The text that follows is a PREPRINT.

Please cite as:

Fearnside, P.M. 1987. Causes of deforestation in the Brazilian Amazon. pp. 37-53 In: R.F. Dickinson (compilador) The Geophysiology of Amazonia: Vegetation and Climate Interactions. John Wiley & Sons, New York, U.S.A. 524 pp.

The original publication is available from: John Wiley & Sons, New York, U.S.A.

THE CAUSES OF DEFORESTATION IN THE BRAZILIAN AMAZON

Philip M. Fearnside
Department of Ecology
National Institute for
Research in the Amazon (INPA)
Caixa Postal 478
Manaus, Amazonas, Brazil

20 November 1984
Revised: 14 April 1985

Paper presented at the United Nations University International Conference on Climatic, Biotic and Human Interactions in the Humid Tropics: Vegetation and Climate Interactions in Amazonia. 25 February - 1 March 1985, São José dos Campos - São Paulo, Brazil.

To appear in: Dickinson, R.E. (ed.) Geophysiology of Amazonia John Wiley and Sons, New York.

The present rate and probable future course of forest clearing in Brazilian Amazonia is closely linked to the human use systems that replace the forest. These systems, including the social forces leading to particular land use transformations, are at the root of the present accelerated pattern of deforestation and must be a key focus of any set of policies designed to contain the clearing process. The present extent and likely changes in the various agricultural systems found in the region are reviewed elsewhere (Fearnside, nd-a). Cattle pasture is by far the dominant land use in cleared portions of the terra firme (unflooded uplands), not only in areas of large cattle ranches, such as southern Pará and northern Mato Grosso, but also in areas initially felled by smallholders for slash-and-burn cultivation of annual crops, such as the Transamazon Highway colonization areas in Pará (Fig. 4.1). Pasture is even dominant in areas like Rondônia where government programs have intensively promoted and financed cacao and other perennial crops (Léna, 1981; Furley and Leite, nd). The forces leading to continued increase in pasture area, despite the low productivity and poor prospects for sustainability of this use system, are those that most closely affect the present rate of deforestation.

The extent and rate of deforestation in Brazil's Amazon rainforest is a subject of profound disagreement among both scholars and policy makers in Brazil and elsewhere. Equally controversial is the question of whether or not potential future consequences of deforestation are sufficient to justify the immediate financial, social, and political costs of taking measures to contain the process. The lack of effective policies to control deforestation in the Amazon today speaks for both the preference among decision makers for minimizing such concerns and the strength of forces driving the deforestation process. Here it is argued that deforestation is rapid and its potential impact severe, amply justifying the substantial costs of speedy government action needed to slow, and at some point stop, forest clearing.

4.1 EXTENT AND RATE OF DEFORESTATION

The vast areas of as yet undisturbed forest in the Brazilian Amazon frequently lead visitors, researchers, and government officials to the mistaken conclusion that deforestation is a minor concern unlikely to reach environmentally significant proportions within the "foreseeable" future. Such conclusions are unwarranted; they also have the dangerous effect of decreasing the likelihood that timely policy decisions will be made with a view to slowing and limiting the process of deforestation. Not only is better monitoring information needed for describing the process, but also better understanding of underlying causes of deforestation. Such understanding would allow more realistic projections of future trends under present and alternative policy regimes, and permit identification of effective measures to control the process.

The most recent available survey of deforestation covering the entire Brazilian Amazon was made by Brazil's National Institute for Space Research (INPE) based on LANDSAT satellite images taken in 1978 (Tardin et al., 1980). The same study also interpreted images from 1975. The survey's finding that only 1.55% of the area legally defined as Amazonia had been deforested up to 1978 contributed to the popular portrayal in Brazil of deforestation as an issue raised only by "alarmists." The INPE figure underestimates clearing because of the inability of the technique to detect "very small" clearings and of the difficulty of distinguishing second growth from virgin forest. For example, the Zona Bragantina, a 30,000 km2 region surrounding the town of Bragança in northeastern Pará that was completely deforested in the early years of this century (Egler, 1961; Sioli, 1973), is larger than the area indicated by 1975 images analyzed in the INPE study as deforested in Brazil's entire Legal Amazon, and is almost four times the area indicated as cleared in the state of Pará (Fearnside, 1982). Regardless of any underestimation due to image interpretation limitations, the conclusion that the area cleared through 1978 was small in relation to the 4,975,527 km2 Legal Amazon is quite correct.

Unfortunately, the small area cleared by 1978 is a far less important finding than another less publicized one apparent from the same data set (Carneiro et al., 1982): the explosive rate of clearing implied by comparing values for cleared areas at the two image dates analyzed, 1975 and 1978. If the growth pattern over the region as a whole was exponential during this period, the observed increase in cleared area from 28,595.25 to 77,171.75 km^2 implies a growth rate of 33.093% $year^{-1}$, and a doubling time of only 2.09 years. Deforestation rates vary widely in different parts of the region, being highest in southern Pará, northern Mato Grosso, and in Rondônia and Acre. An analysis of a longer time series of LANDSAT images from one of these areas, Rondônia, is presented elsewhere (Fearnside, 1982). Comparisons of cleared areas for 1973, 1975, 1976, and 1978 in two areas of government-sponsored colonization by farmers with 100 ha lots, and in two areas dominated by 3000 ha cattle ranches, indicate that deforestation in these areas may have been progressing in an exponential fashion during the period, although data are too few for firm conclusions (Fearnside, 1982).

LANDSAT image interpretation by the Brazilian government for the state of Rondônia as a whole (243,044 km2) indicates that cleared areas rose from 1,216.5 km2 in 1975 (Tardin et al., 1980) to 4,184.5 km^2 in 1978 (Tardin et al., 1980) to 7,579.3 km^2 in 1980 (Carneiro et al., 1982) to 13,955.2 km^2 in 1983 (Brazil, Ministério da Agricultura, 1985; Fearnside and Salati, nd). The cleared area therefore increased from 0.50% to 3.12% of Rondônia's total area in only five years, and jumped to 5.74% in the succeeding three years. It should be remembered that limitations of the image interpretation methodology mean that the true cleared areas were probably larger than these numbers imply. Even with this limitation, the clearing estimates reveal not only that

deforestation proceeded rapidly throughout the period, but that it showed no signs of slowing as of 1980 (Fig. 4.2) and continued through 1983 at a faster-than-linear pace.

