that time were "*to give men without land a land without men*".

resources were discovered in the area through radar monitoring (Moran, 1981 and Sawyer, 1984), and the government hoped that extractive activity could be carried out during the construction.

This program represented the initial accessing of the areas of terra firme that constitute 98% of the whole Amazon basin, and which were previously preserved from the impact of migrations. Until then, only flood plain (*várzea*) areas were settled, since they had higher soil fertility.

Similar to the Belém-Brasília road, the Transamazon highway was constructed without a prior analysis of economic feasibility. Consequently, its route wasn't proximal to the most fertile soils in the area. Bridge construction was avoided to minimize costs, and the road followed the topography of the region. Low areas were impassable during the rainy season, since they got flooded. The artificial lake of the Tucuruí dam later inundated approximately 100 Km of the highway (Henriques, 1984).

On each side of the highway, a 10 Km strip of land was destined for small-scale farmers, who received a 100-hectare plot, which extended 500 Km along the highway and 2 km back from the road. Auxiliary side-roads of 10-20 Km were built every 5 Km (Jordan, 1987). The design of the plots followed a traditional fishbone structure (Figure 4), and one-half of each rectangular plot was left as uncleared forest.

The colonization was basically centered in three river-towns, all located in Pará state: Altamira (on the Xingú river), Marabá (near Tocantins river), and Itaituba (on Tapajós river). The first was the most important, having settled the majority of farmers (54% of the families settled in 1974).

The goal for the period between 1970-74 was to settle 100,000 low-income families in the area (Schmink and Wood, 1992). Settlers received credit facilities, basic infrastructure and financial support for the first six months to buy provisions and agricultural implements. However, only around 7,000 families were settled by mid-1974, reflecting a major program failure. Seeds distributed by the government were inappropriate to the Amazon climate. The availability of credit was delayed. Settlers ended up planting the wrong crops, given the soil and climate characteristics. The final production was low. Basic infrastructure was deficient. There was little concern for the medical needs of the population, and malaria rates were huge. The design of the plots didn't follow the natural landscape such as rivers and hills, leaving some plots

with very bad conditions for agriculture. The quality of soil was much lower than initially expected (only 3% could be classified as naturally fertile). No transportation network was available to send the agricultural output to other regions of Brazil. Storage facilities were inadequate, compromising part of the crop yield. Finally, the number of migrants attracted to the area was much larger than the area could absorb (Moran, 1993, Martine, 1981 and Jordan, 1987). In a word, the carrying capacity of the area was exceeded.

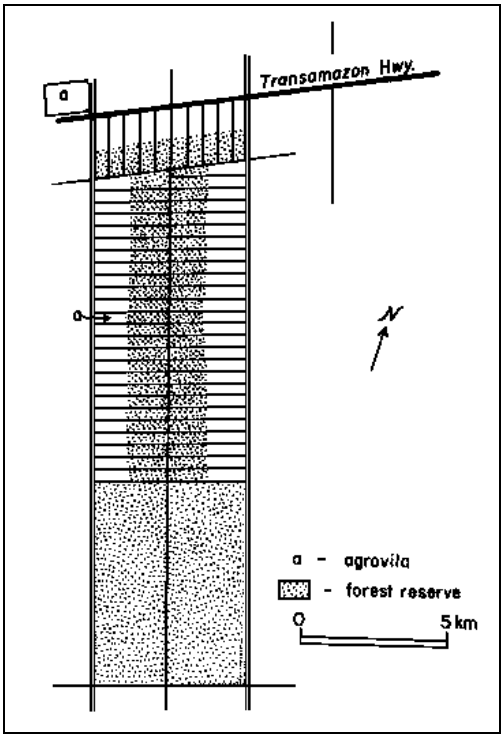

Figure 4 – Design of plots along the Transamazon Highway (Moran, 1981:16)

In agricultural terms, the most successful settlers were those already living in the Amazon for a long time. They could identify the soil quality based on the type of natural vegetation growing in it. However, even they experienced low yields.

The agencies coordinating the settlement used reference maps of soil quality with an inappropriate scale for agriculture decision-making[4]. Although the technical staff that elaborated the maps knew these limitations, the agencies used the maps as precise information. In some areas the soil was so poor that people just refused to be settled.

[4] The maps used were on a scale of 1:100,000 (extracted from the RADAMBRASIL Project, 1979), while for farm-level decision making the ideal is a scale of 1:20,000 or, preferably, 1:10,000.

Lack of knowledge of the ecology of vector-borne diseases was reflected in the proliferation of health risks. No water drainage system was built and the highway, at some points, passed through seasonal streams. The result was the proliferation of many sites of stagnant water that provided ideal conditions for mosquito breeding and malaria infestation. Incidence of malaria was huge. In 1971 49% of the hospital admissions at Altamira Hospital were related to malaria, and in 1973 11.4% of the population living in a 250-Km radius of Altamira had malaria (Moran, 1981). The peak of malaria transmission occurred in the beginning of the rainy season, when the breeding sites proliferate, and when the farmers were planting a new crop. The colonists saw the lack of medical assistance as one of their major problems, although the government thought that the major problems were those related to agricultural production (transportation network, seeds, pests, etc).

In 1975 the idea of settling small farms along the highway was formally abandoned, and the focus changed to large business. Companies (many of them foreign-owned) bought huge tracts of land and indigenous communities and small farmers were pushed off their lands. Violent conflicts started and were often resolved in favor of the companies. As Martins (1984:486) asserts:

> "Conflict over land in Brazil, particularly in Amazonia, has produced three distinct forms of violence. Physical violence by the police and gunslingers against squatters or rural workers was the first step in strengthening private over public authority. Second, evictions carried out by gunmen and other private agents constitute a form of violence by the courts in favoring the interests of private firms over personal rights. The consequences of these two have led to a third type of violence: the direct intervention by the executive branch in land questions, and the exclusion of other public and private entities. […] The more the government becomes immersed in defending the expansion of private enterprise in Amazonia, the more politicized the land disputes become."

In 1986, just one year after the focus was changed to large-scale private enterprises, 335 projects had already been approved in the agricultural sector (a large number of them for cattle activities), 171 in the industrial sector, and 22 for infrastructure (Moran, 1981).

2.1.3. POLONOROESTE

The colonization process in Rondônia was also related to a road. The BR-364, linking Cuiabá to Porto Velho, was opened in precarious condition at the end of the '50s, and improved in 1970, when the government set up the first colonization projects along the road. The

transportation network following the BR-364 was opened to vehicles in 1967, and some of the most fertile soils of *terra firme* were near the roads (Leite and Furley, 1985).

The first colonization program, created in August 1969, was the Integrated Settlement Project of Ouro Preto (PIC Ouro Preto). It was designed to resolve the problems of 300 families who had been attracted to the area in the past, but were left with no support by a private colonization company[5]. Soon the information that the government was distributing land in an area with supposedly fertile land attracted a spectacular number of migrants to the area. Originally designed to support 500 families, the PIC-Ouro Preto had its capacity expanded to 5,000 families (Martine, 1982). Six additional projects were implemented by 1975; and the total number of families settled was, approximately, 22,700 (Martine, 1990). As far as the lands near the BR-364 were being occupied the population movement took a route to the interior, generating many land conflicts with the indigenous tribes.

The BR-364 became totally paved in 1984 as part of a program developed by the government with the aid of the World Bank (POLONOROESTE). At the same time, new forms of colonization, called settlement projects, were started. Figure 5 shows the major settlement projects promoted in Rondônia, as well as the protected forest and indigenous areas. It's easy to see the origin of conflicts between native Indians, settlers, and land speculators. The Indian reserve 17, represented by the dashed line, conflicts with two settlement projects.

POLONOROESTE - Northwest Region Integrated Development Program - was a complex, ambitious and totally new challenge both to the World Bank and to the Brazilian government. It was the Bank's first attempt to support agricultural development in the Amazon, combining many different sectors (transport, rural development, education, health, Amerindian protection, environment and agriculture).

However, there was not a general consensus within the Bank between "developmentalists" and "environmentalists[6]". Promoting frontier occupation in a largely unknown, but ecologically sensitive area, was seen by developmentalists as a unique opportunity to generate a rural

[5] There was also the goal to eliminate illegal appropriation of land in the territory (a cadaster study made in 1967 revealed that 93% of the land in Rondônia belonged to the Union.

[6] This discussion and the later consequences of the project motivated the creation, in July 1987, of an Environment Department at the World Bank, and an increase in the Bank's environment staff.

settlement model for tropical frontier areas. At the same time this activity was considered a potential danger to ecological preservation and Amerindian welfare. Environmentalists questioned the feasibility of a sustainable agricultural production in the area, given its distance from ports and principal markets, and given the uncertainty of the soil conditions. They were also wary about the potential consequences of a possible accelerated occupation (due to migration).

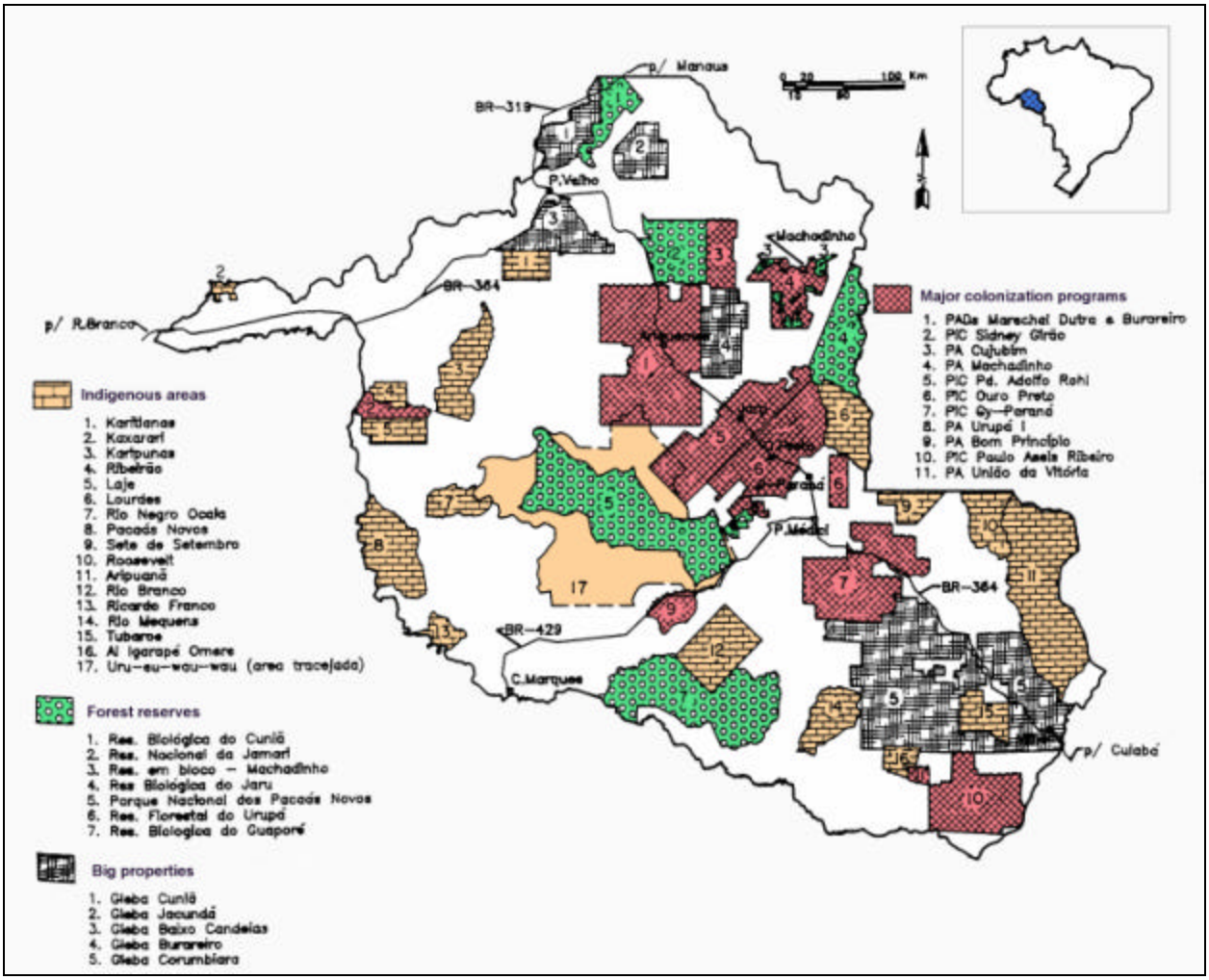

Figure 5 – Settlement areas in Rondônia (adapted from Sydenstricker, 1992:26)

The environmentalists, however, did not receive a lot of support from the Brazilian government, which was more interested in building a major road (one of the major objectives of POLONOROESTE, as will be shown later) and facing the socioeconomic problems in the area. As a result, environmental concerns were secondary, and highway engineers and agricultural specialists took the leadership.

Whenever environmental concerns were raised, the Brazilian government made it clear that it would not give up the plans to build the highway, even without the Bank's support[7]. Therefore, the World Bank decided to support the project.

Despite the controversy, the Bank saw the project as an opportunity to improve the living conditions of the poorest segments of the population, to support institutional development and policy reform, and to promote domestic import substitution and increase export capacity in order to minimize the problem of foreign currency constraint.

POLONOROESTE was approved between December 1981 and December 1983, consisting of five interrelated projects financed by six interlinked loans that amounted to a total of US$ 434.4 million (see Annex I). There was also a special program to protect the Amerindians, but totally financed with domestic resources. The total program cost was initially estimated at nearly US$ 1.6 billion, and it was designed to be implemented in three overlapping stages. The execution and coordination of the program was the responsibility of various federal and state Brazilian agencies.

The overall goal of the program was "to pave the existing BR-364 highway connecting the capital cities of Cuiabá (Mato Grosso) and Porto Velho (Rondônia) and to provide for the investments necessary to achieve the harmonious socio-economic development of the region influenced by this road and protect its physical environment and Amerindian populations" (World Bank).

Each of the three stages of the project had particular objectives and specific strategies, as detailed in Annex II. We can summarize them as:

- Reconstruction and pavement of the BR-364 highway
- Construction of a secondary feeder road network
- Environmental protection
- Implementation and consolidation of settlement projects
- Land tenure regularization
- Assistance to indigenous population

[7] Actually, the road construction plan was approved by the Brazilian government before the implementation of POLONOROESTE.

