Human Carrying Capacity Estimation in Brazil's Amazonian Settlements as a Guide to Development Policy

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Abstract

Amazonian settlement is often viewed by Brazilian planners as a means of absorbing migrants leaving other parts of the country because of land tenure concentration, agricultural mechanization, population growth, environmental degradation, and population displacement by development projects. Human carrying capacity estimation studies suggest that these expectations are unrealistic.

For the purpose of obtaining human carrying capacity estimates useful in planning decisions, this quantity is operationally defined in terms of a gradient of increasing probability of colonist failure as a function of population density. Carrying capacity is considered to be reached when the probability of colonist failure exceeds a defined maximum acceptable level. The gradient, or colonist failure/population density profile, is constructed using results from a series of stochastic computer simulations run at different population densities.

The results from a study in the Transamazon Highway colonization area near Altamira, Pará, suggest that carrying capacity is low. Brazil must take effective measures to reduce population expulsion from the northeast and south-central parts of the country. The currently used agricultural and ranching systems are not sustainable and provide meager yields while they last. Large-scale implantation of intensive agriculture is barred by physical, agronomic, and cultural limitations.

Brazil's agro-ecological zoning is currently underway. Preliminary zoning maps produced by the Brazilian Enterprise for Agriculture and Cattle Ranching Research (EMBRAPA) indicate large areas for agriculture, including the western two-thirds of the state of Acre.

Expectations of high carrying capacity based on this type of agriculture are unrealistic, such as the calculation of FAO's Agro-Ecological Zoning Project that Brazil could support over seven billion people were Amazonia converted to intensive farming. The modest size and distant location of Brazil's phosphate deposits make fertilizer-intensive agriculture inviable on the scale of Amazonian clearings.

The limited capacity of the region to sustain arable farming leads to the conclusion that remaining forest areas outside of reserves should be used for extraction of non-timber forest products (extractive reserves), or for long-cycle sustainable forest management. These uses have the great advantage of maintaining the biological and environmental functions of the forest. However, they can only support a sparse population, and

can play no role in absorbing overflow from other parts of the country.

Limited capacity to support population through agriculture not only means that less people can be maintained than would otherwise be the case, but also indicates the importance of non-agricultural means of using Amazonian land and of alternative means of support for the population. Among the changes needed are industrial and energy policies designed to maximize urban employment (including biotechnological use of forest products), and creation of institutional mechanisms to convert the forest's environmental services into sources of support for the population.

I.) Introduction

The term carrying capacity refers to the number of individuals that can be supported in a given area; the level of consumption at which they are to be supported and the time the area is to be capable of providing this support varies with the definition. Human "carrying capacity," as used with reference to policy decisions affecting development and population, is the population density that can be sustained indefinitely. The great variability over time and space in the systems that support human populations has a strong influence on carrying capacity. Methods that take this variability into account are therefore likely to better reflect what will be sustainable in the real world. Stochastic estimates include random variation in at least some of the parameters (with the result that the probability of an outcome is less than one).

Assumptions about the human carrying capacity of areas ranging from individual farms or villages to the entire globe underlie innumerable decisions made daily by national governments and international bodies. These decisions, many of which are made by default, lead to inaction on population, environment, and development policies. The conceptions of decision makers regarding how many people can be supported in any given area are frequently far from reality, often implicitly assuming that carrying capacity is very large or even infinite. It is rare that decisions are based on any kind of numerical carrying capacity estimate, however crude.

Policy makers at the highest level often visualize carrying capacity in completely unrealistic terms. Then U. S. President Ronald Reagan stated that "farm studies" show that the earth could support 28 billion people if all tillable land were "farmed at the level of American farming worldwide" (Holden, 1980: 989). This kind of belief is based on the assumptions that (1) sufficient resources exist to supply U. S. levels of inputs such as fossil fuels and fertilizers to the world's arable land, and

(2) land in other parts of the world, such as the rainforest areas of Amazonia (Fig. 1), will respond to these inputs in the same way as the soils of North America's grainbelt. Unfortunately, both assumptions are incorrect. At a global level, arguments for carrying capacity being substantially lower than the earth's present population are given by Ehrlich _et al_. (1989). Assumptions regarding the carrying capacity of Amazonia weigh heavily in any global calculation because of the region's vast size and present sparse population.