LANDSAT data from 1980 images (Brazil, Ministério da Agricultura, IBDF, 1983) reveal that strong exponential growth in cleared areas over the 1975-1980 period also occurred in Mato Grosso and Acre, while increase was roughly linear in Pará, Maranhão and Goiás (Fearnside, 1984a, nd-b). No 1980 data are yet available for Roraima, Amazonas or Amapá.

Some of the forces behind deforestation are linked to positive feedback processes, which can be expected to produce exponential changes. Roadbuilding, for example, is closely tied to the rate of arrival of new immigrants: more and better roads attract more immigrants, while the presence of a larger population justifies the construction of still more and better roads (Fig. 4.3). In Rondônia the population has been growing even more rapidly than in other parts of the region because of the flood of new immigrants from southern Brazil (Fig. 4.2). Projections of unchanging exponential rates for deforestation into the future, even in deforestation foci like Rondônia, are hazardous as anything but illustrations because there are many other factors affecting the process. As the relative importance of different factors shifts in future years, some of the changes will serve to increase deforestation rates, while others will slow them. Within completely occupied blocks of colonist lots, for example, clearing of virgin forest proceeds roughly linearly for about six years, after which a plateau is reached (Fearnside nd-c). The rate at which an individual lot is cleared is increased by such events as the arrival of road access and turnover in the lot's occupants (Fearnside, 1980a, nd-c) (Fig. 4.3).

At present, regional scale clearing statistics appear to be dominated by immigration, along with other forces that accelerate deforestation such as the positive effect of improved road access on market availability and land value appreciation. In the future, the behavior of the population already established in the region should gain in relative importance. Other reasons for an eventual slowing (but not halting) of clearing include poorer soil quality and inaccessability of remaining unoccupied land, the finite capacity of source areas to supply immigrants at ever increasing rates, decreased relative attractiveness of Amazonia after this frontier of unclaimed land "closes," and limits of available capital, petroleum and other inputs that would be necessary if rates of felling should greatly increase (Fearnside nd-d). However, nothing short of a comprehensive program of government actions based on conscious decisions can be expected to contain deforestation before the region's forests are lost (Fearnside nd-b).

The accelerating course of deforestation cannot be adequately represented by any simple algebraic formula such as the exponential equation, nor can its eventual slowing be expected to

follow a smooth and symmetrical trajectory such as a logistic growth path. The complex interacting factors bearing on the process are more appropriate for analysis with the aid of computer simulation (Fearnside, 1983a). An idea can be gained of the relationships of the factors involved by examining more closely some of the causes of deforestation in Amazonia.

4.2 CAUSES OF DEFORESTATION

Present causes of deforestation can be divided, somewhat artificially, into proximal causes (Table 4.1) and underlying causes (Table 4.2). Proximal causes motivate land owners and claimants to direct their efforts to clearing forest as quickly as possible. The underlying causes link wider processes in Brazil's economy either to the proximal motivations of each individual deforester, or to increases in numbers of deforesters present in the region.

Some of the principal motives for deforestation apply most forcefully to large landholders, expecially those motives connected to government incentive programs. These represent forces relatively easily controlled by governmental actions, as has already occurred to a small degree (see note, Table 4.1). Deforestation is also linked to longstanding economic patterns in Brazil, such as high inflation rates, which have shown themselves to be particularly resistant to government control (Fig. 4.4).

Changes in agricultural patterns in southern Brazil have had heavy impacts. The rise of soybeans has displaced an estimated 11 agricultural workers for every one finding employment in the new production system (Zockun, 1980). Sugarcane plantations, encouraged by the government for alcohol production, have likewise expelled smallholders. Replacement of labor-intensive coffee plantations with mechanized farms raising wheat and other crops, a trend driven by killing frosts and relatively unfavorable prices, has further swollen the ranks of Amazonian immigrants (Sawyer, 1982).

Within Amazonia, most evident are the forces of land speculation (Fearnside, 1979a; Mahar, 1979), the magnifying effect of cattle pasture on the impact of population (Fearnside, 1983b), and the positive feedback relationship between roadbuilding and population increases (Fearnside, 1982).

Profits from sale of agricultural production are added to speculative gains, tax incentives and other forms of government subsidy in making clearing financially attractive. Small farmers often come to the region intent on making their fortunes as commercial farmers, but they gradually see the higher profits to be made from speculation as their neighbors sell their plots of land for prices that dwarf the returns realized from years of hard labor. Agriculture then becomes a means of meeting living expenses while awaiting the opportunity of a profitable land sale and a move to a more distant frontier. Although individual

variability is high, most aspire to produce enough to live well by the standards of their own pasts while awaiting an eventual sale. Farmers usually see such sales as providing the reward for "improvements" made on the land during their tenure, rather than as speculation. Larger operators are more likely to begin their activities in the region with speculation in mind but are likewise always careful to describe themselves as "producers" rather than speculators.

Subsistence production is always a contributor to forest clearing, although it is not presently the major factor that it is in many other rainforest areas, as in Africa (Myers, 1980, 1982). The speculative and commercial motives for clearing in Amazonia mean that the relationship of commodity prices to clearing is positive for most of the farmers involved. In areas of the tropics where cash crops are grown primarily for supplying subsistence needs, the relationship can be the reverse: a positive feedback loop exists whereby falling prices for a product mean that larger areas must be planted for the farmer to obtain the same subsistence level of cash income, while the resulting increased supply of the product further drives prices down (Gligo, 1980: 136; Plumwood and Routley, 1982). For most Amazonian farmers, however, desire for cash so greatly exceeds the income-producing capacity of the farms that only the restraints of available labor and capital limit the areas cleared and planted (Fearnside, 1980b).

Future deforestation trends should reflect changes in the balance of forces listed in Tables 4.1 and 4.2, as from declining impact of new arrivals relative to the resident population. Future trends can also be expected to show the effects of projected major developments (Table 4.3). As timber export, presently a negligible factor, becomes more important, outright deforestation will be supplemented by the often heavy disturbances following selective felling that presently characterize much of the forest conversion in Asia and Africa. Charcoal production, expecially that derived from native forest, is foreseen as a major factor in the southeastern portion of the region in the coming decades.

Large firms, such as lumber companies requiring marketable timber, or steel manufacturing industries requiring charcoal, pose the additional problem of playing more active and forceful roles in seeing that environmental conflicts of interest are resolved in their favor. Chances are higher, as compared to the case of relatively small investors, that concessions will be made at the expense of previous governmental commitments to reserves of untouched forest. This recently occurred in the case of timber concessions operating in the area now flooded by the Tucuruí Hydroelectric Dam: despite not having fulfilled its role in removing forest from areas to be flooded, the concessionnaire was reportedly granted logging rights to 93,000 ha in two nearby Amerindian reservations when commercially valuable tree species proved less common than anticipated in the reservoir area,

according to the head of the firm involved (Pereira, 1982).