- Provision of social, financial and production infrastructure to small rural areas
- Malaria control

POLONOROESTE was designed to be a colonization program that could be considered, in the future, as a model of Amazon colonization, avoiding the typical problems of settlement efforts in the past[8]. It included an elaborate plan for infrastructure and financial support (many more than most official settlements had done before), as well as a defined agricultural production strategy, based on the cultivation of perennial crops and fruit trees. In order to stimulate intensive use of the land and to preserve the forest reserves, the size of the plots was limited to 40 hectares, and their shape was irregular (completely different from the "fishbone" pattern usually seen). In order to consider the fluvial net, each plot would have water resources at a reasonable distance (Sawyer and Sawyer, 1987).

The results of POLONOROESTE were far below the initial projections (the outcomes of POLONOROESTE will be reviewed in detail on section 4). Alternative scenarios with respect to migration rates, and their possible consequences to the environment and to the health of the population, were not considered. No sustainable carrying capacity study[9] was made (a necessity always stressed by the Bank's environmentalists), which left the initial expectations with little or no validation.

The concerns of the Bank's environmentalists were soon justified. Deforestation was increasing rapidly bringing serious consequences for the ecological equilibrium and for the health of the population. In addition, sustainable agriculture was not a reality, as was initially anticipated. Amerindian rights were frequently violated. An outbreak of malaria was observed in the region, soon called the "world capital of malaria" (Sawyer and Sawyer, 1987). The Bank recognized all these problems, and as a result it cancelled 21% of the more than US$ 434 million that it had initially approved (see Annex I for more details).

[8] High deforestation rates, conflicts for land (including violence), poor health conditions (specially due to the increase in malaria cases), turnover of plots due to poor soil, and a lack of local, state and federal support.

[9] Sustainable carrying capacity is the maximum number of persons that can be supported in perpetuity on an area, with a given technology and set of consumptive habits, without causing environmental degradation (Fearnside, 1986).

2.2. Migratory movements

Three major migratory movements characterize the Brazilian frontier expansion after the World War II. During the '40s and '60s Northeasterners moved to the South (Paraná state), attracted by the rich lands for coffee plantations. The second period was the cattle expansion in Goiás and Mato Grosso (on the Center-west region) during the '60s, in response to an increase in the demand for beef. The third period, during the '70s and '80s, was a northwestern movement.

A major difference between the first and the last two movements can be identified. Attraction to the south was based on economic opportunities in agriculture, bringing very skilled farmers to the area. People went to the center-west and to the northwestern part of Brazil because of extremely unfavorable socio-economic conditions. Droughts in the Northeast, unemployment, and massive mechanization and land speculation in the South, associated with the promise of cheap and fertile lands in the Amazon, brought thousands of people, especially to the state of Rondônia (Martine, 1990 and Moran, 1981). The selection of migrants was extremely unfavorable in the center-west and northwest movements. Furthermore, technical and financial assistance, and land ownership was effective in the South, while it failed in the other areas.

Between 1970 and 1980 the net migration in the legal Amazon was on the order of 1.1 million people (Wood and Wilson, 1984), 700 thousand of these went to the states of the North region. This massive migration promoted severe changes in the socioeconomic, ecological, and demographic characteristics of the area, most of them negative. They were more than a proof that considering the Amazon as the magical and instant solution the problems of the country was a terrible mistake. As Wood and Wilson state (1984:151):

> "… frontier schemes that profess to resolve the problem of population pressure can be viewed as concrete manifestations of the overall ideological framework that orients public policy. […] in the absence of fundamental reform, Amazonia's capacity to absorb surplus labor is little more than false rhetoric."

Despite this earlier evidence, the scenario of the 1980s was not much different. Promotion of colonization projects continued. Particularly in Rondônia, the migration process began to be significant in the early 1970s, leading to dramatical growth of the population. While the whole population of the country was growing at a yearly rate of 2.48% during this period, Rondônia registered an astonishing yearly growth rate of 16.03% (Table 1), with even higher increases in the rural area.

Table 1 – Rondônia's population and rate of growth – 1960/1996

Year	Absolute population			Yearly rate of growth (%)		
	Total	Urban	Rural	Total	Urban	Rural
1960	69,792	30,186	39,606	4.76	7.03	2.66
1970	111,064	59,564	51,500	16.03	14.39	17.69
1980	491,069	228,539	262,530	7.89	10.11	5.51
1991	1,132,692	659,327	473,365	1.65	2.96	-0.29
1996	1,229,306	762,755	466,551			

FONTE: IBGE, Demographic Census.

A great number of migrants came from the South, especially from Paraná (Table 2). It is important to highlight the massive migration during 1985 and 1986, when a new agricultural settlement project was opened in Rondônia (Machadinho Project, the case study analyzed in this paper). The consequences of this impressive process were huge and mostly negative, resulting in a deceleration of the migratory movement in the following years.

Table 2 – Number of migrants to Rondônia during 1979 to 1988 by state of origin

State of Orign	Year									
	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Paraná	13,772	19,143	13,754	10,588	22,816	28,275	36,305	49,850	23,375	8,220
Mato Grosso	8,564	8,598	8,787	8,465	10,732	13,703	20,419	20,124	12,422	8,084
Mato Grosso do Sul	3,318	4,821	4,532	3,507	6,365	6,989	9,584	10,847	5,559	2,487
São Paulo	2,317	3,317	5,597	5,836	9,466	13,088	17,026	14,791	9,192	5,165
Espírito Santo	2,030	2,740	3,347	3,493	6,029	6,709	13,713	14,019	12,941	5,862
Minas Gerais	1,523	2,723	2,705	7,251	9,407	10,460	18,255	17,015	9,266	4,306
Goiás	1,250	1,694	2,014	3,640	3,991	4,162	6,434	6,532	4,074	3,086
Ceará	699	475	941	1,048	2,113	1,872	3,039	3,471	3,414	1,957
Bahia	622	985	1,056	1,746	3,664	4,198	5,587	6,143	6,891	2,372
Amazonas	—	—	7,125	4,072	3,264	3,542	2,490	2,179	952	2
Pará	—	—	2,552	1,538	2,715	1,439	1,746	1,539	1,141	926
Outros	2,696	4,703	7,808	6,872	12,161	11,418	17,023	19,379	14,427	9,483
TOTAL	36,791	49,199	60,218	58,056	92,723	105,855	151,621	165,889	103,654	51,950

FONTE: Perdigão and Bassegio, 1992:175.

As Table 1 shows, during the 1980s the urban area increased faster than the rural area. Although this may seem surprising at first, it just reveals another feature of the process. Part of the migrant population experienced agricultural failure, diseases and violent conflicts over land. They emigrated from the state. However, another portion decided to try their luck in urban areas. Ultimately, for the first time since the 1960s, the rural population decreased during the 1990s.

3. IMPACTS OF FRONTIER EXPANSION ON ENVIRONMENT AND HEALTH

The interactions between agricultural colonization, environment and health, at given levels of socio-economic conditions, are very complex. Neither a strictly ecological

transformation analysis nor a simple model of agricultural potential confronts all the issues that needed to be considered in the design of a colonization project, or point to the main reasons for the possible observable consequences. The analysis of all factors together provides a richer understanding of the causes of different outcomes, as well as the basis for a rational and successful set of policies.

The impacts go beyond just agriculture and ecosystem structure. Until 1989 Rondônia produced only 45% of its total energy consumption, and the demand was increasing. At that time Samuel dam was constructed, despite serious environmental concerns. However, the seasonality of rainfall in that part of the Amazon brought a very specific seasonal consequence: during the dry season, when the reservoir capacity was reduced, and large areas of land became exposed, the density of anopheles mosquitoes increased rapidly, as well as the number of malaria cases (Browder and Godfrey, 1997). Essentially, the process of frontier expansion itself became a threat to the health of the population. The inadequacy of health services necessitated by this process even exacerbated the negative consequences of malaria.

3.1. Agricultural outcomes

An agricultural colonization process transforms inputs (soil, rain, irrigation, labor, fertilizers, etc) through technologies and patterns of work and ownership, into other outputs (Lipton and Kadt, 1988). The outcome of these transformations affects the environment and health in different ways. In a scenario where technologies are rare, work is basically manual and ownership of the land is not guaranteed. The success of the colonization process will be in danger; and the consequences to the environment and health will be potentially negative.

Scarce use of technologies implies that little or no measure will be taken to improve the quality of the soil, to replace nutrients lost in past crops. Increasing areas will be cleared, cultivated until exhaustion, and then simply abandoned. The lack of information on the best crops for the available soil can end up in the cultivation of the wrong ones. This leads to little or no production at all. The primary lesson is that before any agricultural colonization project starts, a clear understanding of its potential must available, and technical orientation must be given to

farmers[10]. Migrants will tend to produce what they previously did in their area of origin, using the same techniques. This can be a serious mistake.

A farmer's choice of crops to plant can be a major source of health risk. In areas producing rice, a very well planned irrigation system must be implemented, in order to avoid standing water where mosquito larvae are developing. Experiences in China and in some areas of the Brazilian Amazon show that appropriate irrigation in rice fields can result in both a reduction in mosquito density – linked to reduced malaria transmission – and an increase in rice yield.

If work is basically manual, the final harvest will be much lower than what is required for profitable farming. This inhibits generation of financial resources to improve technology in the future. When the land clearance process is primitive and of bad quality, there is an expansion of breeding sites for mosquitoes (discussed in detail below), and exposure of the soil to faster rates of erosion. Disputes over land, as has been frequently observed in the Amazon, contribute to the increase of deforestation, since people working in one area can be pushed from it. When they move to new sites they start the clearing and planting process all over again. Concerning the outputs, if adequate storage facilities and transportation are not available, part of the crop yield can deteriorate, even unnoticed, and the health of both producers and consumers can be jeopardized.

In addressing the patterns of work, seasonal workers are least immune to local diseases; and they are frequently exposed to higher risks of becoming ill. It is important to note that this is a recurrent process. Once people get sick there is a negative effect on production. Then other workers come to replace them, and they get sick too.

A final remark is that the agricultural outcome can affect health through nutrition. An inadequate or unsuccessful production can reduce food intake, thereby causing individuals to be more susceptible to a broad range of diseases. This contributes negatively to future production, and provides another example of a downward spiral.

[10] Besides the information about the best crops, a clear understanding of the physical characteristic of the area is necessary, in order to avoid problems like the ones that happened in the Transamazon colonization project, when seeds adapted to the dry climate of the northeast where distributed to farmers. The result was a total failure on the production.

3.2. Ecological transformation and malaria transmission

Tropical rain forest areas assure good conditions for the spread of insects, given their high temperatures, humidity, and rainfall throughout most of the year. In the case of *Anopheles darlingi* in the Amazon basin of Brazil, natural breeding places are observed in the forest margins at the beginning and end of the rainy season. Inside the undisturbed forest, however, the ideal conditions for *Anopheles darlingi* are seldom found, since standing water is acidic and the partial shade favored by this species is absent. Manmade modifications, if not well planned and controlled, will tend to break this natural equilibrium.

In any colonization project the first environment transformation is the process of clearing the land and preparing it for cultivation. Forest clearing provides the necessary partial shade for mosquito breeding, and brings up the notion of forest fringe, a frontier between the forest and the property, where the risk of malaria transmission is very high.

A very common technique for clearing the land and preparing it for cultivation in the Amazon is slash-and-burn. The beneficial aspects of burning are: the increase in the levels of pH, phosphorus, calcium and magnesium, and the decrease in the level of toxic aluminum ions. A poor burn compromises the crop yields, and contributes to the proliferation of breeding sites for mosquitoes (Fearnside, 1986).

In colonization areas the quality of the burn is related to the distribution of trees on a settler's land, to individual resources (availability of chainsaw or not), and to credit incentives. A poor clearing and burning process can cause the obstruction of steams and will leave the taller trees standing. This provides the necessary partial shade for *Anopheles darlingi* breeding.

Other manmade transformations, intrinsically related to population movements to new areas, are water pollution due to sewerage, waste, and mining activities. In the Amazon it is common for mercury to be used in gold mining. Mercury pollutes the water and contaminates the aquatic species in the rivers. The health of the human population is compromised when people consume fish contaminated with mercury. In addition to pollution of streams, pits left by mining workers catch rain water – of high pH than Amazon streams – and these are ideal mosquito breeding sites.

Road construction, which is necessary for colonization projects, poses a particular health threat. Opened and unpaved roads have poor drainage; and culverts that form pools of stagnant

Historically, mitigation of malaria transmission in the Amazon has been the exception rather than the rule. During World War II, when a new rubber rush was observed, many workers died (approximately 27,000) or became extremely ill because of malaria[11]. Most had come from the Northeast region, with no immunity against the disease. Most of the agricultural colonization projects in the Amazon represented ecosystem transformations that created extreme malaria risk. During the 1970s they accounted for more than 80% of the nation's cases.

Transformation of the forest fringe is generated by the ecological changes induced during colonization projects. Farmers can be more or less exposed to *Anopheles darlingi* mosquitoes depending upon their houses are built and even the hours of the day when they are out of doors. Furthermore, the ruptures in the natural equilibrium can contribute to shifts in mosquito behavior (biting preference, frequency, and locus). Negative impacts on health are considered to be one of the major causes of dropout of settlers, and, ultimately, of the failure of the colonization efforts.

Finally, the above points make it abundantly clear that malaria in the Amazon cannot be studied only on medical and biological terms. Connections between population, environment, land use and economic conditions are essential to understanding the phenomenon of malaria risk.

4. THE CASE STUDY OF MACHADINHO

The Machadinho Settlement Project (Figure 7) was officially created by INCRA (National Institute for Colonization and Agrarian Reform) in 1982, as part of the POLONOROESTE Program. Occupying part of the municipalities of Ariquemes and Jaru, the original area of the project covered 5,920 Km^2 divided into seven tracts with 5,520 plots.