Sustainable carrying capacity is operationally defined in terms of a gradient of probabilities of failure (Fig. 2). Failure rates are those sustainable over some long time period at the corresponding human population densities. The criteria for failure can be defined in a variety of ways and can include multiple limiting factors or combinations of factors. They can include measures of environmental degradation as well as individual consumption.

The maximum acceptable probability of colonist failure, as well as the criteria for failure, can be chosen in accord with socially defined values. Probability of failure increases with human density in a hypothetical relationship that should apply within some range of possible human densities. Note that the curve in Figure 2 rises to a failure probability of one on meeting the vertical axis. The probability of failure would be expected to rise at low population densities due to a sort of "Allee effect," the phenomenon common to many species of reduced survival and reproduction at lower densities. In human terms, the probability of failing to maintain adequate consumption standards would increase at very low densities due to the difficulties from lack of infrastructure, cooperation, and other benefits of society.

Once a maximum acceptable probability of colonist failure has been selected (point _P_ in Figure 2), the carrying capacity (_K_) is the corresponding population density above which density-dependent effects cause the combined (density-dependent and -independent) probability of failure to exceed this maximum value. In a case where extremely high levels of risk cause the curve to exceed the maximum acceptable probability of colonist failure at all points, a reasonable solution would be to select the minimum probability of failure as the point corresponding to _K_.

II.) Assumptions in Carrying Capacity Estimates

Assumptions of carrying capacity estimates often invalidate the techniques for their intended purposes. Street (1969) has identified several assumptions common in carrying capacity studies of shifting cultivation systems. Most frequent is the assumption that farming and fallowing practices in use at the time of fieldwork do not result in environmental degradation. If degradation is taking place in an area, then the carrying capacity values obtained by substituting the observed fallow time, farmed time, and so on, for the parameters in a shifting cultivation carrying capacity formula will not represent a sustainable carrying capacity.

Variability is a characteristic of agricultural systems everywhere that is frequently assumed to be unimportant in carrying capacity calculation. The effects of variability in yields and other factors were the focus of a carrying capacity study of colonists on Brazil's Transamazon Highway (Fearnside 1986a). The high levels of variability characterizing tropical agriculture will reduce carrying capacity both by necessitating planting a large buffer of additional land each year as insurance against poor yields and by reducing the margin protecting the population from failures due to both density-related causes and background levels of density-independent failures.

Although most carrying capacity studies ignore variability because it is difficult to study, the importance of this factor cannot be overemphasized. Estimators of carrying capacity should consider carefully the implications of Harry Hopkin's remark to then U. S. President Franklin D. Roosevelt: "People do not eat, in the long run, nor, on the average; they eat every day." In addition to variability over time, variability in income or consumption between individuals and groups within society is fundamental to quantifying carrying capacity (Catton, 1987).

III.) Models for Estimating Carrying Capacity

A.) The KPROG2 Model

A simulation model, known as KPROG2, has been written for estimating carrying capacity in the Transamazon Highway settlement areas. The model attempts to avoid many of the restrictive assumptions that have plagued many carrying capacity estimation efforts that have applied algebraic formulas to shifting cultivation. The features, input parameters, and results of the KPROG2 model are discussed elsewhere (Fearnside, 1979a, 1983a, 1985a, 1986a, 1990a). The model represents the observed agroecosystem of Transamazon Highway colonists, rather than what might be achieved under improved technologies. Sectors are included for initial resources, land-use allocation, product allocation, and population. The model is stochastic, with probability distributions included for many variables affecting crop yields and colonist behavior. Carrying capacity is estimated by performing a series of runs of the model with the population density fixed at different levels, and calculating the proportion of simulated colonists failing to meet defined standards for diet and monetary standard of living. The results of the runs are used to construct a curve representing the relationship between population density and colonist failure probability, such as that in Figure 2. Carrying capacity is considered to be reached when the probability of colonist failure exceeds a defined maximum acceptable level.