Future deforestation appears likely to proceed at a rapid rate. Although limited availability of fossil fuel, capital, and other resources should eventually force a slowdown, this cannot be counted on to prevent loss of large areas of forest. Even at rates slower than those of the recent past, the forest could be reduced to remnants within a short span of years. The deforestation process is subject to control and influence at many points. Decisions affecting rates of clearing must be based on understanding of the causes of deforestation. Such decisions are taken, either actively or by default. They define areas to undergo agricultural or other development, and reserves where such development will be excluded. Making timely choices of this kind depends on decision makers' conception of the likely course of deforestation. Understanding the system of forces driving the process is also essential for evaluating the probable effectiveness of any changes contemplated.

4.3 POLICY IMPLICATIONS

The negative consequences of deforestation (Fearnside nd-d) should give pause to planners intent on promoting forms of development requiring large areas of cleared rainforest. Nevertheless, such plans continue to be proposed and realized. Part of the problem is a lack of awareness among decision-makers of the magnitude of the eventual costs implied by these actions, but such lack of knowledge explains only a part of the reluctance to take effective actions to contain and slow deforestation. At least as important is the distribution of the costs and benefits, both in time and space. Most of the costs of deforestation will be paid only in the future, while the benefits are immediate. Many of the costs are also distributed over society at large, while the benefits accrue to a select few. In the many cases where land is controlled by absentee investors there is even less reason for negative consequences within the region to enter individual decisions. In other cases the costs are highly concentrated, as when indigenous groups are deprived of their resource base, while the perhaps meagre benefits of clearing are enjoyed by a constituency that is both wider and more influential.

Brazil's national government has the task of balancing the interests of different generations and interest groups. At the same time, the Amazon has long suffered from exploitation as a colony whose products serve mainly to benefit other parts of the globe, most recently and importantly the industrialized regions of Brazil's Central-South. The unsustainable land uses resulting from this kind of "endocolonialism," as Sioli (1980) calls it, require that decision-making procedures guarantee the interests of the Amazon's residents when conflicts arise with more influential regions of the country. Clear definitions of development objectives are essential as a prerequisite for any planning (Fearnside, 1983c). I suggest that development alternatives be evaluated on the basis of benefits to the residents of the Amazon

region and their descendants. Coherent policies must include the maintenance of the human population below carrying capacity, the implantation of agronomically and socially sustainable agroecosystems, and limitations on total consumption and on the concentration of resources. The inclusion of future generations of local residents in any considerations means that greater weight must be accorded the delayed costs implied by such potential consequences of deforestation as hydrological changes, degradation of agricultural resources, and sacrifice of as yet untappable benefits from rainforest. The folly of present trends toward rapid conversion of rainforest to low-yielding and short-lived cattle pasture is evident, at least with respect to the long-term interests of Amazonia's residents (Fearnside, 1979b, 1980c; Goodland, 1980; Hecht, 1981).

4.4 CONCLUSIONS

1.) Deforestation in the Brazilian Amazon is proceeding rapidly. The future course of rainforest clearing depends on a complex network of interacting factors. Forces such as a positive feedback relationship between roadbuilding and land clearing can be expected to increase deforestation, while factors such as the increasing importance of resident population relative to the influx of immigrants should act to slow, but not stop, the process. Rapid deforestation will probably continue in the coming years.

2.) Many government policies affect deforestation, including those related to land tenure, reserve protection, investment incentives, and inflation.

3.) Policies designed for the long-term benefit of the Amazon's residents and their descendants must include measures to slow and contain deforestation. Such measures must be based on sound understanding of the forces motivating deforestation, as well as a clear definition of development goals. The current pace of deforestation in the region suggests that, if they are to be effective, any measures must be implemented quickly.

ACKNOWLEDGEMENTS

I thank J.G. Gunn, D.H. Janzen, G.T. Prance, J.M. Rankin, and G.M. Woodwell for their valuable comments on earlier versions of the manuscript.

4.5 REFERENCES

Brazil, Ministério da Agricultura, Instituto Brasileiro de Desenvolvimento Florestal (IBDF). 1983. Desenvolvimento Florestal no Brasil, Proj. PNUD/FAO/BRA-82-008. Folha Informativa No. 5.

Brazil, Ministério da Agricultura, Instituto Brasileiro de Desenvolvimento Florestal (IBDF). 1985. Alteração da cobertura vegetal natural do Estado de Rondônia. Map scale: 1: 1,000,000. IBDF, Brasília.

Brazil, Ministério da Agricultura, Instituto Nacional de Reforma Agrária (INCRA). 1980. Imposto Territorial Rural: Manual de Orientação 1980. INCRA, Brasília. 10 pp.

Brazil, Presidência da República, Secretaria de Planejamento, Fundação Instituto Brasileiro de Geografia e Estatística (IBGE). 1982. Anuário Estatístico do Brasil - 1981. Vol. 42. IBGE, Rio de Janeiro. 798 pp.

Bunker, S.G. 1980. Forces of destruction in Amazonia. Environment 22(7), 14-43.

Carneiro, C.M.R., Lorensi, C.J., dos Santos Barbosa, M.P., de O. Almeida, S.A., de Queiroz, E.C., Daros, L.L., Moreira, M.L., and Pereira. M.T. 1982. Programa de Monitoramento da Cobertura Florestal do Brasil: Alteração da Cobertura Vegetal Natural do Estado de Rondônia. Instituto Brasileiro de Desenvolvimento Florestal (IBDF), Brasília. 68 pp.

Caufield, C. 1982. Brazil, energy and the Amazon. New Scientist 96, 240-243.

Clark, C.W. 1973. The economics of overexploitation. Science 181, 630-634.

Clark, C.W. 1976. Mathematical Bioeconomics: the Optimal Management of Renewable Resources. Wiley-Interscience, New York, 352 pp.

de Almeida, H. 1978. O desenvolvimento da Amazônia e a Política de Incentivos Fiscais. Superintendência do Desenvolvimento da Amazônia (SUDAM), Belém. 32 pp.

Denevan, W.M. 1982. Causes of deforestation and forest and woodland degradation in tropical Latin America. Report to the Office of Technology Assessment (OTA), Congress of the United States, Washington, D.C. 55 pp.