Later reviews of the project (based on the negative outcomes of the first years), led the World Bank to cut back this initial design, reducing the original 5,520 plots to only 2,934 in a total project area of approximately 210,000 hectares. The 2,934 plots were designated for rural farmers who were previously landless. The plots were divided into 4 tracts: tract 1 with 602 plots

[11] Almost 40 years later the government recognized the harmful consequences and created a special pension, with a fixed value equal to two minimum wages, to be paid to disabled rubber tappers, that worked in the Amazon during the war, or to their dependents (in the case they were already dead).

and approximately 48,000 hectares; tract 2 with 1,140 plots and approximately 71,000 hectares; tract 3 with 622 plots and approximately 49,000 hectares; and tract 6 with 570 plots and roughly 40,000 hectares. There were also: a main urban center with 2,095 hectares, an airport with 59 hectares, 10 secondary urban centers with 954 hectares, and 17 block forest reserves comprising more than 68,000 hectares (Ecoforça and Millikan, 1996).

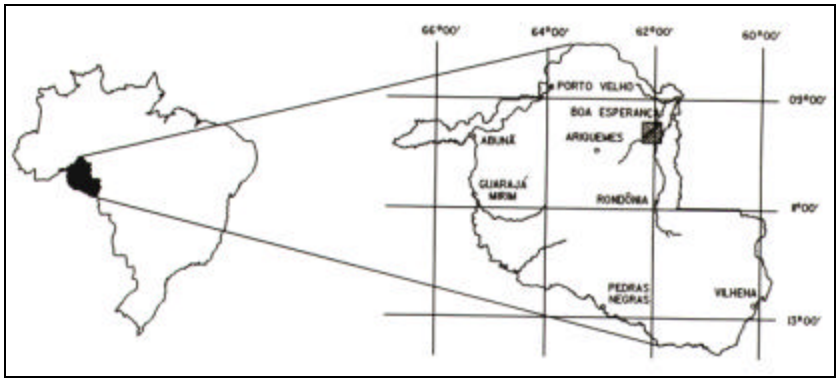

Figure 6 - Spatial location of the study area

The design of the plots was carefully planned, as shown in Figure 8 (for tracts 1 and 2). They followed the course of the rivers, so that each plot would have water resources. Topography was also a consideration in specification of plot boundaries. The Machadinho River is the main tributary in the area and divides tracts 1 and 2. The arrangement of plots distinguishes the Machadinho settlement in any satellite image.

The settlement began in mid-1984, when roads were opened in tracts 1 and 2. Plots were distributed in July and August, too late for clearing and burning before the rainy season[12] (Sawyer and Sawyer, 1987). Many settlers abandoned their lands and later found out that they had been distributed to another applicant, increasing conflicts in the area.

In the beginning the only health center was located at the main urban center. Other health posts were supposed to be installed at the secondary urban centers, reducing the distance that settlers had to travel in order to get health care. These other health posts were not established until the 1990s, and some settlers had to travel approximately 40 miles to reach a health center.

[12] On June the area is cleared and left to dry for 40 days. At the end of august the burning process takes place.

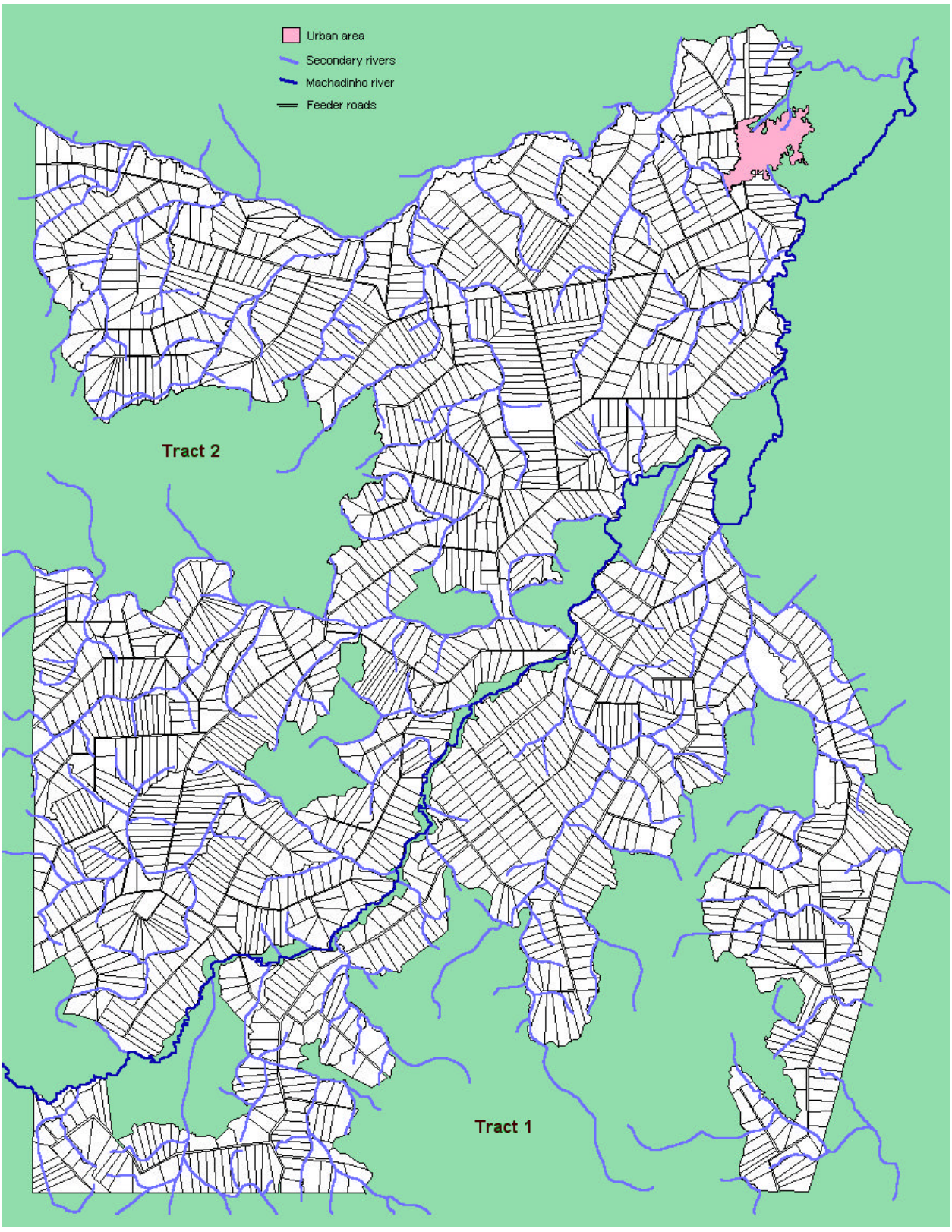

Figure 7 – Plot division and river network on the Machadinho Settlement Project – tracts 1 and 2

Altitude in the area is between 100 and 200 meters. A dense network of streams flowing into the Machadinho River drains the area. The climate is hot with a very short dry season (during the months of June, July, and August). Because of this seasonality in the rainfall, there is great seasonal variation in the water levels of the rivers. Quiet or stagnant pools are observed at the beginning and end of the rainy season. Average annual temperatures are above 25^{o}C, reaching an average monthly maxima above 32^{o}C from July to October. Relative humidity is usually above 80%. All these conditions are favorable to a high density of *A.darlingi* mosquitoes.

4.1. Economical, social, and political context of the settlement

The time period when POLONOROESTE was defined can be characterized by serious economic constraints: rising inflation, a critical balance of payments, and trade balance deficits. As a result of the second petroleum price shock and critical factors, the GDP fell to an average of –1.3% a year between 1981 and 1983 (compared to the "great" years that registered a growth of 9% annually between 1966 and 1980). In 1982 Brazil embarked on an economic stabilization program, resulting in resource cutbacks. These economic constraints affected the ability of the Brazilian government to provide the necessary resources for the colonization process, with serious consequences for its sustainability.

The existing and potential settlers were can be characterized, on average, in the following manner. They were migrants, most of them with no knowledge of agricultural potential or the techniques necessary for farming in a tropical rain forest area. The migrants had no previous exposure to malaria (and consequently no immunity). They had very little knowledge of how malaria can be transmitted and treated. They were attracted by cheap land and promised government support. But the economic recession in which Brazil was in full force, and the wrong policies that the government adopted led to serious social conflicts over property rights, including violence. Tax exemptions and incentives to individuals and firms to "develop" the area brought huge corporations for mining and wealthy landholders for cattle ranching. These groups had no interest in sustainable development, but only an objective of individual profit. Attempts by the military government to solve cases of social tension by offering titles to land promoted the concept that acts of resistance were an effective way to pressure the State. This guaranteed that the strongest would rule and would do so unequivocally.

Politically, the military government was concerned both with the national security and with finding a way to alleviate the social pressure that was increasing during the recession years. Furthermore, there was a total inability to implement a serious program of agrarian reform. The adopted strategy, then, was to find in the Amazon the solution for all these pressures. Occupying the vast territory would – it was claimed - solve the problems of landless people from all over the country.

Although at the time POLONOROESTE was prepared there were numerous examples of unsuccessful colonization projects in the Amazon, it was supposed to be a model of colonization, which would prove that Amazonian occupation could be sustainable. However, the economic and social pressures stopped the political will. It is worth mentioning that part of the social pressure imposed by new comers to the area were a consequence of the publicized excellent conditions of the areas for agriculture (despite the fact that the government didn't actually have a precise knowledge about agricultural potential in the area).

4.2. Characteristics of settlers

To better understand the dynamics of malaria in Machadinho, we have to analyze the basic characteristics of the settlers, since their personal knowledge and behavior are also potential determining factors of the incidence of malaria. Table 3 gives an overview of the basic characteristics of the population living in Machadinho in 1985, 1986 and 1987.

The mean age slightly increased in the period, and the distribution by age groups reflects a general trend in the country. The proportion of children decreased, while the proportion of older people increased. The sex ratio remained pretty much constant during the period.

Paraná was the main sending area in this movement to Rondônia. Almost half of the settlers in 1985 came from this southern state. Mato Grosso also had an important contribution, but it was small compared to Paraná. The great majority of settlers had worked in agriculture before, although in totally different climatic conditions. The average settler in Machadinho was a farmer from the South of the country, who had lost his land due to the intensive process of agricultural mechanization, and who had migrated from the south to the north, searching for land.

Table 3 – Settlers in Machadinho: selected variables – 1985/87

Selected variables	1985	1986	1987
Average age	20.7	21.0	21.4
% of population in selected age groups			
0 a 14	44.4	46.7	44.7
15 a 50	45.0	47.7	49.0
51+	5.6	5.1	6.5
Origin state (%)			
Parana	47.9	42.8	43.1
Mato Grosso	13.1	16.2	15.4
Others	39.0	41.0	41.5
Activity before Machadinho (%)			
Meeiro	35.6	32.6	32.8
Rural-agricultural worker	15.0	18.3	17.4
Skilled urban worker	13.4	13.7	12.6
Sex (%)			
Male	56.0	55.6	55.6
Female	44.0	44.5	44.4
Education of the head of the household (%)			
Illiterate	37.0	36.8	46.6
Lower than 4	40.7	37.4	41.4
4 or more	22.4	18.6	12.1
Education of the head of the household's wife (%)			
Illiterate	35.6	43.9	42.5
Lower than 4	39.0	35.6	39.3
4 or more	19.0	13.4	8.7
Knowledge about malaria (%)			
Believe mosquito is the vector	36.7	31.2	33.4
Believe that don't get malaria from dirty water	32.5	38.3	44.9
House condition (%)			
Poor walls	60.2	31.8	34.8
Poor sealing	95.7	98.1	95.0
Poor covering	60.4	31.4	17.1
Average distance from the house to the forest (meters)	90	118	158
Average distance from the house to the river (meters)	761	753	not available

FONTE: CEDEPLAR/UFMG survey.

In the first years of the settlement education was very low. In 1987 only 12% of the heads of the households and 9% of their wives had four years of education or more. The high rates of illiteracy contributed to the minimal knowledge about how malaria is transmitted. In 1985 only 37% of the settlers were aware that the mosquito was the vector of the disease, and only 33% knew that drinking dirty water does not transmit malaria. As a direct consequence, personal protective and preventive measures against malaria were inefficient or totally absent (an extreme case is not

authorizing the spraying of DDT). Cultural beliefs also were a threat, since sick people would be deprived of some particular types of food believed to be "hot". They could not be consumed out of fear that the fevers experienced by an individual would be worse.

Since the promised credit support was not effective[13], most of the settler constructed very poor houses as soon as they arrived at their plots. The expected behavior was that, as agricultural production progresses, they would improve the quality of their houses. It was common to find houses with only three walls, or with no windows, for example, offering no resistance against mosquito biting. During the 1985/87 period the quality of walls and house covering improved significantly. However, house sealing remained deficient. More than 95% of the houses had a poor sealing, what would offer little protection against mosquitoes.

In 1985 the settlers had their houses at a distance of, on average, 90 meters from the forest. Through the years this distance increased, as would be expected, since deforestation was also increasing. The average distance from the houses to the rivers was around 750 meters. These characteristics reinforced the level of malaria risk to which settlers were exposed. Living near the forest with little or no personal or housing protection maximized exposure to *A.darlingi.*

4.3. Agricultural potential

Prior to the beginning of the settlement project two reconnaissance soil surveys were available. The first one, the RADAMBBRASIL project, was made in 1979, on a scale of 1:100,000. It provided only a rough indication of general resources in the area. It was not suitable for agricultural decision-making, although it was used for this purpose. The second survey was conducted in 1982, by the Brazilian Agricultural Research Corporation - EMBRAPA[14] and National Institute for Colonization and Agrarian Reform - INCRA (that was the institution responsible for coordinating the settlement process). It was made on a scale of 1:50,000 and evaluated the suitability of land for agricultural use in a particular area of Machadinho (the results cover 95% of the plots on tract 2, but no plot on tract 1). Although this scale is not quite the optimal scale for decision-making, the survey gives the most detailed information to-date for the area, and will be used here as reference.

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[13] Settlers were supposed to receive 2 m^3 of boards to build their houses, but this didn't happen as expected.
[14] EMBRAPA's mission is to provide feasible solutions for the sustainable development of the Brazilian agribusiness by generating, adapting and transferring knowledge and technology that benefit the Brazilian Society.

The assessment of land suitability for agricultural purpose was carried out assuming that the typical family to be settled would be poor and would use primitive forms of technology. Five types of constraints were evaluated. These were: lack of soil fertility, lack of water, excess of water or lack of oxygen, susceptibility to erosion, and restrictions to mechanization. Each constraint was classified as absent, light, medium, high, and very high.