The choice of criteria for defining colonist failure is critical to the numerical results obtained from analyses of this type. The more demanding the standards for diet, monetary income, or any other factors, the greater the proportion of simulated colonists who will fail to meet them; by the same token, the lower the specified maximum acceptable probability of failure, the lower the corresponding carrying capacity. Using dietary intakes recommended by the United Nations or by Brazilian government agencies, Brazil's minimum wage as a standard for monetary returns, and a maximum acceptable probability of colonist failure based on statements in official publications, one is led to the conclusion that Amazonian forest areas should not be colonized at any density. An alternative solution is to consider carrying capacity to be the density corresponding to the minimum probability of colonist failure calculated. In either case, the conclusion is inescapable that carrying capacity is low.

Estimates of carrying capacity assume implicitly that agriculture will be sustainable if population densities are sufficiently low. Such an assumption may be reasonable for traditional shifting cultivation systems such as those currently or formerly practiced by many indigenous peoples, but becomes strained if applied to colonists, squatters, ranchers, or other major groups in Amazonia today. The problem is that people behave in unsustainable ways even if land is available in abundance. Sometimes people are "forced" to such behavior by institutional and economic factors (e.g., Norse, 1992: 38), but often unsustainable choices are made irrespective of external forces. Cattle pasture, which soon dominates the landscape in areas of large ranches and small farmers alike, degrades after about a decade (Fearnside, 1989a). The current results from KPROG2 underestimate the true importance of cattle pasture on the Transamazon Highway, as the land-use allocations are based on colonist behavior observed in the first years of settlement before the trend to planting pasture became so strong (Fearnside, 1980a). Were the trend to pasture fully reflected in the model results, the carrying capacity outlook would be even bleaker.

The accumulation of secondary forest biomass is much slower on abandoned pastures than in a traditional shifting cultivation fallow (Fearnside and Guimarães, 1996). An emerging system of shifting ranching promises to produce very little. In cattle ranches on the Belém-Brasília Highway, for example, a second round of use by recuperating abandoned pastures is now taking place. However, this is only possible when ranches sell off timber stocks from the uncleared portions of each property (Mattos and Uhl, 1994: 151)--a windfall source of income that cannot be expected to apply to any subsequent cycles of pasture regeneration. Cattle pasture is planted for a variety of reasons unrelated to beef production (Fearnside, 1983b), and represents one of the least effective means of supporting rural population. In the case of large ranches financed through the Superintendency for Development of the Amazon (SUDAM), for example, Benchimol (1989: 60, cited by Schmink and Wood, 1992: 127) reports that only 26,345 jobs were created at a cost of US$56,936 each, while Ozias Carneiro, the head of the Banco da Amazonia S.A. (BASA) testified before a parliamentary commission that the 333 cattle projects financed through 1979 occupied 9 million ha and created only 16,000 jobs (Schmink and Wood, 1992: 98).

B.) The FAO/UNFPA/IIASA Study

A major effort to estimate carrying capacities of developing countries was completed in 1982 by the Food and Agriculture Organization of the United Nations (FAO), in collaboration with the United Nations Fund for Population Activities (UNFPA), and the International Institute for Applied Systems Analysis (IIASA) (Higgins et al., 1982). While the methods and the interpretation of the results can be criticized on many grounds, it is a tremendously important sign that the study was done at all. Recognition that carrying capacity estimation merits a major funding and research effort is a significant departure from the past. The effort was also done on a scale intended to affect policy decisions, rather than merely as an illustration of how a new method might work. The reports (FAO, 1980, 1981; Higgins et al., 1982) are not widely distributed, although a popular presentation was commissioned that at least outlines what was done (FAO, 1984).