Egler, E.G. 1961. A Zona Bragantina do Estado do Pará. Revista Brasileira de Geografia 23(3), 527-555.

Fearnside, P.M. 1979a. The development of the Amazon rain forest: priority problems for the formulation of guidelines, Interciencia

4(6), 338-343.

Fearnside, P.M. 1979b. Cattle yield prediction for the Transamazon Highway of Brazil, Interciencia 4(4), 220-225.

Fearnside, P.M. 1980a. Desmatamento e roçagem de capoeira entre os colonos da Transamazônica e sua relação à capacidade de suporte humano, \Ciência e Cultura\ 32(7) suplemento, 507 (abstract).

Fearnside, P.M. 1980b. Land use allocation of the Transamazon Highway colonists of Brazil and its relation to human carrying capacity. Pages 114-138 In Barbira-Scazzocchio, F. (ed.) Land, People and Planning in Contemporary Amazonia. Centre of Latin American Studies Occasional Paper No. 3, Cambridge University, Cambridge, U.K. 313 pp.

Fearnside, P.M. 1980c. The effects of cattle pasture on soil fertility in the Brazilian Amazon: consequences for beef production sustainability, Tropical Ecology 21(1), 125-137.

Fearnside, P.M. 1982. Deforestation in the Brazilian Amazon: how fast is it occurring? Interciencia 7(2): 82-88.

Fearnside, P.M. 1983a. Stochastic modeling and human carrying capacity estimation: a tool for development planning in Amazonia. Pages 279-295 In Moran, E.F. (ed.) The Dilemma of Amazonian Development, Westview Press, Boulder, Colorado, 347 pp.

Fearnside, P.M. 1983b. Land use trends in the Brazilian Amazon Region as factors in accelerating deforestation, Environmental Conservation 10(2), 141-148.

Fearnside, P.M. 1983c. Development alternatives in the Brazilian Amazon: an ecological evaluation, Interciencia 8(2), 65-78.

Fearnside, P.M. 1984a. A floresta vai acabar? Ciência Hoje 2(10), 42-52.

Fearnside, P.M. 1984b. Brazil's Amazon settlement schemes: conflicting objectives and human carrying capacity, Habitat International 8(1), 45-61.

Fearnside, P.M. nd-a. Agriculture in Amazonia. In Prance, G.T. and Lovejoy, T.E. (eds) The Tropical Rain Forest, Pergamon Press, Oxford, U.K. (in press).

Fearnside, P.M. nd-b. Deforestation and decision-making in the development of Brazilian Amazonia. \Interciencia\ (forthcoming).

Fearnside, P.M. nd-c. Land clearing behaviour in small farmer settlement schemes in the Brazilian Amazon and its relation to human carrying capacity. In Chadwick, A.C. and Sutton, S.L. (eds.) The Tropical Rain Forest: Ecology and Resource Management, Supplementary Volume, Leeds Philosophical and Literary Society,

Leeds, U.K. (in press).

Fearnside, P.M. nd-d. Environmental Change and deforestation in the Brazilian Amazon. In Hemming, J., (ed.) Change in the Amazon Basin: Man's Impact on Forests and Rivers. University of Manchester Press, Manchester, U.K. (in press).

Fearnside, P.M. and Rankin J.M. 1982. Jari and Carajás: the uncertain future of large silvicultural plantations in the Amazon, Interciencia 7(6), 326-328.

Fearnside, P.M. and Salati, E. nd. Desmatamento explosivo em Rondônia. (Forthcoming).

Furley, P.A. and Leite, L.L. nd. Land development in the Brazilian Amazon with particular reference to Rondônia and the Ouro Preto Colonization Project. In Hemming, J. (ed.) Change in the Amazon Basin: the Frontier after a Decade of Colonization, University of Manchester Press, Manchester, U.K. (in press).

Gligo, N. 1980. The environmental dimension in agricultural development in Latin America, Comisión Economica para América Latina (CEPAL) Review December 1980, 129-135.

Goodland, R.J.A. 1980. Environmental ranking of Amazonian development projects in Brazil, Environmental Conservation 7(1), 9-26.

Hardin, G. 1968. The tragedy of the commons, Science 162, 1243-1248.

Hecht, S.B. 1981. Deforestation in the Amazon basin: practice, theory and soil resource effects, Studies in Third World Societies 13, 61-108.

Ianni, O. 1979. Colonização e Contra-Reforma Agrária na Amazônia. Editora Vozes, Petrópolis, Rio de Janeiro. 137 pp.

Kleinpenning, J.M.G. 1975. The Integration and Colonisation of the Brazilian Portion of the Amazon Basin. Katholieke Universiteit, Geografisch Planologisch Instituut, Nijmegen, Holland. 177 pp.

Kleinpenning, J.M.G. 1977. An evaluation of the Brazilian policy for the integration of the Amazon region (1964-1974), Tijdschrift voor Econ. en Sociale Geografie 68(5), 297-311.

Léna, P. 1981. Dinâmica da estrutura agrária e o aproveitamento dos lotes em um projeto de colonização de Rondônia. In Mueller, C.C. (ed.) Expansão da Fronteira Agropecuária e Meio Ambiente na América Latina. Departamento de Economia, Universidade de Brasília, Brasília, 2 vols. (irregular pagination).

Mahar, D.J. 1979. Frontier Development Policy in Brazil: a Study

of Amazonia. Praeger, New York. 182 pp.

Mesquita, M.G.G.C. and Egler, E.G. 1979. Povoamento. Pages 56-79 In Valverde, O. (ed.) A Organização do Espaço na Faixa da Transamazônica, Vol. 1: Introdução, Sudeste Amazônico, Rondônia e Regiões Vizinhas. Fundação Instituto Brasileiro de Geografia e Estatística (IBGE), Rio de Janeiro. 258 pp.

Moran, E.F. 1980. Developing the Amazon. Indiana University Press, Bloomington, Indiana. 292 pp.

Myers, N. 1980. Conversion of Tropical Moist Forests, National Academy of Sciences Press, Washington, D.C. 205 pp.

Myers, N. 1982. Depletion of tropical moist forests: a comparative review of rates and causes in the three main regions, Acta Amazonica 12(4), 745-758.

Pereira, F. 1982. "Tucuruí: já retirados 15% da madeira." Gazeta Mercantil (Brasília), 6 October 1982, p. 11.