Three different agricultural management levels were defined: primitive (A), predevelopment (B) and developed (C). The primitive (A) is based on manual work, with low technological level and very little investment to improve the land conditions. The predevelopment level (B) imply on the use of animal traction, medium technological level, some investment to improve land conditions, and some use of available information on land potential. Finally, the developed level (C) has high technology, with mechanization present in all agricultural phases, intensive investment to improve the land, and intensive use of information. Considering the expected potential settlers, emphasis was given to the primitive and predevelopment levels.

Three different types of land improvement were defined, which could be implemented only on predevelopment and developed management levels.

The final classification of level of suitability for agriculture was obtained from a combination of constraints, level of management, and strategies for land improvement. It was found that 12.3% of the studied area was good for agricultural use in at least one level of management; 48.4% had medium quality in at least one level of development; 34.7% presented restricted conditions; and 4.6% was inappropriate for agriculture and should be preserved. Using the plot design of the Machadinho settlement project, we classified the plots of tract 2. The major findings are presented in Table 4.

A large diversity of soils is observed. Some plots have up to four different types of suitability for agricultural use, ranging from good to inappropriate. This can compromise the success of the settlement process if farmers are not aware of the distinctions. At the primary level of management (A), more than 90% of the plots are classified as restricted agricultural use, contradicting the publicized soil fertility in the area. In accordance with Sawyer (1979), recommendations of potential areas for colonization in the Amazon did not include Machadinho as a favorable area for agriculture.

EMBRAPA's survey emphasizes that the major problems related to low crop production already observed in the area were a consequence of low soil fertility, inadequate agricultural management, lack of infrastructure and financial support, and lack of accurate information and technical assistance. These concerns were incorporated into the POLONOROESTE conception, but they failed in practice (infrastructure was poor, and financial and technical support was ineffective).

Table 4 – Percentage of plots according to suitability for agricultural use Machadinho settlement project (95% of plots in tract 2)

Suitability for agricultural use	Level of management		
	A	B	C
Good	0.18	0.28	5.62
Medium	0.00	26.82	54.75
Restricted	36.77	0.83	2.49
Inappropriate	0.00	0.00	0.28
Mixed - Good and medium	0.00	0.46	11.24
Mixed - Good and restricted	0.83	0.00	0.18
Mixed - Good and inappropriate	0.00	0.09	0.65
Mixed - Medium and restricted	0.00	9.12	15.12
Mixed - Medium and inappropriate	0.00	0.92	1.84
Mixed - Restricted and inappropriate	1.75	0.00	0.28
Mixed - Good, medium and restricted	0.00	0.09	0.37
Mixed - Good, restricted and inappropriate	0.37	0.00	0.00
Mixed - Medium, good and inappropriate	0.00	0.28	1.01
Mixed - Medium, restricted and inappropriate	0.00	0.18	0.28
Mixed - Restricted and wet soils	55.30	3.13	0.28
Mixed - Good, restricted and wet soils	2.58	0.65	0.83
Mixed - Medium, restricted and wet soils	0.00	53.82	1.75
Mixed - Restricted, wet and inappropriate	1.75	0.28	0.00
Mixed - Good, medium, restricted and wet soils	0.00	0.28	1.11
Mixed - Good, restricted, wet and inappropriate	0.46	0.28	0.00
Mixed - Medium, restricted, wet and inappropriate	0.00	2.12	0.00
Mixed - Good, medium, restricted, wet and inappropriate	0.00	0.18	0.00
Impossible to apply the management level	0.00	0.18	1.94

NOTES: 1. Inappropriate areas are recommended for preservation.

2. Wet soils present characteristics for the production of crops adapted to the excess of water.

To conclude, EMBRAPA recommended the predevelopment level of management for the area, but recognized that, at first, this would be impossible, given the socioeconomic conditions of the future settlers. The best choice, though, would be to maximize the returns of the primitive level through the cultivation of selected crops during the first years. This would generate the necessary resources to move on to the predevelopment level of management.

A list of selected adapted crops recommended by the EMBRAPA study for each management level is shown on Table 5. It is important to note that on POLONOROESTE's

recommendations, it was specified that perennial crops and fruit trees should be the basic production composition. The first of these was economically and ecologically suited to the area, and the second one was able to avoid the typical short-cycle crop disturbance on the ground. It could protect the surface from both the sun and run off, and maintain higher levels of organic matter (Leite and Furley, 1985).

Table 5 – Selected crops recommended for Machadinho according to the level of agricultural management

Management level	Selected crops
A – Primitive	Cassava, rice, rubber trees, guarana, pineapple, banana, mango, guava, cupuacu, sapoti, bacuri, graviola, abiu, peach palm, abrico, biriba, mapati, brazil nut
B – Predevelopment	Maize, beans, soy, sugar cane, sweet potato, coffee, pumpkin squash, melon, cucumber, chayote, watermelon
C – Developed	Cocoa, black pepper

We have no evidence that settlers actually had access to this kind of information. A sample survey made in Machadinho (Miranda and Mattos, 1993 and Miranda et al, 1997) suggests that they didn't, as can be seen by the analysis of three variables:

- Technical assistance by Technical Assistance and Rural Extension Enterprise - EMATER – In 1986 43.4% of the settlers didn't received any technical assistance. This number rose to 71.5% in 1989, and came back to the initial level in 1996 (44.2%).
- EMBRAPA – In 1986 65.1% of the settlers didn't know about EMBRAPA, and 88.8% never visited one of its agencies. In 1989 these figures changed to 38.9% and 67.3%, and in 1996 they were 48.1% and 64.7%, respectively.

The numbers above show that the typical settlers in Machadinho didn't have access to crucial information for the success of their agricultural production. This led to serious consequences for the adopted patterns of land use, as will be seen next.

4.4. Patterns of land use

Considering the management levels described in EMBRAPA/SNLCS (1982) we can associate with each plot the type of agriculture being practiced: primitive, predevelopment or developed. Since we don't have much information concerning the investment in land improvement and the use of technical knowledge, classification according to the three different levels was made based on the availability of a chainsaw and planter. When a chainsaw was not

available, the plot was considered as having primitive agricultural management. If both implements were available, a developed level was attributed. Finally, if a chainsaw, but no planter, was available, the plot was classified as having predevelopment agricultural management. The resulting classification is presented in Table 6.

Table 6 – Level of agricultural management associated to occupied plots in the Machadinho settlement project

Tracts	Year of the survey								
	1985			1986			1987		
	A	B	C	A	B	C	A	B	C
Tract 1									
Freq.	30	7	12	57	5	24	56	4	30
%	61.2	14.3	24.5	66.3	5.8	27.9	62.2	4.4	33.3
Tract 2									
Freq.	97	11	29	217	19	103	203	9	129
%	70.8	8.0	21.2	64.0	5.6	30.4	59.5	2.6	37.8

FONTE: CEDEPLAR/UFMG survey[15].

As expected, the majority of plots are classified as having a primitive level of agriculture. A very small number of plots were classified as having pre-development level of management (level B). This can be a consequence of the criteria used. As indicated previously, level of management involves much more than just having a chainsaw and a planter. For further analysis we consider that the primitive level is a reasonable situation for all the plots. The issue, though, is to investigate if the use given to the land corresponds to what is recommended at this level and if the right crops are being cultivated in these plots.

Based on the information available on the CEDEPLAR/UFMG survey, Table 7 shows some of the crops cultivated by the settlers in Machadinho during 1985/87.

Initially, POLONOROESTE didn't focus on support for coffee production. Actually, according to the EMBRAPA study, this wouldn't be a recommended crop for the primitive level of management (the most common in the area). The productivity obtained with coffee is below the national average. Nevertheless, coffee cultivation progressively gained in importance in the area, as a consequence of a municipal government incentive that produced and distributed seedlings to settlers (Millikan, 1996).

[15] The Center for Development and Urban Planning – CEDEPLAR, from the Minas Gerais Federal University – UFMG, coordinated the survey *Patterns of land use and malaria in the Amazon*. The study area was tracts 1 and 2 of the Machadinho settlement project. Data was collected in 1985, 1986, 1987 and 1995.

The second major perennial crop is cocoa. As in the case of coffee, this type of cultivation wasn't originally included in POLONOROESTE plans. According to EMBRAPA cocoa would be appropriate for areas where a developed level of management could be implemented. At present, cocoa productivity in Machadinho is below the national average and its quality is classified as Type II (relatively good).

Table 7 – Percentage of selected crops cultivated on Machadinho settlement project – 1985/87

Year and crop	Total	Settler's level of management		
		A	B	C
1985				
Cassava	48.39	48.03	27.78	58.54
Rice	33.87	31.50	27.78	43.90
Beans	2.69	2.36	0.00	4.88
Maize	4.30	3.15	0.00	9.76
Coffee	16.67	18.11	11.11	14.63
Cocoa	16.13	16.54	16.67	14.63
Rubber	1.08	0.00	0.00	4.88
1986				
Rice	77.18	75.55	66.67	82.68
Beans	9.18	9.49	4.17	9.45
Maize	9.65	9.49	4.17	11.02
Banana	21.41	22.26	12.50	21.26
Papaya	20.00	20.44	12.50	20.47
Coffee	65.65	63.50	66.67	70.08
Cocoa	43.76	43.07	41.67	45.67
Rubber	33.18	33.21	29.17	33.86
1987				
Banana	93.74	92.28	84.62	96.86
Coffee	88.86	88.42	76.92	90.57
Cocoa	54.99	54.08	53.85	56.60
Guarana	24.59	17.76	7.69	37.11
Rubber	33.41	30.50	15.38	39.62

FONTE: CEDEPLAR/UFMG survey.
NOTE: Cassava, rice, beans and corn are annual/semi-annual crops; coffee, cocoa, guarana and rubber are perennial crops; banana and papaya are fruit trees.

Rubber should have been the most important perennial crop in Machadinho, but problems with rural credit and technical assistance were major constraints. According to Miranda et al (1995) approximately 20% of rubber trees already had the right diameter to enter into production. However, a special training is necessary for success in rubber cultivation and harvesting. If no technical support is given, there is a risk that more than eight years of investment can be lost.

The productivity of annual crops is very sensitive to soil quality. Maize is cultivated primarily as a subsistence crop. Rice also plays an important role as a subsistence crop, but part of the production is also sold at local markets. It is considered the first crop cultivated as soon as the settler is established on the plot (Miranda et al, 1995). Production of beans is extremely low in the area and it is mostly used for subsistence.

Cultivating more than one crop was the most common situation. In 1987 there was an average of 2.83 crops per plot at the primitive level of management, 2.38 at the predevelopment level, and 3.21 at the developed level. In 1986 the situation was pretty much the same, with averages of 2.77 at level A, 2.38 at B, and 2.94 at C. In 1985, when the colonization process was started, the averages were lower: 1.20 at level A, 0.83 at B, and 1.51 at level C. Some explanations can be given for the low average of crops in 1985. First, the distribution of plots was too late for preparing the land for cultivation before the rainy season (slashing and burning) and most of the burns were of poor quality. Second, credit subsidies for inputs were not available. Finally, many people didn't live on the plots that were cultivated.

The important question to investigate now is what are the effects of these practices on malaria rates and on average amount of land cleared, used for pasture, or planted and with secondary vegetation (*capoeira*) areas.

4.5. Malaria risk and incidence

A major problem in the Amazon is malaria control. Programs to spray DDT and to diagnose and treat the disease begun in 1959. They were very effective. By 1970 there were only 50 thousand cases in the whole country. In 1982, after the colonization period had begun, this number rose to 200 thousand, concentrated in Amazonian settlement and mining areas. By 1988 there were half a million cases, basically concentrated in Rondônia, southern Pará, and Maranhão. Although morbidity was very high, mortality was relatively low.

In June 1980 Rondônia's state government adopted a basic health care policy, with emphasis on fighting malaria and reinforcing the rural health care network. POLONOROESTE's Health Project was designed to help implement this state policy, with major goals of improving malaria control, constructing a network of primary and secondary level rural health care facilities, and supporting health research. This concern was justified by the high rates of malaria in the Northwest, especially Rondônia (before the 1980s many migrants had already come to the

area and settled in previous colonization projects, usually with little adequate health infrastructure). Health services were unequally distributed before the project, and a very small fraction of the population had access to primary health care[16].

Malaria control would be a local responsibility, with federal assistance. The state would also be responsible for the construction of new health care facilities. The maintenance of these new units would be later transferred to the municipal government. Only the research activities would be administered at the federal level. In summary, the focus was to be on the regionalization and decentralization of health services, but with recognition of the limited local capacity.

It was expected that the basic health needs of a growing and large population (the new settlers) would be satisfied through the promotion of essential health care. Initial estimates showed a potential gain due to labor days saved (given improved malaria control) of US$ 1.3 million by the end of 1986.

In 1984, two years after it started, the performance of the project was considered irregular and its progress slow. The POLONOROESTE emphasis on road construction left other efforts usually behind schedule. The number of large health units to be built was reduced, while the number of small ones increased. The lack of a provision for maintenance of facilities and equipment was soon identified as a deficiency in the project.

When the Machadinho colonization project started, the health infrastructure was definitely not ready for the malaria outbreak observed in the area. A network of local pharmacies developed without control, charging abusive prices for anti-malarial drugs.

4.5.1. The vector and the parasite

The principal vector of malaria transmission in the Amazon is the mosquito named *Anopheles darlingi*. Only female mosquitoes are involved since males do not feed on blood. They prefer breeding places with clean, low running, deep, partly sunlit and clear water with pH near neutral, with aquatic plants but free of decomposing organic matter (Sawyer, 1992).

Research conducted in the Amazon in 1931 showed that in studies of comparative captures *A.darlingi* was found in much greater number indoors (endophilic) than outdoors

[16] Basic health care was available to only the 40% of Rondônia's population living at the capital and other urban centers.

(exophilic). Hayes and Charlwood, working in the Amazon in 1977, noticed that in houses that had been sprayed with DDT *A.darlingi* entered to feed but not to rest, as they would do in unsprayed houses. Early records show that *A.darlingi* was to some extent exophilic before the use of DDT (Elliott, 1972). In the 80's several studies stated that *A.darlingi* was the most important malaria vector in the Amazon, but feeding almost outdoors (in contrast with its endophilic behavior in areas of Venezuela and Suriname).