It is worthwhile to examine the FAO/UNFPA/IIASA study in some detail, as the illusion that it embodies that Amazonia can be turned into a major breadbasket--an idea that long predates the FAO/UNFPA/IIASA study--is a persistent and pernicious one in Brazilian planning for the region. The study's results contain numerous glaring inconsistencies with reality, indicating that such efforts need to be based on more ground truth. The Brazilian Amazon is all mapped in the FAO/UNFPA/IIASA study as capable of supporting between one-half and one person per hectare at the present low-input level of technology, and between five and ten people per hectare with high inputs (fertilizers, mechanization, and an optimal mix of rain-fed crops). These calculations lead to the conclusion that Brazil could support an incredible 7.1 billion people were high levels of inputs applied (Higgins et al., 1982: 104). The low-input level estimates are supposed to reflect the present mix of crops grown; one wonders whether the FAO data base recognizes that unproductive and unsustainable cattle pasture is the dominant land use in Brazilian Amazonia (see: Fearnside, 1979b, 1980b, 1983b). Even were the technology of choice the apparently assumed shifting cultivation, many factors limit population densities to low levels (Fearnside, 1985b).

The implied possibility of converting the region to high-input mechanized agriculture runs up against limits of resource availability to supply the inputs. Amazonia has virtually no deposits of phosphates; transporting them is both expensive and, when the vast extent of Amazonia is considered, quickly enters into conflict with the absolute limits of this resource. The temptation is strong to view Amazonia as a potential cornucopia capable of solving population and land distribution problems; the limits of applying the intensive agriculture suggested make this a cruel illusion. These limits are best illustrated by the inviability of applying to any significant part of Amazonia the "Yurimaguas technology" for continuous cultivation that has been under testing in the Peruvian Amazon (Nicholaides et al. 1985; see Fearnside, 1985b, 1987, 1988). Input limitations set strict bounds on the expansion of all fertilizer-demanding agricultural systems, including agroforestry systems (Fearnside, 1995).

One of the factors leading to the high carrying capacity values the study ascribed to Amazonia is the assumption that land quality in uncultivated areas is equal to that in already cultivated ones. The study goes so far as to claim that "there is evidence that the productivity of the reserves may be higher, but, for the sake of simplicity, it is assumed that the potential productivity of the unused land is the same as that of the land under cultivation" (FAO, 1984: 43). Unfortunately, as is true in most parts of the earth, the best land is brought into cultivation first, with land quality progressively declining in new settlement areas until only very marginal lands remain. In Brazil's state of Rondônia, for example, 42% of the land in colonization projects settled in the 1970s was classified by a government soil survey as "good for agriculture with low or medium inputs;" for projects started in the first half of the 1980s 15% of the land was so classed, while for planned areas the amount is a minuscule 0.13% (Fearnside, 1986b).

The FAO/UNFPA/IIASA study consistently indicates higher carrying capacities in lowland humid tropical areas as compared to areas at middle altitude or latitude. This stems from the great weight the yield algorithms place on the length of the growing season and the average temperature--the higher the better in both cases. However, the distribution of dense human populations around the world follows a very different pattern: most are at middle altitudes or latitudes. Several factors contribute to the observed pattern of human occupation, including the distribution of younger (more fertile) soils near mountain ranges or glaciated areas, and the greater barriers that human diseases such as malaria have posed to tropical lowland occupation. Of greatest relevance to the FAO/UNFPA/IIASA study are the characteristics of tropical lowland climates that are less favorable to agriculture than the study's yield algorithms acknowledge. Diurnal variation is important: when temperatures are high both during the day and at night, plants (including crop plants) respire at night much of the photosynthate gained during the day, thereby obtaining a lower net primary productivity than when days are warm but nights are cool as in middle elevations in the tropics. Seasonality is also important: year-round warmth at low latitudes causes populations of plant disease organisms, weeds, and insect pests to increase continuously. No winter or strong dry period provides free pest control to the farmer (Janzen, 1973). Higher temperatures also cause soil organic matter to degrade more quickly, which shifts the equilibrium between accumulation and degradation to a lower level and reduces the fertility of any given type of soil (Nye and Greenland, 1960). For all of these reasons, a year-round growing season is not the unalloyed blessing implied by the FAO/UNFPA/IIASA calculations.