Plumwood, V. and Routley, R. 1982. World rainforest destruction--the social factors, The Ecologist 11(6), 4-22.

Saunders, J. 1974. The population of the Brazilian Amazon. Pages 160-180 In Wagley, C. (ed.) Man in the Amazon, University Presses of Florida, Gainesville, Florida. 329 pp.

Sawyer, D. 1982. Frontier expansion and retraction in Brazil. Paper presented at the Seminar on Frontier Expansion in Amazonia. University of Florida, Gainesville, Florida, February 8-11, 1982. (forthcoming).

Sioli, H. 1973. Recent human activities in the Brazilian Amazon Region and their ecological effects. Pages 321-334 In Meggers, B.J., Ayensu, E.S. and Duckworth, W.D. (eds.) The Tropical Forest Ecosystem in Africa and South America: a Comparative Review. Smithsonian Institution Press, Washington, D.C. 350 pp.

Sioli, H. 1980. Foreseeable consequences of actual development schemes and alternative ideas. Pages 257-268 In Barbira-Scazzocchio, F. (ed.) Land, People and Planning in Contemporary Amazonia. Centre of Latin American Studies Occasional Paper No. 3, Cambridge University, Cambridge, U.K., 313 pp.

Smith, N.J.H. 1982. Rainforest Corridors: the Transamazon Colonization Scheme. University of California Press, Berkeley, California. 248 pp.

Tambs, L.A. 1974. Geopolitics of the Amazon. Pages 45-87 In Wagley, C. (ed.) Man in the Amazon. University Presses of Florida, Gainesville, Florida. 329 pp.

ardin, A.T., Lee, D.C.L., Santos, R.J.R., de Assis, O.R., dos

Santos Barbosa, M.P., de Lourdes Moreira, M., Pereira, M.T., Silva, D., and dos Santos Filho, C.P. 1980. Sub projeto Desmatamento, Convênio IBDF/CNPq-INPE 1979. Instituto Nacional de Pesquisas Espaciais-INPE, Relatorio INPE-1649-RPE/103, São Paulo, São José dos Campos, 44 pp.

Zockun, M.H.G.P. 1980. A expansão da Soja no Brasil: Alguns Aspectos da Produção. Instituto de Pesquisas Econômicas da Universidade de São Paulo, São Paulo, 243 pp.

Table 1. Proximal causes of deforestation

PRINCIPAL PRESENT MOTIVES	LINK TO DEFOREST-ATION	RELATIVE IMPORTANCE BY SIZE OF HOLDING	
		Small Properties	Large Properties
1.) Land speculation.	Clearing establishes proprietary claims, raises resale value of land.	Important in squatter areas and for tentatively documented colonists in official settlement areas.	Important in areas held by grileiros (land grabbers) as well as in legally documented areas (difficult to defend from squatters).
2.) Tax incentives.	Businesses can avoid paying taxes owed on enterprises elsewhere in Brazil if money is invested in Amazonian ranches (Bunker, 1980; de Almeida, 1978; Fearnside, 1979a; Mahar, l979).	Not a factor.	Important in projects approved by the Superintendency for the Development of Amazonia (SUDAM) (mostly in Pará) or by the Superintendency for the Manaus Free Trade Zone (SUFRAMA) (in Amazonas).@7oa@8o
Tax penalties.	Higher taxes on "unused" (i.e. uncleared) land (Brazil, Ministério da	Not important.	May become important.

		Agricultura, INCRA, 1980).		
3.)	Negative interest loans and other subsidies.	Financing of government-approved ranching projects at nominal interest rates lower than inflation.	Not a factor.	Important. As with tax incentives, most important in southern Pará.
4.)	"Chronograms" for incentivated projects.	Government-approved ranching projects must adhere to a schedule for clearing to qualify for continued incentives.	Not a factor.	Important in SUDAM and SUFRAMA project areas, but many ranches receive subsidies without full compliance.
5.)	Special crop loans.	Cacao, coffee, rubber, black pepper, sugar cane, and annual crops are financed in some areas. These crops would not be attractive without the favorable loan terms.	Important in official colonization areas.	Important for relatively few large holdings, although medium-sized holdings (500-2000 ha) benefit in Rondônia.
6.)	Export-	Beef, and to	Important among	Important, although

	able product-tion.	a lesser extent cacao, upland rice, and other crops, are sold in other regions or countries.	small farmers who depend on cash crop sales for year-to-year survival. Speculative benefits come as a windfall for these, although a significant number of lots are owned by non-resident speculators for whom agricul-tural produc-tion is a minor consideration.	often larger holdings are integrated into more diversified investment portfolios. In the case of oper-ations largely motivated by subsidies and speculative oppor-tunities, sale of production, even if meagre, adds to the profit from clearing.
7.)	Subsis-tence produc-tion.	Relatively minor.	Minor, espec-ially in gover-ment coloniza-tion areas, where most clearing is for cash crop planting.	Not significant.

New incentives for cattle ranches from the Superintendency for Development of the Amazon (SUDAM) were suspended in 1979 for areas classified as "high forest," but new projects continue to be approved for "transition forest" areas, and the hundreds of pre-viously approved projects in the high forest areas continue to receive incentives for clearing, most of which has yet to be done.

Table 2. Underlying causes of deforestation

Cause	Link to Deforestation
1.) Inflation.	a.) Speculation in real property, especially pasture land. b.) Increased attractiveness of low-interest bank loans for clearing.
2.) Population growth.	a.) Increased demand for subsistence production (minor factor). b.) Increased capacity to clear and plant, both for subsistence and cash crops. c.) Increased political pressure for road building (feeds back to item 4).
.) Mechanization of agriculture in southern Brazil and absorption of small holdings by large estates in the south and northeast.	a.) Immigration of landless laborers (increasing felling both as squatters and as workers on other properties). b.) Immigration of smallholders to purchase land (both augment item 2).
4.) Road building and improvement.	a.) Immigration to Amazonia (feeds back to item 2). b.) Increased clearing by persons already present.
5.) Low land prices.	a.) Extensive land uses (e.g. pasture). b.) Little concern for sustainability of production. c.) Attraction of smallholders to immigrate

	to Amazonia. d.) Little motivation for landholders to defend uncleared areas from squatters. e.) Greater potential speculative gains.
.) National politics.	a.) Tendency of Amazonian interior residents to support incumbent governments provides incentive to increase political representation of these areas by creating new territories and states, justified by population growth achieved through colonization programs and highway construction. b.) During specific periods of social tension in non-Amazonian portions of Brazil, as in 1970, road building and colonization programs in Amazonia have been seen as ways to alleviate pressure for land reform (e.g. Ianni, 1979). The effect of publicity surrounding the programs appears to be more important than actual population flow.
7.) International geopolitics.	Government leaders frequently justify road building and colonization near international borders as protecting the country from invasion (Kleinpenning, 1975, 1977; Tambs, 1974). These claims can be effective in rationalizing government programs desired for other reasons (Fearnside, 1984b; Kleinpenning, 1977: 310).
8.) Concentration of land tenure in Amazonia.	Displaces population when squatters' claims or small holdings are taken by large ranches. Displaced persons move to clear new areas.