The exophilic behavior of the mosquito is a point of discussion. Some argue that the use of DDT could have contributed to this transformation, selecting only the exophilic strains of mosquitoes to be more prevalent. Others consider that extensive deforestation and disorganized occupation could be indirectly responsible for modifications in the mosquitoes behavior, subtracting their former sources of food (wild animals, who were scared away by the new settlers) and bringing man closer to their breeding places (Deane, 1988). Another question is whether and how new strains of mosquitoes would evolve in the future, due to constant environmental changes (WHO, 1956).

In addition to these differences in biting location, the vectors in the Amazon also show a particular pattern of biting activity during the day. The biting curve is basically bimodal, with peaks in the early evening (6:00 p.m.) and at dawn (5:00 to 6:00 a.m.), exactly the hours in which workers are carrying out outdoor activities (Coimbra Jr., 1988). This U-shape behavior of the biting activity is totally different from what is observed anywhere else in the World, where the distribution is typically unimodal – inverse U-shaped (Sawyer, 1992).

All these differences indicate that *A.darlingi* is not a homogeneous species. Although chromosomal and isoenzymatic studies show a high degree of heterogeneity, no morphological characteristics for separation of sub-species have been found (Rosa-Freitas et al, 1992).

4.5.2. Impacts of POLONOROESTE and ecological transformations

As pointed out by Millikan (1996), eight factors seem to contribute the most to the persistence of malaria in Machadinho:

- The existence of permanent breeding sites for *A.darlingi* along rural roads, created due to poor drainage.
- Poor housing conditions.

- The deforestation and expansion of cattle pasture.
- The permanent influx of temporary laborers with no immunity.
- Rapid frontier expansions in several locations near the Machadinho project.
- Persistent deficiencies in professional staff, equipment and materials of the health system.
- The routine behavior of rural population (agricultural work, washing clothes and bathing in the river margins, fishing, etc), which facilitates the outdoor transmission.
- The low level of knowledge about the disease.

From these eight factors, only the last two are not directly driven by the negative consequences of POLONOROESTE[17]. In general, a lack of administrative skill to manage the huge resources and many different activities was observed. In addition, the coordination of the different projects that composed POLONOROESTE was carried out by more than ten different institutions, but without effective interaction among them.

One of the major problems, resulting from the emphasis given to POLONOROESTE, was the pace of the implementation of each project that composed the program. Road building activities were within or ahead of the deadlines, but the other program components suffered delays. Many migrants were using the road to come to a place with no adequate infrastructure to support them. The health sector was not prepared to deal with consequences observed in the first years of the program, particularly the malaria epidemic. Health posts that were supposed to be built were not ready. Health care for the first settlers was limited to the health center located at the urban area of Machadinho. Residents of plots that were most distant from this urban area had to travel up to 40 miles in the search for care. If the feeder roads had already been completed, the settlers would not have been isolated during the rainy season. In addition, managerial and operational difficulties were observed in the attempts to strengthen malaria control activities.

Immediately after the Settlement Project started in Machadinho, an uncontrolled influx of migrants was observed (the number of migrants jumped from 49 thousand to 166 thousand between 1980 and 1986). The situation was compounded by the fact that newcomers had no

[17] The original plan of POLONOROESTE included the creation of six colonization areas, and the settling of 15,000 farm families. However, given the "unexpected" poor soil conditions, only 5,000 farmers were settled. Part of the project and a corresponding portion of the loan were cancelled.

immunity against malaria and had very poor knowledge of the disease[18]. The combination of high human population density, a high vector density, and lack of immunity of settlers was destined to produce a malaria outbreak in the area.

The migration process was not associated with an increase in the wealth of the region, since migrants were basically poor people attracted by cheap land. Basic infrastructure, water supply, sewage disposal, housing characteristics, health services, and educational levels, although major concerns in POLONOROESTE, were all deficient at the beginning of the Machadinho Colonization Project. This, in addition to malaria, many other serious health problems were observed, including leishmaniasis, schistosomiasis, tuberculosis, leprosy, diarrheal diseases, intestinal parasites, respiratory diseases, and injuries resulting from work-related accidents and violent conflicts concerning property rights.

Figure 8 – Rondônia forest cover in 1975 (http://www.bsrsi.msu.edu/trfic/index.html)

[18] The effects of poor knowledge are addressed in detail in the next section. It is not a direct effect of POLONOROESTE, since it is characteristic of the migrant. But one can actually argue that it is an indirect effect, because the project promoted a selective migration to the area in favor of people with poor knowledge.

The financial support promised for both housing (special wood and other essential materials to build a safe house) and agriculture (distribution of seeds and basic equipment) was not effective. Many settlers barely had money to build a good house, clear the land and prepare it for cultivation.

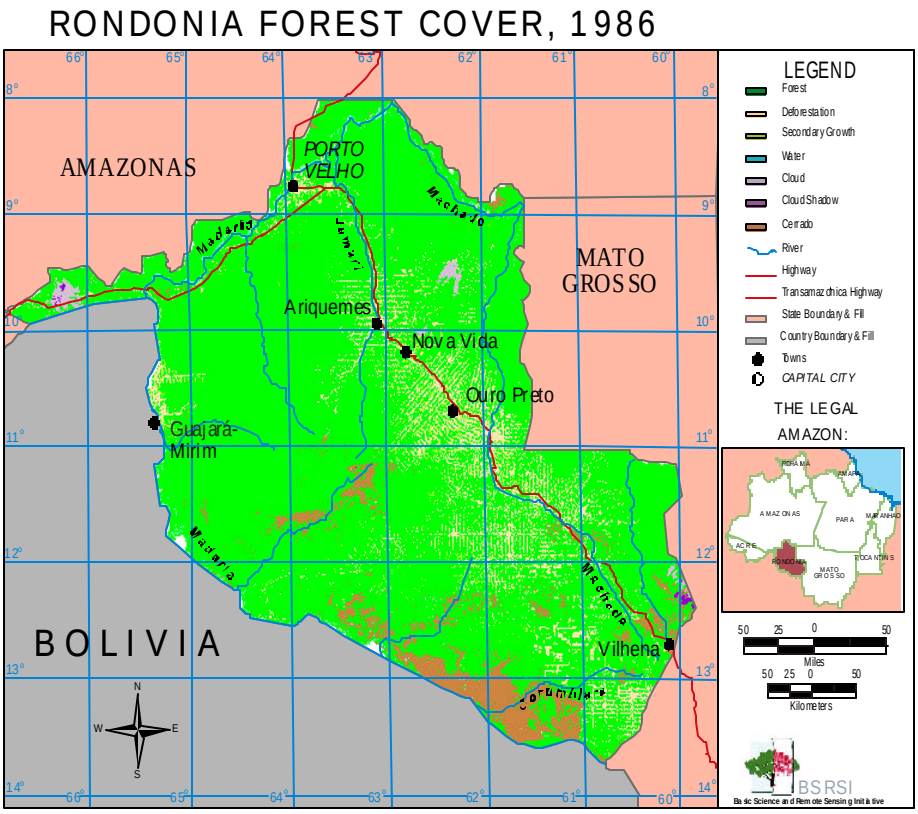

Figure 9 – Rondônia forest cover in 1986 (http://www.bsrsi.msu.edu/trfic/index.html)

Poor drainage along the constructed feeder roads contributed to the permanent availability of breeding sites. Thus, aside from the natural breeding sites found in the area, multiple human activities ended up promoting the proliferation of new ones (mining and poor forest clearing, for example).

Although not responsible for its onset, POLONOROESTE contributed to the acceleration of environmental degradation in Northwest Brazil. This is clearly seen in satellite images taken in 1975, 1986 and 1992 (Figures 8, 9 and 10). One can easily see that by 1975 the whole state was basically jungle, with some deforestation along the BR-364, in the Ouro Preto colonization project (started in 1969). Progressively, deforestation increased and was concentrated along the BR-364. In numbers, in 1975 only 0.3% of the total state area was deforested. In 1978 the

percentage was 1.7, slightly increased to 3.1 in 1980, and jumping to 23.7% in 1988 (Mahar, 1989). Although these numbers vary according to the source, it is a fact that increasing deforestation, accompanied by an increase in forest burning, was in progress.

In addition to clearing and burning of land, other man-made transformations of the environment were also important. Among these are the water pollution due to sewerage, waste, and mining activities, as well as the mining in the *garimpos* (gold and cassiterite). Mining was always associated with violent social conflicts and natural resource exhaustion.

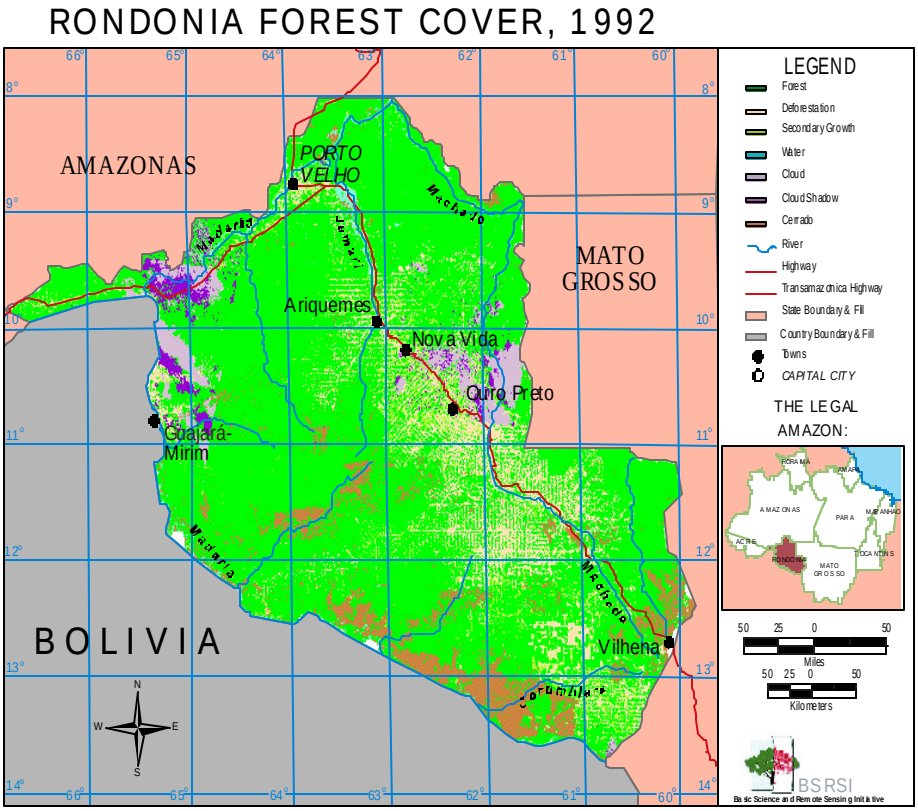

Figure 10 - Rondônia forest cover in 1992 (http://www.bsrsi.msu.edu/trfic/index.html)

Since the soil conditions were much poorer than initially expected, agricultural returns were limited. Many settlers abandoned their plots after successive malaria infections and continued crop failures. However, while many people abandoned their lands, an even higher number of migrants came to the region, creating a permanent influx of people (with no malaria immunity) always interacting and changing the environment. It was estimated that almost one quarter of the settlers present in 1985 were no longer on their plots in the next years (Martine, 1990).

Transforming a plot into pasture area was one of the alternatives found to minimize the economic effects of a crop failure. However, this activity implied much more deforestation. In addition, the high rate of plot turnover exposed the settler to starting the process all over again. This means that he will begin with a poor clearing area, having poor housing conditions and being highly exposed to malaria transmission. The problem reached very serious dimensions, since some areas outside the demarcated plots of Machadinho were also being deforested.

With respect to the Amerindian health conditions, a special project allowed the purchase of vehicles and equipment. Doctors and nurses were assigned to Indian reserves either to live (with increased salaries) or to make regular visits, providing drugs and health care to sick people. However, rising inflation eroded the salaries, and equipment was not maintained or replaced and began to deteriorate. Local health centers were not working properly, and traditional health practices were of limited effectiveness in dealing with new diseases brought in by settlers. Ultimately, the Indians had to travel long distances to search for health care, further exposing them to serious illness.

All of the above factors together made the situation so critical[19] that one internal Bank memorandum stated "the incidence of malaria in places like Machadinho is alarming" jeopardizing "the ability of project staff to stay healthy" (World Bank).

4.5.3. Inefficacy of traditional control measures

Traditional measures for malaria control are well known and the World Health Organization -WHO usually encourages countries to adopt some. They can be summarized as (Shuler, 1985; Nájera, Liese and Hammer, 1992; and Bruce-Chwatt, 1987):

1. Anti-parasite
   1.1. In man
   1.2. In mosquito
2. Anti-vector
   2.1. Chemical control
      2.1.1. Larviciding

[19] Given the consequences of POLONOROESTE in the first years, other loans were later approved. This included the Amazon Basin Malaria Control Project (Loan 3072-BR), in the amount of US$ 99 million, approved on May 25, 1989.

2.1.2. Adulticiding (household or outdoor spraying)

2.2. Environmental management

2.2.1. Environmental modifications (irrigation systems, filling, sanitation and drainage)

2.2.2. Environmental manipulations (water-level fluctuations, regulation and improvement of natural water courses, intermittent irrigation, sluicing, salinity, vegetation clearing and aforestation/deforestation)

2.2.3. Man-vector contact reduction (site selection, bednets, repellents and protective clothing)

2.3. Biological control

2.3.1. Anti-larval (predators, parasites, pathogens, bacteria and hormones)

2.3.2. Anti-adult (chemo-sterilants and genetic control)

Most anti-malarial drugs were developed during and after the World War II. While none is completely effective in all stages of the disease, they are essential to limit death and minimize the loss of productivity. Distribution of anti-malarial drugs on a large scale depends on available funds for their purchase. However, mass administration of anti-malarial drugs has led to parasite resistance in many areas of the world. Resistance to quinine was detected as early as 1910 in Brazil, and now drug resistant strains of parasites are spreading throughout the Amazon. Chloroquine resistance was detected in the Amazon almost 30 years ago. This represents a major problem.