The group's implied recommendation that developing countries should encourage migration into tropical lowlands from more highly populated areas at higher altitudes and/or latitudes (e.g., FAO, 1984: 21) is likely to prove an environmental catastrophe, as such programs already have in such countries as Brazil, Colombia, Ecuador, Bolivia and Indonesia. The suggestion that "fragmented" land holdings must be grouped into "consolidated" properties as part of the transition to high-input agriculture (FAO, 1981: 16) would play havoc with the social function of many tropical settlement programs. The conclusions on human carrying capacity are affected by the study's lack of consideration of equity in the distribution of food produced, in addition to the active anti-equity bias of the land tenure system the report implicitly recommends.

The FAO/UNFPA/IIASA study's recommended responses to the collision of rising populations with limited resources lean heavily to the side of increasing inputs of fertilizers, pesticides, etc., plus converting to agricultural use the remaining areas of natural ecosystems. The need for policy changes to slow population growth is missing from the conclusion, although the general benefit of slowing population growth is mentioned briefly in the introduction to the popular report (FAO, 1984: xiv-xv).

The belief that large-scale expansion of agriculture is possible in Amazonia, as expressed in the FAO/UNFPA/IIASA study, is critical to decisions now being taken on the future of Amazonian development. The decrees establishing Brazil's Ecological-Economic Zoning (Decrees 0919 of 21 June 1990 and 707 of 22 December 1992) mandate that the country be divided into zones and that subsequent development conform to the zoning decisions. Preliminary zoning maps produced by the Brazilian Enterprise for Agriculture and Cattle Ranching Research (EMBRAPA) indicate large areas for agriculture, including the western two-thirds of the state of Acre (Brazil, EMBRAPA, 1988). A preliminary zoning by the Brazilian Institute for Geography and Statistics (IBGE) differs from that of EMBRAPA in its recommendations for most of Amazonia, but agrees that western Acre should be used for agriculture (Régis, 1989). The zoning is now being done by the Secretariat of Strategic Affairs (SAE), Brazil's internal intelligence agency formerly called the National Information Service (SNI). FAO is providing technical assistance (although not the same individuals responsible for the FAO/UNFPA/IIASA study). SAE is working through state-level agencies, many of which are strongly in favor of expanding agricultural settlement.

IV.) FINDING A NEW BASIS TO SUPPORT AMAZONIA'S POPULATION

Evidence of many kinds suggests that the carrying capacity of areas under Amazonian rainforest is low with present agricultural technology and with technologies that are likely to be feasible for the vast expanses of infertile soils in the region. The consequences of this for Brazil's development planning are profound. The limits to population growth are clearly lower than they would be were the mythical agricultural bounty of Amazonia a reality. Of more immediate concern is the need of supporting by means other than agriculture many present Amazonian farmers and would-be migrants to the region. Two questions invariably present themselves: what to do with the rest of the area that cannot be used for agriculture, and what to do with the rest of the population that cannot be employed as farmers.

Amazonia's population is now supported in ways that can only be temporary. Agriculture and cattle ranching activities are unsustainable as practiced, and unlikely to be converted into sustainable systems over sufficiently wide areas (Fearnside, 1990b). Timber extraction is predatory, and unlikely to take place as sustainable management under current economic system (Fearnside, 1989c). Harvest of non-timber extractive products is important as a potentially sustainable use of forest in some areas, but has little potential to absorb large human populations (Fearnside, 1989b). Industrial development has given very low priority to employment generation, the most extreme example being Aluminum smelting in eastern Amazonia which uses two-thirds of the output of the Tucuruí Hydroelectric Dam to support less than 2000 jobs (Fearnside, 1989d; 1990c). The ALBRÁS smelter at Barcarena, Pará (population 5000, including workers and dependents), uses more electricity than the entire city of Belém (population 1.6 million) (Brazil, ELETRONORTE, 1987: Pará 12). Manaus, the second largest city in the Amazon region, depends on industries assembling imported equipment in a tax-free zone, an activity that would inviable except for a plethora of subsidies (Pinto, 1992). Brazil's perennial economic difficulties do not permit maintenance of the level of subsidies that has prevailed since the Manaus Free Trade Zone (SUFRAMA) was established in 1967. Economic recession and reduction of subsidies caused employment to decline over the 1992-1994 period, despite provisions in Brazil's 1988 constitution guaranteeing maintenance of SUFRAMA through 2025. Fortunately, economic recovery in 1995-1996 arrested the decline.