9.) Fear of forest.	Deep-seated psychological aversion to forest and fear of dangerous animals impedes forested land uses. This fear is especially powerful among recent arrivals from other regions (e.g. Moran, 1980: 99).
10.) Status from cattle.	Longstanding Iberian tradition of according higher social status to ranchers than farmers leads to preference for pasture independent of expected profit (Denevan, 1982; Smith, 1982: 84).
11.) Availability of alternative investments elsewhere.	Heavy discounting of expected future costs and returns for investments in the Amazon, leading to little concern for sustain-ability of production systems (see Clark 1973, 1976).
12.) Distribution of environmental costs of deforestation over society at large.	Increases relative economic attractiveness to individual investors of land uses requiring large deforested areas, as compared to intensive use of small clearings or sustained management of standing forest (see Hardin, 1968).
13.) Unsustainable land use choices for cleared areas.	Clearing more area to substitute for no-longer-productive land.
14.) Low labor requirement of predominant land use (e.g. pasture).	a.) Small population can clear and exploit a large area. b.) Little contribution to solving problems of unemployment, underemployment, and landlessness, which encourage further deforestation.

15.)	Low agricultural yields.	a.) Increased area needed to supply subsistence demand (relatively minor). b.) Money from government subsidies spent on unproductive ranches and other projects fuels inflation by increasing purchasing power of beneficiaries, without contributing corresponding amounts of production to the economy (feeds back to item 1).

Table 3. Expected additional motives for future deforestation.

Motive	Reason expected
1.) Timber export.	Expected to increase with coming end to Southeast Asian rainforests now supplying world markets (Fearnside and Rankin l982).
2.) Charcoal production.	Expected to increase for steel production for the Grande Carajás Project, in south-eastern Pará. Both native forest harvest and plantations are planned.
3.) Support of mineral development sites.	Expected to accompany developments at Carajás, Trombetas, Serra Pelada, and elsewhere.
4.) Hydroelectric projects.	Planned projects at Balbina (Rio Uatumã) Samuel (Rio Jamari) and Itapunara (Rio Jari) would total 4445 km^2 of reservoir area (Goodland, 1980), plus additional unknown areas from 2 dams on the Rio Xingú and up to 4 additional dams on the Rio Tocantins (Goodland, 1980)@7oa@8o. Existing dams in the region at Curuá-Una (Rio Curuá-Una) and Paredão, also known as Coary Nunes (Rio Araguari), and Tucuruí (Rio Tocantins) total 2539 km^2. Some new area will be cleared by persons displaced by the dams, as well as by expected support communities. Fluctuations in released water volume, as at Balbina, will also kill substantial forest areas downstream of the dams. Forest loss from hydroelectric projects, however, is small when compared with losses to ranching or other activities.

Ultimate goals for the Rio Tocantins and its tributaries reportedly call for construction of 8 large dams (including Tucuruí) plus 19 smaller ones, while the Rio Xingú would eventually have 9-10 large dams (Caufield l982).

FIGURE LEGENDS

Fig. 4.1.Brazil's "Legal Amazonia."

Fig. 4.2.Growth of population and deforested area in the state of Rondônia. Deforested area is growing even more rapidly than population in this focus of rainforest clearing in Amazonia. Ten-year interval populations are from census data compiled by the Brazilian Institute for Geography and Statistics (IBGE) (Saunders, 1974; Brazil, Presidência da República, IBGE, 1982: 74); 1976 intercensal estimate is by IBGE (Mesquita and Egler, 1979: 73). Deforestation estimates for 1975 and 1978 are from Tardin et al. (1980); 1980 estimate is from Brazil, Ministério da Agricultura IBDF (1983).

Fig. 4.3.Causal loop diagram of the relationship between roadbuilding and deforestation. Signs by arrow heads indicate the direction of change that would result from an increase in the quantity at the tail of the arrow. Roads and population form a positive feedback loop. Roads also increase land values, leading the original colonists to sell their land top newcomers who clear more rapidly. Improved transport for agricultural production makes farming more profitable, leading colonists to clear and plant larger areas.

Fig. 4.4.Causal loop diagram of the relationship of inflation to deforestation for cattle pasture. High inflation leads to land speculation as a means of preserving the value of money. Pasture is planted to secure these investments against squatters or other claimants. The low production of beef from pastures on these soils means that the money invested in ranching is increasing the demand for products in the marketplace without contributing anything that can be bought. The increase of demand over supply raises prices, contributing to still higher inflation.