Spraying techniques, although one of the most frequently used measures, also have many problems. Long periods of exposure to DDT favors a selective pressure on mosquitoes, leading to resistance and changes in behavior. By 1983, resistance to one or several insecticides has appeared in 57 species of anopheles. Furthermore, in the Amazon the transmission is largely due to outdoor biting, so indoor protection (bed nets and indoor spraying) is of limited value. Another point is that the typical house in colonization projects is of poor quality, which compromises the positive effects that DDT could bring. Finally, even if there were no resistance to DDT, spraying so huge an area demands a transportation network and services that definitely are not available and that the Ministry of Health cannot afford.

4.5.4. Incidence during 1985-87

Malaria was seen as an intractable problem. Despite the intensification of spraying, case detection and treatment activities, the size and complexity of malaria in the area was a threat. In 1985, 65.7% of the population in tracts 1 and 2 had malaria at least once, and this number

jumped to 90.1% in the next year. Also in 1986, 55.9% of people had more than 5 malarias (Sydenstricker, 1992).

Table 8 shows the evolution of malaria cases in Rondônia before and during the implementation of POLONOROESTE's Health project.

Table 8
Malaria cases in Rondônia before (1970/81) and during (1982/88) the implementation of POLONOROESTE's Health Project

Year	Slides examined	Positive cases	% Positive
Before Health Project			
1970	22,960	5,790	25.2
1971	26,862	5,650	21.0
1972	30,413	5,617	18.4
1973	34,540	7,323	21.2
1974	37,311	8,187	21.9
1975	54,981	16,705	30.3
1976	58,706	16,157	27.5
1977	83,729	23,488	28.0
1978	96,034	27,989	29.1
1979	130,756	45,356	34.6
1980	179,943	59,145	32.8
1981	203,298	59,595	29.3
During Health Project			
1982	213,463	58,936	27.6
1983	245,545	80,703	32.8
1984	433,323	151,095	34.8
1985	502,350	168,302	33.5
1986	539,092	189,986	35.2
1987	621,461	228,866	36.8
1988	828,322	278,268	33.6

Source: SUCAM (Superintendence for Public Health Campaigns), Rondônia.

Positive cases grew from almost 6 thousand in 1970 to slightly more than 59 thousand cases in 1980 and more than 168 thousand in 1986. In these years, respectively, Rondônia represented 11%, 35% and 42% of all cases of malaria. Nationally, in 1985, 10,492 positive cases were registered in Machadinho, representing 39% of the slides examined. In this same year, Machadinho was responsible for 7% of malaria cases in Rondônia and almost 3% in Brazil. According to Sawyer and Sawyer (1987) it was also responsible for many of the cases exported to southern Brazil, through migratory movements.

As apposed to malaria in Africa, in the Amazon morbidity is very high but mortality is low. The consequences to agricultural production are significant. According to Miranda and

Mattos (1993) and Miranda et al (1997) the average number of working days lost due to disease was 55 in 1986, 39 in 1989, and 22 days in 1996. Peaks of malaria infection occur at the beginning and the end of the rainy season. The latter period is exactly the time when land is prepared for the next agricultural season. Getting sick at this time can compromise production, since settlers basically depend on family labor, and cannot replace their labor force easily. As Sawyer and Sawyer (1987:66) affirmed:

> "High malaria prevalence may contribute to *negative* selectivity with regard to both attraction and fixation of settlers who have more resources and skills. Those who go to Machadinho and stay there have few alternatives. Malaria is a particular serious problem for family farmers, because they cannot easily substitute for disables labor and because they must bear the direct and indirect costs of malaria of the entire family. Speculators and commercial farmers, on the other hand, need not reside on the farm and can hire labor as needed. Turnover of settlers, to which malaria contributes, leads to reconcentration of property, defeating the social purpose of colonization. In economic terms, malaria makes the strong stronger and the weak weaker."

The occurrence of many mining camps in the region is a serious factor for malaria transmission. The population of these areas has high mobility, extremely precarious conditions, and the extraction techniques favor the proliferation of breeding sites[20], transforming these areas into serious reservoirs of malaria. Even more critical is the fact that people working in the camps move frequently from one place to another, carrying the parasite to wherever they go. Once the density of mosquitoes is high, transmission of malaria is facilitated. Specifically in Machadinho, almost nobody living in tracts 1 and 2 worked in mining camps (only 0.2% in 1986).

There are significant differences in malaria rates by sex, age, activity and distance of the house to the forest, as reported by Sawyer and Sawyer (1987). The focus on this paper, however, is on differences by agricultural potential and land use, as shown in the next section.

4.6. Relations between agricultural potential, land use and malaria

The primitive level of management is the most frequent among settlers, while the majority of plots have soils with restrictive or restrictive and wet conditions for agricultural use (as shown before in Table 4). Figures 11, 12 and 13 highlight the types of soil, showing the

[20] Mining camps (*garimpos*) are typical sites of malaria, sexually transmitted diseases, hepatitis, and a variety of human diseases associated to uncontrolled boomtowns. The extensive forest clearing and the innumerous digs opened have poor drainage favoring the proliferation of breeding sites for mosquitoes. Usually workers practice self-medication, contributing to the increase of drug resistance.

different crops cultivated, and the annual malaria rates in each plot in 1985, 1986 and 1987. A simple comparison of the three figures shows how the occupation of plots occurred in Machadinho during the first three years of the colonization project.

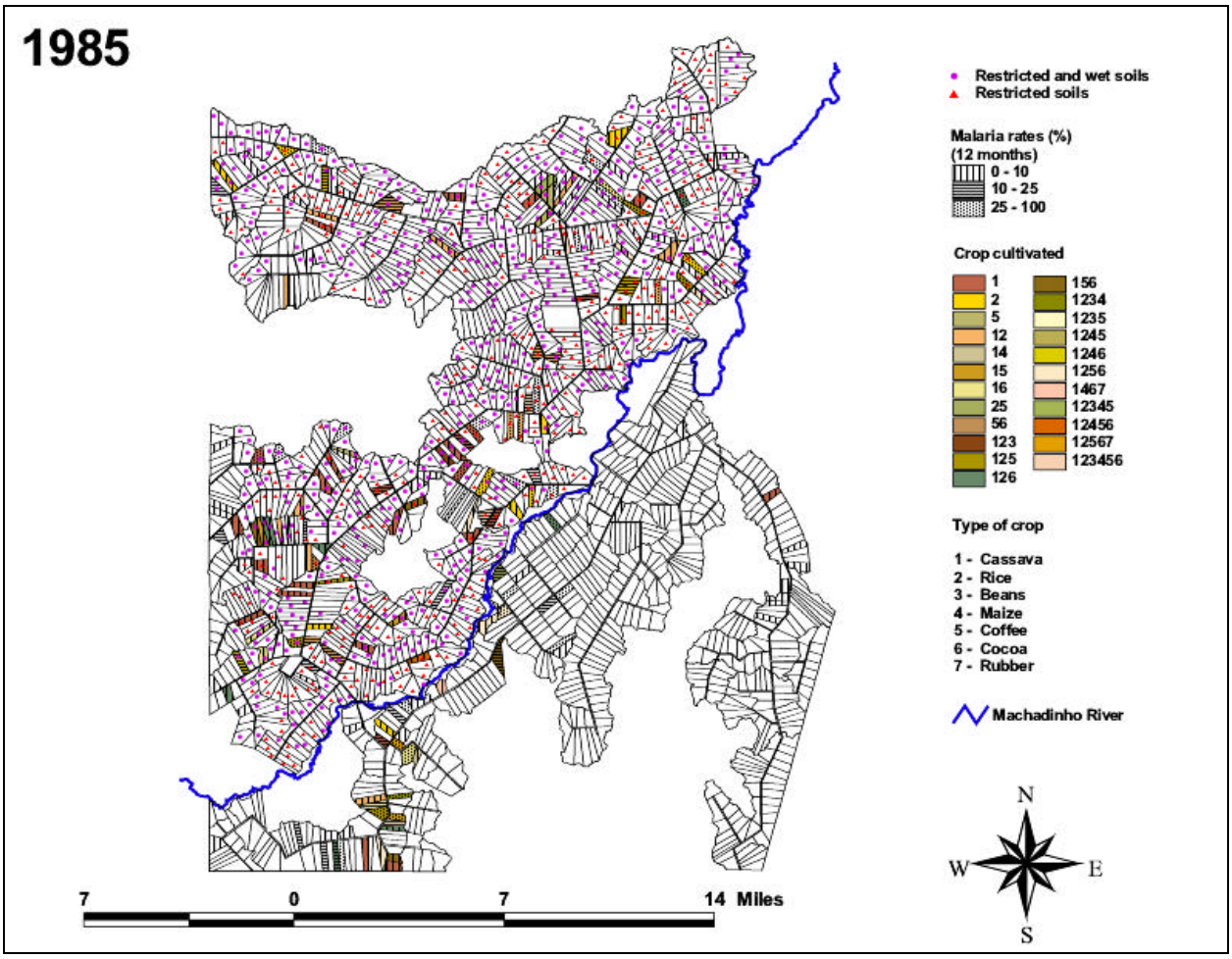

Figure 11 – Annual malaria rates and crops cultivated in tracts 1 and 2 of Machadinho - 1985

The annual malaria rates were obtained from self-reported information. For each month of the year, people were asked if they had malaria and where they were living during that month. Singer and Sawyer (1992) worked with perceived malaria illness reports, collected in a field survey in southern Pará in 1994, showing that such data is reliable in the early stages of colonization. The advantage of self-reported information is that it provides data in a highly mobile population, where blood samples would be difficult to obtain. The possible problems with this type of measure, as Sawyer and Sawyer (1987) point out, are related with sensitivity and specificity. The first one is related to the ability in recognizing the symptoms of malaria. This doesn't seem to be a problem in Machadinho, since most of the settlers presented no

previous immunity against the disease, and so manifestation of the illness is easily recognized. The second one discusses the possible confounding effects with other febrile diseases. This also doesn't seem to be a problem in Machadinho, since the high prevalence of malaria in the area reduces the chance that the disease will be confounded with low prevalence diseases, such as arboviruses.

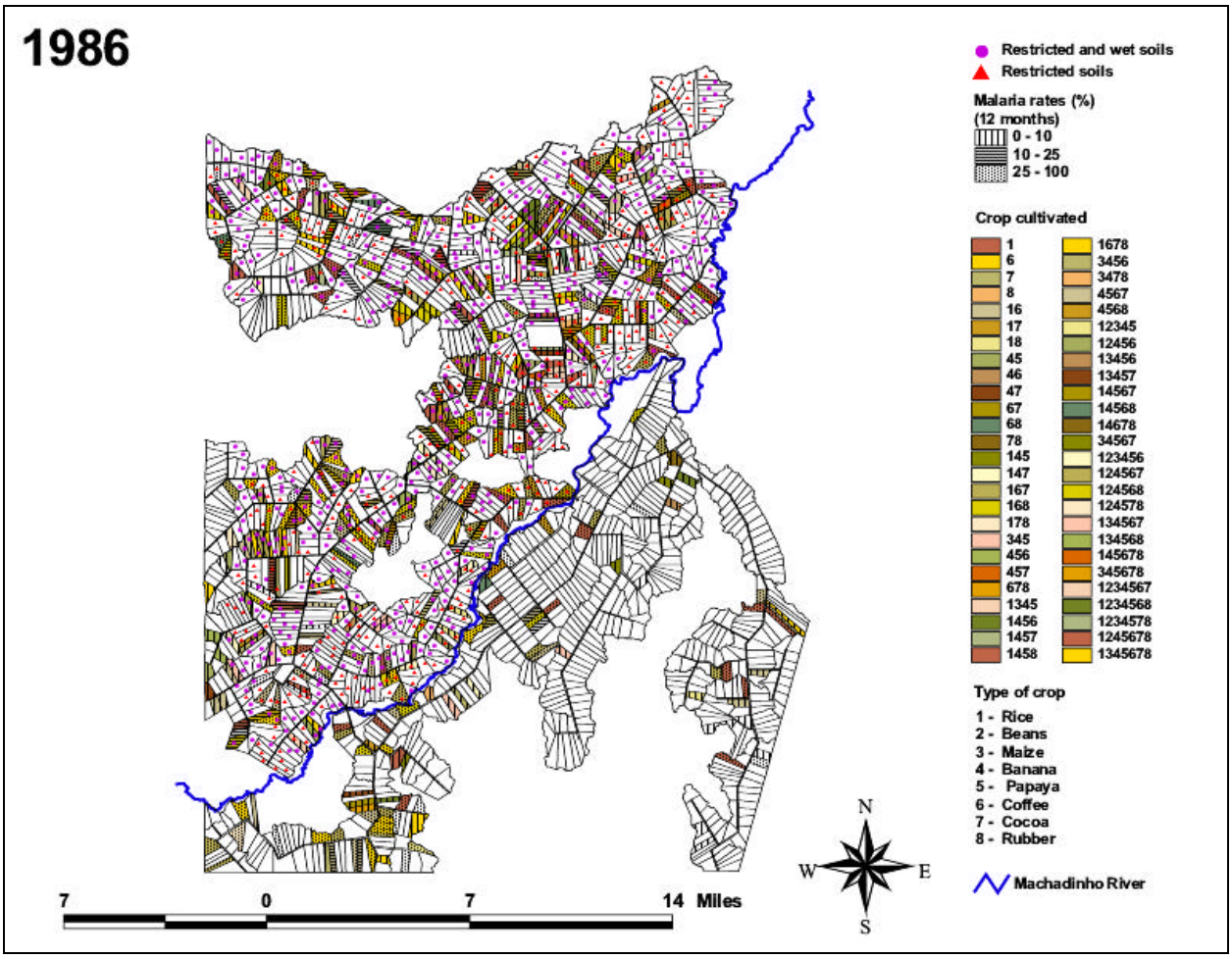

Figure 12 - Annual malaria rates and crops cultivated in tracts 1 and 2 of Machadinho - 1986

Although there is no precise information on the soil characteristics of plots in tract 1, there is no reason to believe that they would be much different from those observed in tract 2. For a primitive level of management, most of the soils are likely to offer restrictive or restrictive and wet conditions for agriculture.

According to the EMBRAPA survey, cultivation of cocoa should be made only with a developed management level, given the high demand of nutrients required by this type of crop

(most of the soils would need a chemical compensation for good production). However, this is a frequent crop in Machadinho (actually the second major perennial crop). It could be argued that this is one of the main reasons for the low productivity and medium quality of cocoa in the area. The same problem occurs with coffee, maize and beans, which should be produced only with predevelopment management practices. Maize and beans are mostly cultivated as subsistence crops. Coffee is the major perennial crop in the area, although with low productivity levels.