Radically new means of support are needed for Amazonia's population, both in rural and in urban areas. In rural areas, the existing potential must first be used for agriculture in already deforested areas and extractive use of designated areas of standing forests. However, the key to making use of standing forest economically attractive is likely to lie not in fine-tuning the economic system surrounding forest commodities, but rather in developing ways to turn the supply of environmental services into a part of the solution for supporting the local population. Appropriate institutional mechanisms are now totally lacking. The first step is research on valuation of environmental services. These include biodiversity maintenance, carbon storage, and water recycling. Institutional mechanisms for negotiating international agreements on these values come next. Separate institutions are then needed to collect funds on the basis of the services agreed upon, and to apply these to programs that will result in achieving the two objectives: supporting the population and maintaining forest with its services intact (Fearnside, 1996).

The most appropriate maintainers of forest areas are the indigenous and traditional peoples who already live there. Formal agreements would be needed to ensure that such forest areas are not later diverted to other uses (Fearnside and Ferraz, 1995). Indigenous peoples stand to benefit by negotiating to have all or part of their lands declared as protected areas, because this strengthens their claim to large areas of forest (which is continually under attack by politicians in Amazonia). The tribes should also gain some material benefit from protecting the forest, as compensation for the environmental services that the forest provides. Negotiations would have to be done directly with the tribes. Such uses do not offer a solution to supporting the many migrants who have come to the region and are now engaged in agriculture, ranching, logging, and goldmining activities.

Support of population in urban areas is fundamental, both for maintaining the present urban population and for supporting population that cannot be sustained in the countryside. Some changes are obvious, such as the need to cancel the subsidy for electricity sold to the aluminum industry (Portaria No. 1654 of 13 August 1979), which would result in shutting down the smelters and freeing up large amounts of energy for industries that supply more employment.

One opportunity for support of urban populations in Amazonia is development of biotechnology industries. A dramatic demonstration of this was offered by the positions of the United States during the 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro. The U. S. refused to sign the Biodiversity Convention in the face of pressures from virtually all the rest of the world. A last-minute attempt by the head of the U. S. delegation to obtain authorization to negotiate further was categorically rebuffed by the White House with the explanation that concessions on biodiversity would cost the U. S. many jobs. This is an indication of how much is at stake, given that politicians are notorious for being motivated almost exclusively by short-term considerations. Biodiversity has great potential as a source of material for biotechnology and genetic engineering, but virtually all of this potential is a thing of the future.

Commercialization of biodiversity represents a significant potential source of employment; the question is only "employment for whom?" Will it go to the U. S. or to countries such as Brazil where most biodiversity is located? Within Brazil, the same question must also be faced: will the employment go to São Paulo or to Amazonia? Amazonia has a relationship with São Paulo that is in many ways similar to the relationship between Brazil and the United States. The natural tendency would be for the employment benefits of biotechnology to gravitate to São Paulo, unless a high-level decision is made to channel this development to Amazonian cities such as Manaus. Placing these industries near the forest would help to reverse the historical pattern of outsiders pillaging the region's resources, and would contribute to motivating people in the region to maintain forest. In the end, Amazonian forest will only be maintained if the people of the region see this as in their own interests.

Any development strategy must begin with a clear definition of its objectives and beneficiaries. Respecting carrying capacity is fundamental to attaining virtually any objective, and examination of this factor often reveals underlying inconsistencies and hypocrisies in plans ostensibly meant to benefit the poor. The usual emphasis on expanding the pie often begs the more important questions of how and for whom the pie is divided. Accepting limits does not mean condemning the poor to poverty; rather, it means condemning the rich to face up to dividing the pie.

Defining carrying capacity inevitably leads to specific decisions on the productive systems used and the limits beyond which they cannot yield sustainably, the distribution of wealth within the population, the average standard of living and the minimum level acceptable, as well as intergenerational allocation of resources. When proposals are made to open additional tropical forest land to clearing for agriculture, many of the wider problems that policy makers frequently hope to solve through such initiatives are bound to remain unsolved unless limits are recognized and the more difficult but more far-reaching decisions are taken to halt deforestation and bring population into balance with resources. All development strategies have limits to the number of people that can be supported, including tapping environmental services and opportunities for urban employment.