Fig. 1

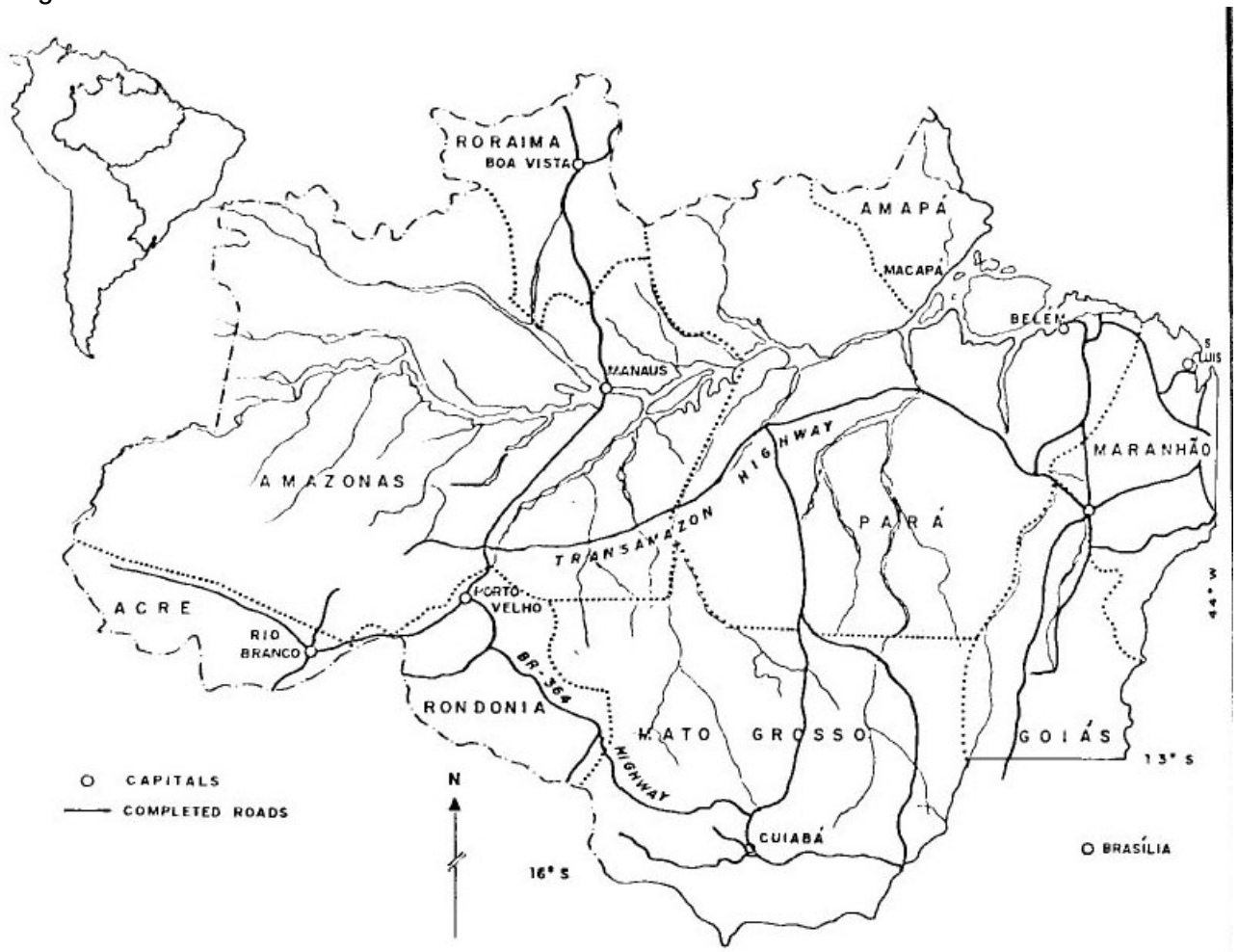

RORAIMA
BOA VISTA
AMAPÁ
MACAPÁ
BELÉM
S. LUIS
MANAUS
AMAZONAS
TRANSAMAZON HIGHWAY
MARANHÃO
PARÁ
ACRE
PORTO VELHO
RIO BRANCO
BR-364
RONDONIA
MATO GROSSO
GOIÁS
HIGHWAY
CUIABÁ
BRASÍLIA
CAPITALS
COMPLETED ROADS
N
16° S
13° S
44° W

Fig. 2

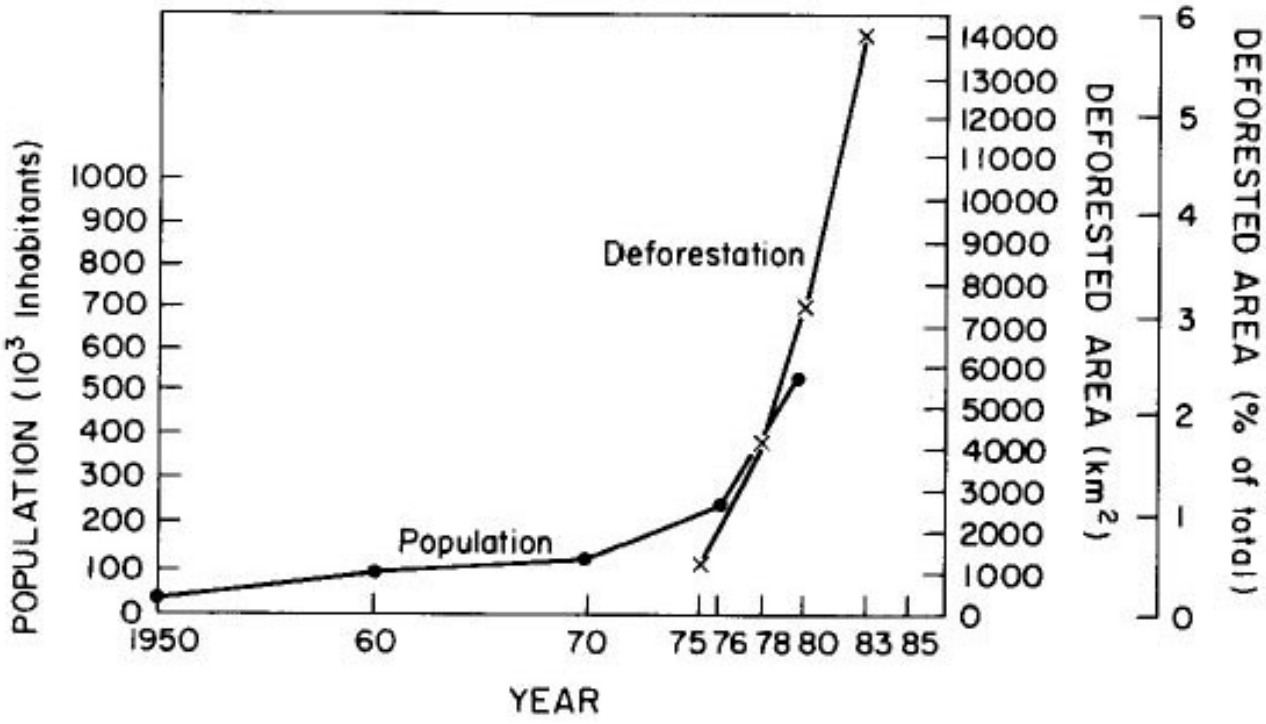

POPULATION (10^3 Inhabitants)
1000
900
800
700
600
500
400
300
200
100
0
Deforestation
Population
1950
60
70
75
76
78
80
83
85
YEAR
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
DEFORESTED AREA (km^2)
6
5
4
3
2
1
0
DEFORESTED AREA (% of total)