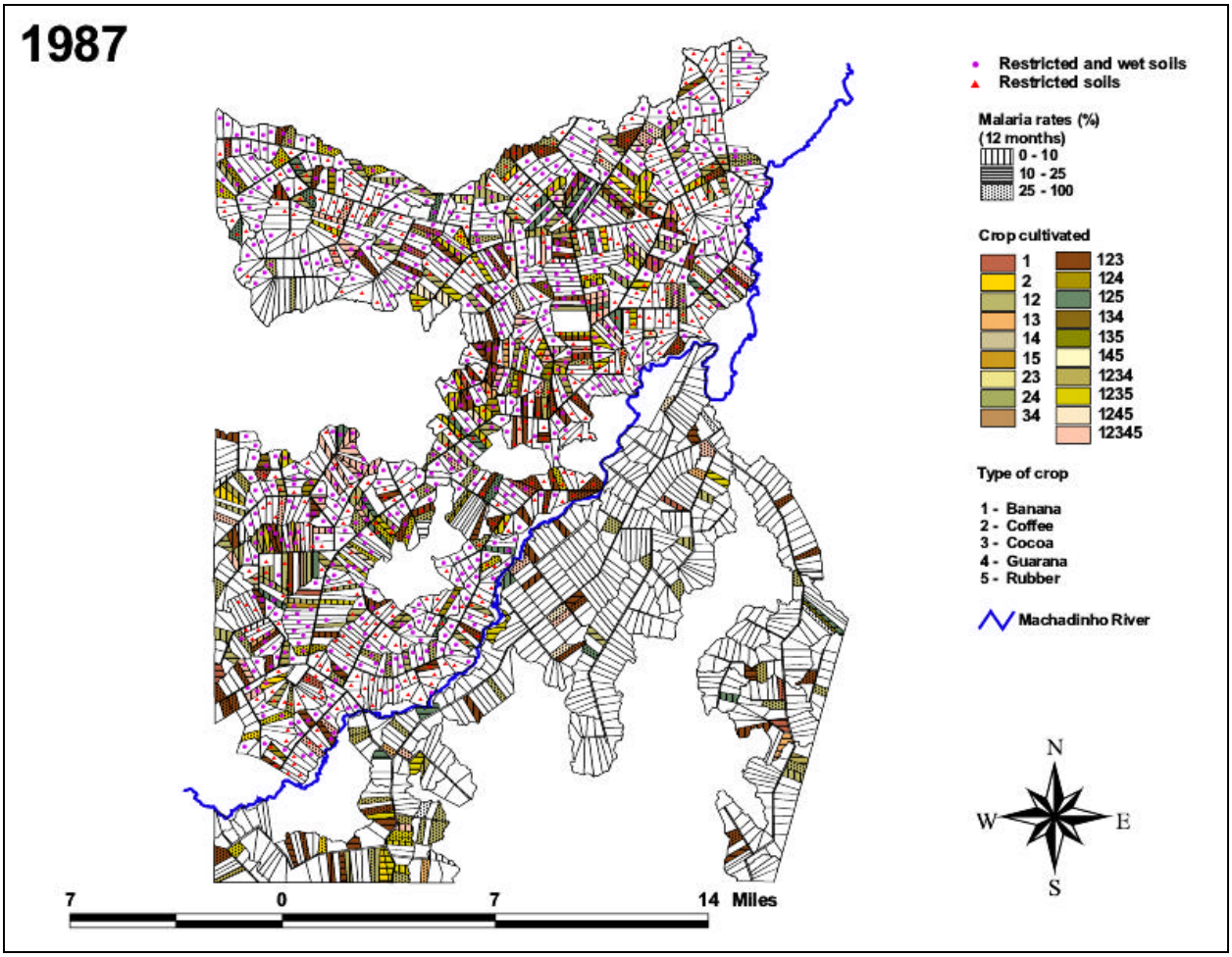

Figure 13 - Annual malaria rates and crops cultivated in tracts 1 and 2 of Machadinho - 1987

Table 9 summarizes the malaria rates for each of the most frequent types of soil. Although duration-dependent malaria rates decreased in 1987, the analysis of the rates for occurrence of malaria at least once show that, in this year, almost everybody living in restricted soils for agricultural practice, at the primitive level of management, got sick at least one time. The consequences for production are serious.

The analysis for specific crops reveals interesting findings. Rice should be cultivated in soils that present wet conditions. In 1985, plots that had restricted and wet conditions, and that were cultivated only with rice, were associated with an annual malaria rate of 32%. However, 60% of people on soils with restricted and wet conditions got sick at least once. If rice was the only crop in restricted soils it was observed that 80% of people had malaria at least once. It could be argued that, with primitive levels of management, the quality of irrigation for rice crops implemented in restricted soils was precarious and risky. Taking advantage of the wet conditions of the soil was a better strategy. However, the information about soil quality was not available to the settler, and in the absence of technical support, the best that the farmer could do was to apply previously acquired knowledge. Unfortunately, knowledge of agricultural practices in the South or in the Northeast doesn't mean a lot in the Amazon.

Table 9 – Malaria rates by suitability of agriculture use – Machadinho, tract 2, 1985/87

Year and type of soil	Total of plots	Malaria rates (%) (12 months)	Malaria rates (%) (at least once)
1985			
Restricted	52	19.823	51.923
Restricted and wet soils	64	15.942	39.063
1986			
Restricted	133	33.589	70.677
Restricted and wet soils	172	27.727	69.767
1987			
Restricted	130	20.824	94.615
Restricted and wet soils	164	17.644	87.805

NOTE: Malaria rates for 12 months are defined as the number of months with malaria in a period of 12 months divided by the total number of months of exposure in that period.

Malaria rates for at least one occurrence are defined as the number of people who had at least one month with malaria divided by the total number of people exposed.

In 1985 and 1986, plots with more than four different crops being cultivated were associated with low malaria rates. A possible reason is that in order to have such a diversity of crops, large areas of forest must be cleared. This moves the forest fringe away from the house (albeit the risk is still present and high, especially when the settler is working on the crop). In 1987, however, most of the people got infected at least once, and multi-cropping practices didn't seem to offer a "protection" anymore.

In 1985 and 1986, coffee and rice was a bad combination in both restricted and restricted and wet soils, with almost everybody in the plots having at least one malaria episode. Planting

only cassava in 1985 was associated with plots where almost 40% of the people got malaria. It could be argued that, since it was the beginning of the settlement project, these people didn't have enough resources to clear and prepare the land for cultivation before the rainy season. Planting cassava was an issue of subsistence more than an economic strategy. The cleared area was very small and actually the family was living inside the dense forest, which is less risky than living near the forest (at the forest fringe). However, it could also be argued that the quality of deforestation was very poor, and as more areas are cleared, the areas used for planting cassava can become potential breeding sites for *A.darlingi*. Unfortunately there is no information on cassava cultivation in 1986 or 1987, but the careful analysis of particular plots on the maps can fill in this gap. From Figures 11, 12 and 13 one can clearly see that from the 19 plots with restricted or restricted and wet soils, planting only cassava in 1985, 7 were empty in 1986 (plot turnover). In 1987 all of them were occupied again basically with coffee and/or cocoa.

The analysis of particular groups of plots shows how crop practices and malaria rates changed through time. From 1986 to 1987 many plots that previously had rice as the basic crop, switched to or dramatically increased coffee production. This change was accompanied by reductions in annual malaria rates. Some plots not occupied in the first two years of the project, started with a large diversity of crops in 1987. However, those near the forest reserves experienced high annual malaria rates.

The dynamic process described above show that agricultural potential and land use does effect observed malaria rates. How much of this effect is direct or indirect, generated by the interaction of all the many variables playing in this context, has to be determined. The important issue is that it is not possible to think about fighting against malaria in the Amazon without taking these complex dynamics into account.

Providing farmers with technological resources won't have the desired effect if their knowledge about the disease is not significantly improved. Analogously, increasing their level of education won't make any difference if they aren't aware of the consequences of man-made ecological transformation.

5. MAJOR LESSONS

The analysis of Machadinho colonization project leaves no doubt that it was very far from being a model of successful colonization in the Amazon. Lessons learned from this experience are important for future policies. They can be summarized as:

a) The Amazon cannot be the used as the solution to social pressures of the country. Past governments refused to face the agrarian reform in the country and instead continued the myth that the frontier represented an opportunity for those with the ambition and courage to seize it.

b) Part of the POLONOROESTE failure can be attributed to the lack of commitment of the Brazilian government[21] and all the institutions involved in controlling the activities. Even when the failure was recognized, the government attitude was not to make it public.

c) The major focus on road building, with less concern for the other components of POLONOROESTE, compromised the success of the whole project. Activities related to the Health project were usually behind schedule.

d) Strictly political issues did not drive road construction and colonization efforts. Lack of careful studies allowed roads to be opened and people to have access to inappropriate areas, generating serious social problems.

e) A mix of favorable natural conditions for mosquito breeding, man-made transformations of the environment - especially deforestation - intense mobility of the population, personal behavior, shortage of health units and low knowledge of the disease made malaria in Machadinho more than a health problem.

f) The exclusive use of traditional control measures against malaria transmission would fail in the area.

g) Local pharmacies in Machadinho charge absurd prices for anti-malarial drugs, with no control from the government. A study made in the area, interviewing some pharmacists,

[21] Brazil has clear examples that when commitment is made, and if there is real interest in private companies to cooperate, good results can be obtained, even in areas of high risk, such as gold mines, hydroelectric projects and construction camps (Sawyer, 1992). The analysis of historical control of malaria in Brazil is full of these examples: control in the Amazon during the World War II, to protect collectors of native rubber; control in the city of Breves (Pará state) in 1945; control in the southern region timber extraction (Deane, 1988); and control in Maranhão state (Silva, 1989).

confirmed this situation. When asked about the prices of the anti-malarial drugs, pharmacists said that they could not be revealed. Otherwise, the government would eliminate their commerce. Although exorbitant pricing is well known in the area, no official measure has been taken to prevent this situation or to punish violators of pricing regulations.

h) The community power in Machadinho was originally very poor. However, this situation is actually improving in the area. Local agencies have not promoted any special activity. Nevertheless, since 1984 many studies have been made in the area, and one of the strategies is to promote community meetings, where information about health, social and political issues are discussed.

i) Vector and parasite characteristics are unique in Machadinho. The biting behavior is typically exophilic and the peak hour biting curve follows a U-shape pattern. Resistance both to DDT and to drugs is observed in the area.

j) The general infrastructure conditions (housing, water, etc) are poor and sanitary conditions are deficient.

k) The government did not take any serious measures to control deforestation in the area, as well as in areas near the borders of the colonization project.

l) The overall health of the Amerindian population worsened.

m) As a whole, malaria in Machadinho can be called frontier malaria, a notion that incorporates the social perspective in the health problem.

n) Lack of technical support at the start of the colonization project, together with the large diversity of soil types in the area, was an important factor in the low crop production.

o) With a primitive level of management, soil conditions are hardly improved. Cultivating inadequate crops for the type of soil present can even increase the already high risk of malaria transmission.

p) Malaria in the Amazon is a complex issue that involves social, political, economical, ecological and agricultural issues. Any efficient measures to improve health conditions must consider all these factors together.

6. RECOMMENDATIONS

Based on the facts here discussed, a set of recommendations for malaria control is proposed here.

- The health strategy to control malaria should be based on a vertical approach, given the dimensions and serious impacts of the disease. But the strategies used to control malaria must be reviewed, since the adoption of traditional measures proved to be inefficient.
- Establish an intersectoral effort in order to integrate actions on health and educational sectors. Information about how malaria is transmitted and treated, what can be done to decrease its transmission, how to take medicines, and which personal behavior should be avoided is crucial in promoting health. Community meetings, schools, media, and health centers are some of the potential channels for spreading this knowledge.
- Promote specific research studies, in order to increase the knowledge of vector habits and preferences, possible drug resistance, and parasite characteristics in the area. The results of these studies could point out the need for a diversification of the drugs distributed by FNS (National Health Foundation), and also for a set of recommendations related to prevent human exposure.
- Health centers must be available in all areas already occupied. They should be reachable even during the wet season, and should have adequate equipment and trained personnel to provide early detection and treatment of malaria. They must keep good records of all occurrences, in order to create the necessary data for intensification/reorientation of policies. This information is crucial also for general health surveillance in the Amazon, which should incorporate GIS (Geographical Information Systems) methodologies that will allow for a stratification of the disease, determination of different types of malaria transmission in the area, as well as different risks of transmission.
- Search for collaboration of private companies, NGOs and international funding institutions in order to finance the construction of better houses, to improve sanitary conditions, to minimize the existing breeding sites for the mosquitoes, and to promote the use of bednets. Streams and rivers should be kept free from obstruction, reducing the favorable conditions for mosquitoes.

- Suggest a change in the hours of school and of work in order to prevent the outdoor biting at the peak biting hours (on the dusk and the dawn). This measure has to be taken in cooperation with all the companies and schools settled in the area. Additionally, the population has to be aware of the reasons for this shift, and the importance of staying home during the critical times. Without this consciousness, people would go out anyway, and there would be no positive effects.
- Create a conscience of health as an individual right, and as such, something that can be achieved. This can only be done with effective community participation.
- In the areas where indoor biting is still the most frequent vector-man contact, emphasize and promote the use of bednets and insecticide spraying.
- Promote a campaign that informs the population of the problems in the area, the fragility of the forest, and the idea that no other settlement projects will be promoted. There is no way to limit migration to Amazon. It is unethical, since the individuals have the free right to choose where to live. But to give a real sense of what is going on in the Amazon is an obligation of the government.
- Promote commitment from all levels and sectors (health and non-health ones) of the government. This is also a key point. The failure of the POLONOROESTE was partly caused by the lack of this commitment.
- Given the population concentration and intense movement in *garimpos*, actions for malaria control in these areas should be basically in the form of case detection and treatment.
- In order to increase coverage and decrease the average duration of episodes, case detection should continue on Sundays and holidays, when people from the rural areas usually go to the urban centers.
- Health centers should provide anti-vomit medicines to insure that anti-malarial drugs will be absorbed. They should also inform patients about adverse effects, treating infected people more as patients and less as malarial cases.
- Regulate and monitor the distribution of drugs in local pharmacies, with a clear pricing policy.