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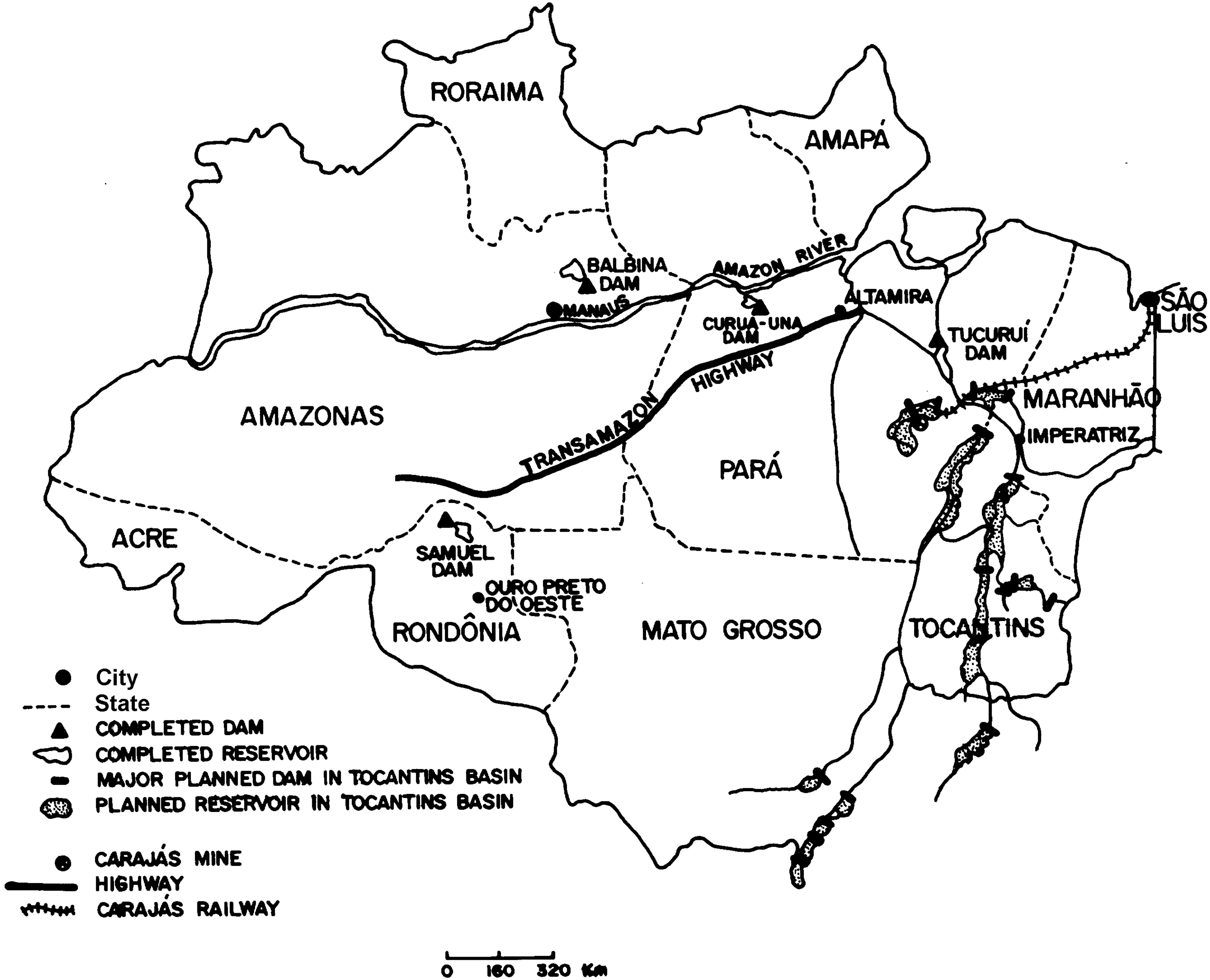
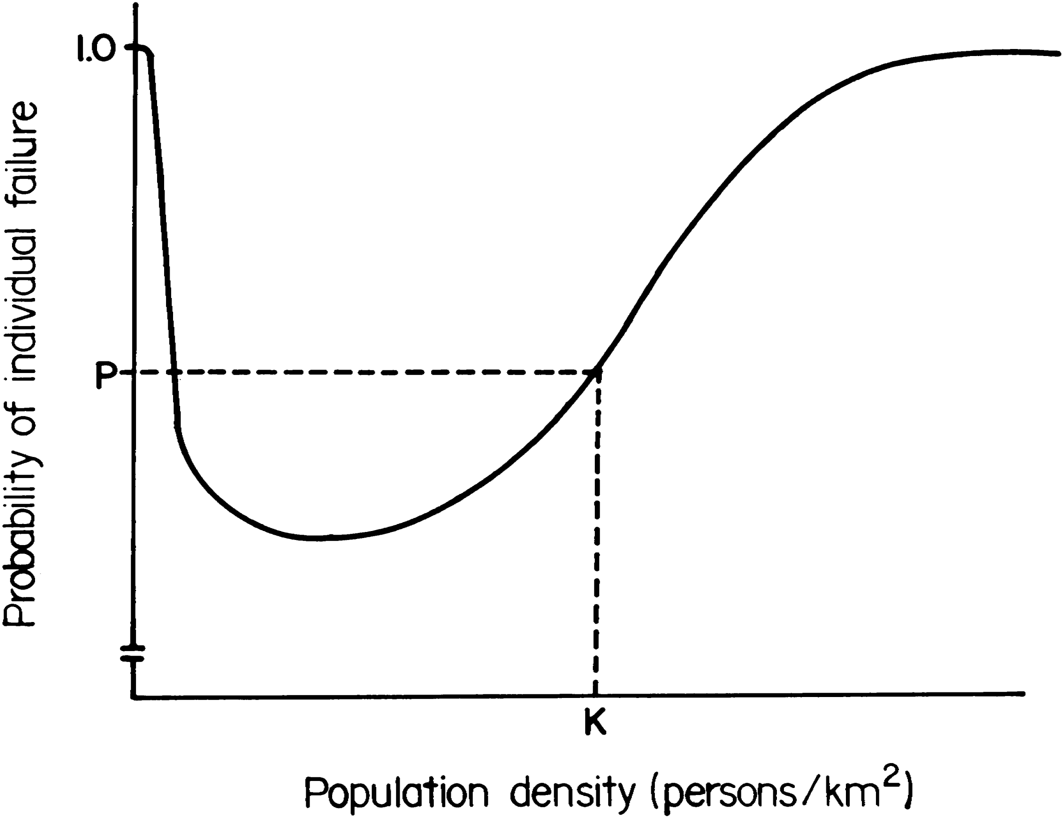
FIGURE LEGENDS

Figure 1. Brazil's Legal Amazon region.

Figure 2. Carrying capacity (K) as determined from the gradient of increasing probability of colonist failure with human population density. Note that this hypothetical curve rises at low densities due to lack of infrastructure and other benefits of society. Carrying capacity (K) corresponds to the point where density-dependent increase in failure probability results in failure rates exceeding the maximum acceptable probability of colonist failure (P) (Fearnside, 1985a).


RORAIMA
AMAPÁ
BALBINA DAM
AMAZON RIVER
MANAUS
CURUA-UNA DAM
ALTAMIRA
TUCURUÍ DAM
SÃO LUIS
MARANHÃO
IMPERATRIZ
AMAZONAS
TRANSAMAZON HIGHWAY
PARÁ
ACRE
SAMUEL DAM
OURO PRETO DO OESTE
RONDÔNIA
MATO GROSSO
TOCANTINS
City
State
COMPLETED DAM
COMPLETED RESERVOIR
MAJOR PLANNED DAM IN TOCANTINS BASIN
PLANNED RESERVOIR IN TOCANTINS BASIN
CARAJÁS MINE
HIGHWAY
CARAJÁS RAILWAY
0 160 320 Km



1.0
P
K
Probability of individual failure
Population density (persons/km²)