Fig. 3

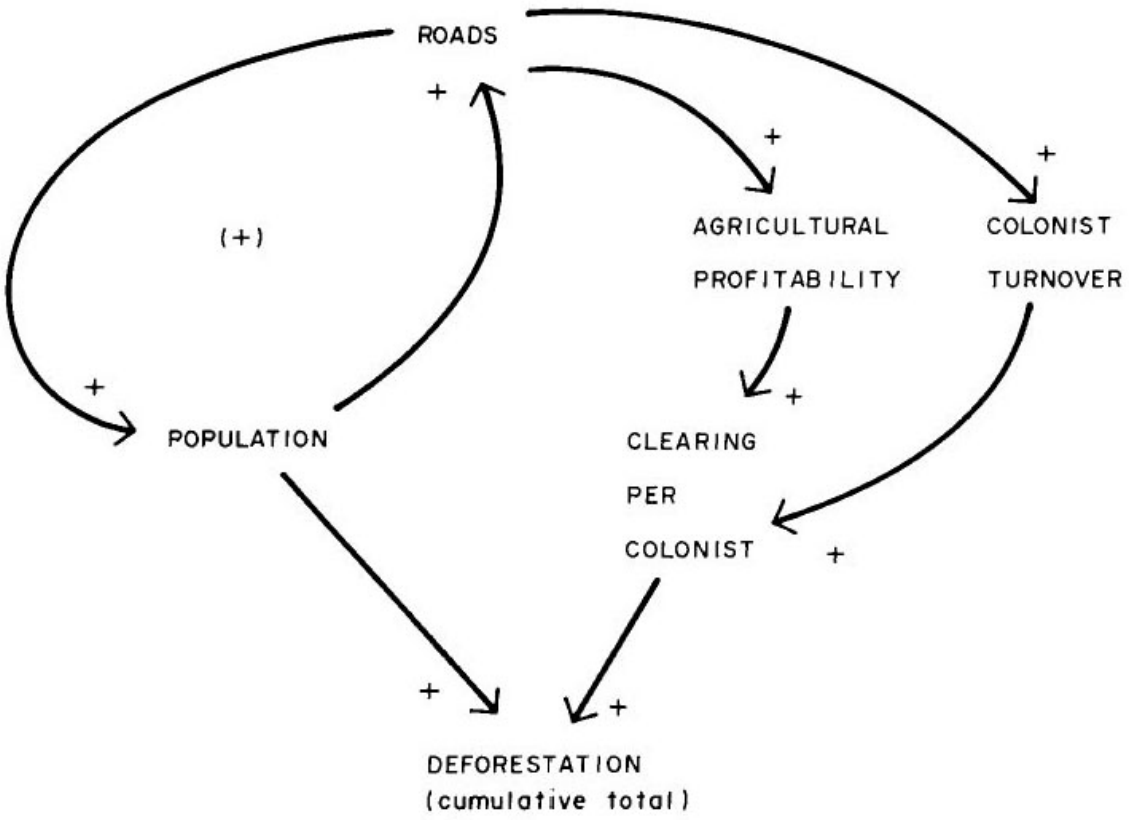
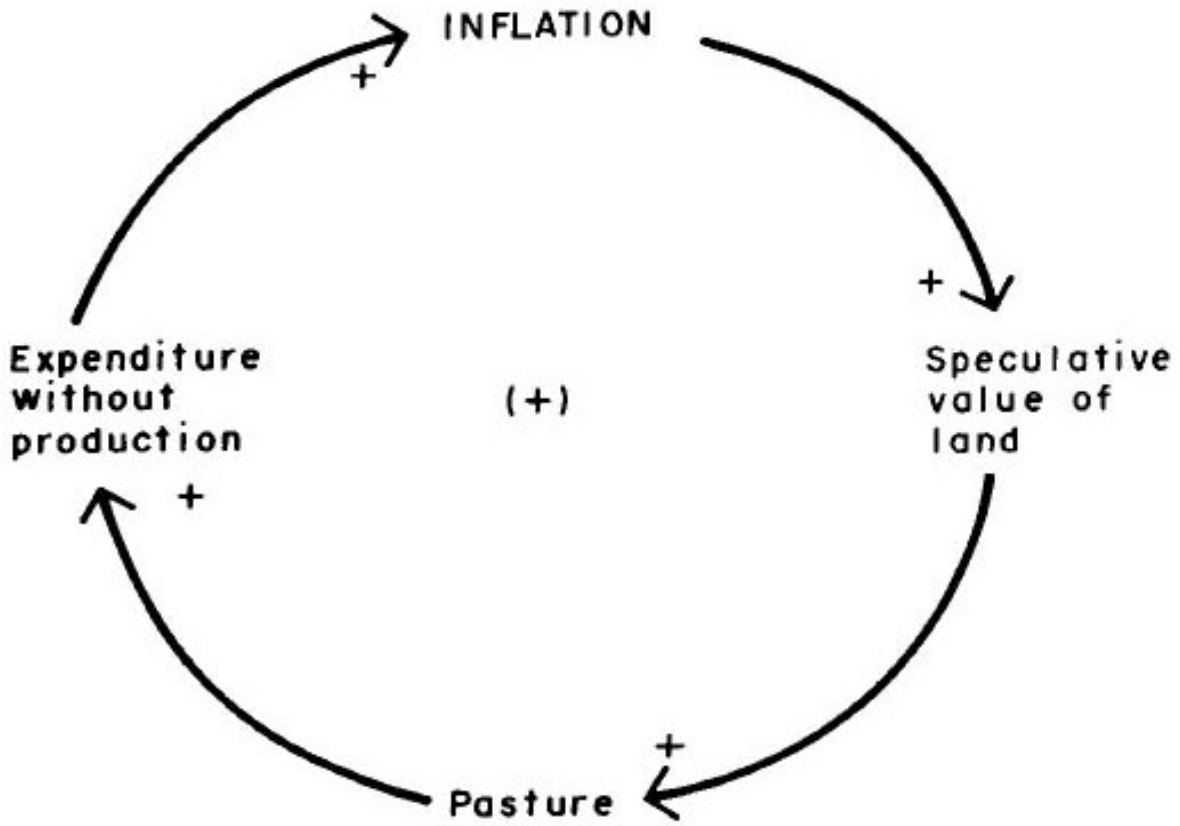

ROADS
+
+
+
(+)
AGRICULTURAL
PROFITABILITY
COLONIST
TURNOVER
+
+
POPULATION
CLEARING
PER
COLONIST
+
+
+
DEFORESTATION
(cumulative total)

Fig. 4


INFLATION
+
+
Speculative value of land
Pasture
+
Expenditure without production
+
(+)