- Guarantee a health package of basic services to the population, including primary health care and the availability of drugs that cover all major diseases in the area. The drugs should be freely distributed, or at a very low cost, giving the poor and sick people the chance of avoiding the absurd high prices of drugs in local pharmacies.
- Special care must be given to the Amerindian population, which lives in even more isolated areas. The health units that once were available to these people should be reinstalled.
- A fiscal policy should tax the capital gains from land sales, in order to increase the cost of speculating in the land market and improve the farming alternative. Furthermore, a policy for collection of property taxes should be effectively implemented, which would increase the cost of maintaining big properties, and encourage landholders to sell portions of the total areas, to the benefit of small farmers.
- Sustainable carrying capacity estimates must be done in order to establish the maximum number of persons that can be supported in perpetuity on the area, with a given technology and a set of consumptive habits, without causing degradation. Acceptable probabilities of colonist failure, and measures of variability (that characterizes tropical agriculture) have to be taken into account. Surveys and researches already conducted in the area by governmental institutions and educational centers constitute the basic inputs for the development of the estimates.
- Fiscal incentives and tax exemptions should be abolished in the Amazon, especially for livestock, which take benefit from the incentives to appropriate huge tracts of land on the agricultural frontier, and promote deforestation.
- Efforts have to be concentrated in land already under cultivation, and promotion to open to new areas must be restricted. Soils of very poor fertility, and which had already been cleared, should be considered for forest recover.
- A high diversity of crops should be promoted, to exploit soil nutrients and sunlight fully. The ground must be covered as much as possible, to minimize erosion and deterioration of soil physical properties.
- The information on soil quality and crop adequacy should be available for settlers, and technical assistance on the better alternatives to improve soil conditions have to be

disseminated. EMBRAPA can be the institution responsible for that. They must assume a proactive position, and not wait for the settlers to go to their local agencies for assistance.

Comparing the measures proposed here with the traditional ones described before, one can see the social emphasis of the former (as recommended by the WHO). In the Amazon the strategy cannot be different, since the characteristics of the population and culture are of paramount importance.

In general, the returns of the proposed measures would be not only for malaria control, but also for the general improvement of health conditions of the population. Although this may seem too ambitious, the issue to keep in mind is that something has to be done now. Facing malaria in the Amazon is a question of persistence, not perfection.

7. CONCLUSIONS

The available evidence shows that colonization in the Amazon was a mistake from the beginning. The inability of the government to engage in the necessary planning and the agrarian reform, associated with political, social and economic pressures, was the major determinant of inadequate frontier settlement. Roads were constructed before any carrying capacity study was ever made. Knowledge of soil quality was poor. Infrastructure was inefficient. Agriculture outcomes were far below expected. Health conditions deteriorated, especially due to malaria outbreaks. Finally, although the migratory movement to the region was extremely significant, many settlement projects couldn't reach their initial goals of number of families settled.

Focusing on Rondônia state, the Machadinho settlement project (part of POLONOROESTE program) was planned to be a model of colonization that would avoid all the errors of previous settlements. However, poor management, economic recession, and a disorganized process of occupation brought all the past problems back and added new ones.

Man-made ecological transformations, poor soil quality, lack of knowledge of the best crops to cultivate, absence of technical and financial support, no immunity against malaria, lack of knowledge of how to prevent and treat malaria, and unique vector behavior acted together in a complex and intricate way, transforming the area into a high risk zone for malaria transmission.

This paper discussed some facets of this intricate process. Malaria rates in the area appear to be highly variable. With a particular focus on agricultural potential and land us, we showed

that plots with different crops can actually show very distinct malaria rates. How much of this difference can be attributed only to land use practices is yet to be determined, since many other factors are contributing to this scenario.

Using a study from EMBRAPA (1982) we showed that soil quality in the area was very poor, especially for the type of settlers that would occupy the area. Landless people with little or no resources wouldn't be able to adopt even the minimal techniques to improve soil conditions and increase the chances of successful production. Productivity in the area is actually below the national average.

Considering that one of the main objectives of POLONOROESTE was to achieve the harmonious socio-economic development of the region influenced by the BR-364, we can say that, particularly in the case of Machadinho, this was not achieved. There is evidence that some indicators actually improved by 1995, such as the level of education and the quality of the houses. The process of changing malaria rates and land use between 1987 and 1995 is yet to be investigated.

Future studies should have to incorporate available 1995 data and analyze the sustainability of the agricultural colonization over a 10-year period. It is important to investigate how the intensity of plot turnover is related to higher malaria rates, agricultural failure, or a combination of both factors. Furthermore, the analysis of longitudinal data, where individual households can be followed through the first three years of the project, is of extreme importance to understanding the dynamics of the settlement, and ultimately the dynamics of malaria transmission. Spatial statistical analysis should be incorporated, and a broader geographical coverage including tracts 1 and 2 should be established.

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ANNEX I – FINANCIAL REVIEW OF POLONOROESTE

Table I.1
World Bank loans for the POLONOROESTE Program

Loan no.	Date of approval	Date of effectiveness	Expected date of completion	Amount (US$ million)	Status of the loan (January 31, 1991)
Phase I					
2060-BR	12/01/1981	April 1982	June 1986	67.0	Closed in March 1990. Fully disbursed.
2061-BR	12/01/1981	April 1982	Dec. 1986	13.0	Closed in June 1988. Slightly over US$ 1 million was cancelled.
2062-BR	12/01/1981	April 1982	Dec. 1985	240.0	Closed in September 1988. Over US$ 42.0 million was cancelled.
2060-1-BR	12/08/1983	May 1984	June 1986	22.8	Closed in March 1990. US$ 18.3 million was cancelled.
Phase II					
2116-BR	03/25/1982	August 1982	June 1986	26.4	Closed in December 1988. A total of US$ 3.7 million was cancelled.
Phase III					
2353-BR	10/25/1983	Feb. 1984	June 1989	65.2	Closed in March 1992. Up to January 1991, a total of US$ 27.2 million had already been cancelled and US$ 12.95 million remained undisbursed.

Source: Sawyer and Sawyer (1987) and Millikan (1996).
Note: The loans were related to:
2060-BR and 2060-1-BR – Agricultural development and environmental protection
2061-BR – Health
2062-BR – Highway construction
2116-BR – Mato Grosso rural development
2353-BR – New settlement projects in Rondônia

Table I.2 - Estimated costs of the POLONOROESTE Program

Component	Amount (US$ million)	% of total
A. Transport		
BR-364 Highway	448.6	41.6
Strengthening of Rondônia Roads Department	30.7	2.8
Feeder roads	91.3	8.5
B. Settlement of new areas	261.5	24.2
C. Land tenure services	8.6	0.8
D. Rural development		
Rondônia	104.0	9.6
Mato Grosso	56.8	5.3
E. Environmental components		
Forestry and reserves	8.9	0.8
Ecological research	7.0	0.6
F. Rondônia Health Project	24.7	2.3
G. Protection of Amerindian Communities	26.6	2.5
H. Administration	10.1	1.0
Total Baseline Cost	1,078.8	100.0
Physical contingencies	136.4	
Price contingencies	332.8	
TOTAL	1,548.0	

Source: Report N$^{o.}$ 3512b-BR.

ANNEX 2 – DESCRIPTION OF THE PHASES, OBJECTIVES AND ASSOCIATED STRATEGIES OF POLONOROESTE

POLONOROESTE	**Phase I**	*I.1. Highway Project (Loan 2062-BR)*	Objectives: • Highway construction and operation	Strategies: • Contract civil workers temporarily for upgrading, including paving, of approximately 1,084 Km of the BR-364 highway between Campinas in Mato Grosso and Ariquemes in Rondônia; • Install 4 bridges, 3 maintenance residences, one weighing station and 9 highway patrol stations and depots; • Provide consulting services to assist DNER (National Highway Department) in the supervision of the civil workers and installation of the weighing stations; and • Acquisition and installation of a weighing scale, vehicles and radios for the federal road patrol, and equipment, vehicles and traffics counters to monitor road behavior.
			• Strengthening of DER-RO (Highway Depart. - Rondônia)	• Construction of residences and maintenance depots; • Purchase equipment and vehicles for road maintenance, training and traffic control, and equipment for offices and laboratories; and • Provide technical assistance to improve DER-RO's administrative and execution capabilities and to train its staff.
			• Feeder roads in Mato Grosso and Rondônia	• Three-year (1982-84) programs to construct new feeder roads in Mato Grosso and Rondônia, as well as improvement of existing ones, to be carried out through BNDES (National Economic and Social Development Bank); and • Develop additional feeder road construction and improvement plans in the POLONOROESTE area.
		I.2. Agricultural Development and Environmental Protection Project (Loan 2060-BR)	Objectives: • Settlement consolidation in Rondônia	Strategies: • Construct farm access roads; • Provide the nucleus of the settlement projects with necessary infrastructure (water supply system, multigrade school, health post, small-scale sawmills, generators; public electricity system, 19 crop drying and storage units, recreational and commercial areas); • Give direct assistance to families in their agricultural production and forest utilization techniques, promoting the adoption of perennial crops; • Agricultural research concentrating on the adaptation of annual crops (corn, rice and beans) to the area conditions, identifying the best crop mixture for small and medium farms; • Promote farmer organization through the establishment of mutual-aid groups; and • Construct schools to provide, initially, for the first four grades of basic education, and later to grades 5 to 8.
			• Environmental protection	• Establish natural reserves and ecological stations in areas of more fragile ecology or with specially diverse fauna and flora; • Strengthen deforestation control capability; and • Study the promotion of sustainable forestry operation in particular areas.
			• Ecological research	• Study and monitor the hydrometereology and biogeochemical balances in the soils; • Prepare an inventory of plant and animal species native to Rondônia; and • Support small-scale research projects.
			• Assistance to INCRA (National Institute of Colonization and Agrarian Reform)	• To guarantee land tenure regularization in previous settled rural areas in Mato Grosso; and • To identify new areas for future settlements, based on soil potential.
		I.3. Health Project (Loan 2061-BR)	Objectives: • Malaria control	Strategies: • Expansion of SUCAM's (Superintendency for Public Health Campaigns) malaria control resources, including equipment, vehicles, motorcycles, bicycles, consulting services, staff, DDT (approximately 800 tons) and drugs. SUCAM would recruit 300 new field workers, organize 55 6-man field operation teams, and contract 70 epidemiological guards to collect blood samples. Management and supervisory staff would also be hired; and • Identification of transmission areas, surveillance of malaria incidence, reduction of infected mosquitoes and treatment of the sick.
			• Health services development	• Construct 39 health centers; • Provide equipment and staff to 50 health posts to be constructed by rural communities; and • Establish 3 referral health centers with offices, laboratories, and delivery and operating rooms.
			• Training and supervision	• Provide the training of 100 rural health workers and 200 health auxiliaries to work in the health centers and posts; and • Disponibilize vehicles and travel expenses for field supervisors.
			• Research and evaluation	• Promote malaria research on: distribution and transmission potential for different types of vectors, mosquito biting patterns, possible alternatives to DDT, cost-effectiveness of traditional control measures, degree of chloroquine resistance of malaria, and alternative drug treatments; and • Provide technical assistance for the monitoring of the project.

DESCRIPTION OF THE PHASES, OBJECTIVES AND ASSOCIATED STRATEGIES OF POLONOROESTE (conclusion)

POLONOROESTE	**Phase II**	*II.1 Mato Grosso rural development (Loan 2116-BR)*	Objectives: • Agricultural service	Strategies: • Identify the natural resource potential of the area, promote agricultural aptitude studies, and gather environmental data in order to preserve the ecological equilibrium; • Promote direct assistance to farmers, in order to improve their agricultural practices; • Undertake a research to identify the appropriate mix of crop rotation and diversification; and • Improve the supply of agricultural inputs.
			• Production infrastructure	• Improve drying and storage units; and • Improvements and maintenance of approximately 1,470 Km of municipal roads.
			• Social development	• Increase access to rural schools and improve the quality of education through better equipped units and adequately trained teachers; • Construct and maintain rural water systems; • Improve the coverage and quality of primary health care services, train staff, and provide vehicles; and • Construct 6 community centers and train community agents to work on health and educational activities.
	Phase III	*III.1 New Settlements Projects in Rondônia (Loan 2353-BR)*	Objectives: • Provide new settlement areas with the necessary production infrastructure	Strategies: • The first step was related to land use planning, settlement layout, demarcation and titling, all left under the coordination of INCRA (National Institute of Colonization and Agrarian Reform). Field evaluations should be promoted and, when necessary, correct preliminary zoning exercises; • Construct approximately 1,550 Km of primary and 1,450 Km of secondary farm access roads, and strengthen maintenance capabilities; • Provide the nucleus of the new settlement projects with schools, health post or referral center, agencies of government entities involved in rural development, sawmills, and commercial and recreational areas; • Continue studies of Phase I and complement them with specific studies based on local soil conditions; • Provide technical assistance to farmers in order to improve their agricultural production (with emphasis on perennial crops) and guarantee soil conservation; • Build crop drying and storage considering the local climatic and agricultural conditions; • Finance the production of tropical fruit trees; • Construct and equip forestry control posts; and • Protect natural parks and reserves, water sources and endangered species.
			• Provide new settlement areas with the necessary social infrastructure	• Construct and furnish 7 four-classroom schools and 223 single classrooms multi-grade schools; • Complementing Phase I Health Project, construct seven large health posts and 71 small health posts. Training for 113 health professionals and vehicles would be provided; and • Encourage the establishment of farmer organizations, and develop community labor (training of settler groups on health, nutrition, and school construction and maintenance).
			• On-farm investments	• Provide financial support for farmers on the acquisition of seeds and initial equipment.
	Amerindian Special Program (Financed exclusively with domestic resources)		Objectives: • Protect tribal lands	Strategies: • Improve physical and administrative infrastructure of FUNAI (National Indian Foundation); and • Demarcate and upgrade existing demarcation of Indian reserves.
			• Provide health care services	• Expand the operation of mobile health units; • Establish new health posts; • Provide full immunization coverage and intensified assistance in outbreaks of communicable diseases; and • Maintain adequate drug supplies at all Indian health posts.
			• Social improvement	• Improve Amerindian education; and • Promote small-scale economic development projects.