SETTLEMENT IN RONDÔNIA AND THE TOKEN ROLE OF SCIENCE AND TECHNOLOGY IN BRAZIL'S AMAZONIAN DEVELOPMENT PLANNING

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Rondônia, a Brazilian state bordering on Bolivia in the southwestern portion of Amazonia (Fig. 1) is the destination of an increasing flood of migrants from Brazil's central-south region, particularly the state of Paraná. The exodus is primarily due to land tenure concentration and agricultural transformation from labor-intensive crops such as coffee to mechanized cultivation of soybeans and wheat, plus sugarcane plantations for alcohol. POLONOROESTE, or the Northwest Regional Development Program, is a World-Bank assisted initiative begun in May 1981 to accelerate Rondônia's economic development (International Bank for Reconstruction and Development, 1981). The centerpiece of the project is the reconstruction and paving of the BR-364 or Cuiabá-Porto Velho Highway, renamed the Marechal Rondon Highway when the paving of this 1500 km lifeline was completed in September 1984.

POLONOROESTE's US$1.55 billion budget for 1981-85 provides for the BR-364 Highway (57% of the total), with lesser amounts alloted to settlement of new areas (23%), rural development (13%), land tenure services (3%), environmental protection including Amerindian affairs (3%), and scientific research (0.5%) (Goodland, 1985: 12, 14). The Urupá and Machadinho settlement areas were financed under POLONOROESTE by 1985; areas planned under the program are Cujubim, Samaúma, Terra Firme, Capitão Silvio, and Marmelo. Bom Principio is a settlement area planned under a separate program (FINSOCIAL, not a part of POLONOROESTE). All settlement is carried out by the National Institute for Colonization and Agrarian Reform (INCRA).

The POLONOROESTE loan agreement calls for a detailed soil and land capability survey to be carried out by the Brazilian Enterprise for Research in Agriculture and Cattle Ranching (EMBRAPA). The survey is to be done for the entire zone of influence of POLONOROESTE (the states of Mato Grosso and Rondônia) at a scale of 1:250,000, with areas identified by this first phase as promising for settlement then being surveyed at 1:50,000 so that land use can be "tailored to the carrying capacity of the land" (Goodland, 1985: 13). Except for one vital fact, the plan appears to be a good means of minimizing the agricultural problems that have occurred in past projects. The flaw in the plan is that long before the maps would ever be ready higher authorities had already decided both that the settlement projects would go forward and that they would be implanted in specific locations, subsequent minor adjustments in settlement area boundaries notwithstanding. In May 1982 the governor of Rondônia announced that at least 150,000 families would be settled in the Guaporé River Valley, the location of the Samaúma, Conceição, Terra Firme and Bom Princípio Projects (See Fig. 1), and that an additional 150,000 families could be absorbed "rationally and without any problems" over a 5-year period in projects elsewhere in the state (*A Critica*, 13 May 1982). Later in the same year EMBRAPA released land capability maps, albeit at one-quarter the level of detail originally planned for the first mapping phase. The 1:500,000 scale maps (Brazil, Ministério da Agricultura, EMBRAPA-SNLCS, 1982; Brazil, CEPA-RO, 1983) are interpreted here with reference to existing and planned settlement areas. The maps reveal that the planned projects are located on much poorer soils than are existing projects, and suggest that prospects for agriculture are poor. Even the coarse scale information (1:1,000,000 mapping based on 1:250,000 imagery) available before the plans were announced indicated low agricultural potential for the areas chosen for the planned projects (Brazil, Ministério das Minas e Energia, DNPM, Projeto RADAMBRASIL, 1978, 1979; Furley, 1980).

The hasty confection of settlement plans in Rondônia, with the various government organs consulted to propose viable agricultural systems for

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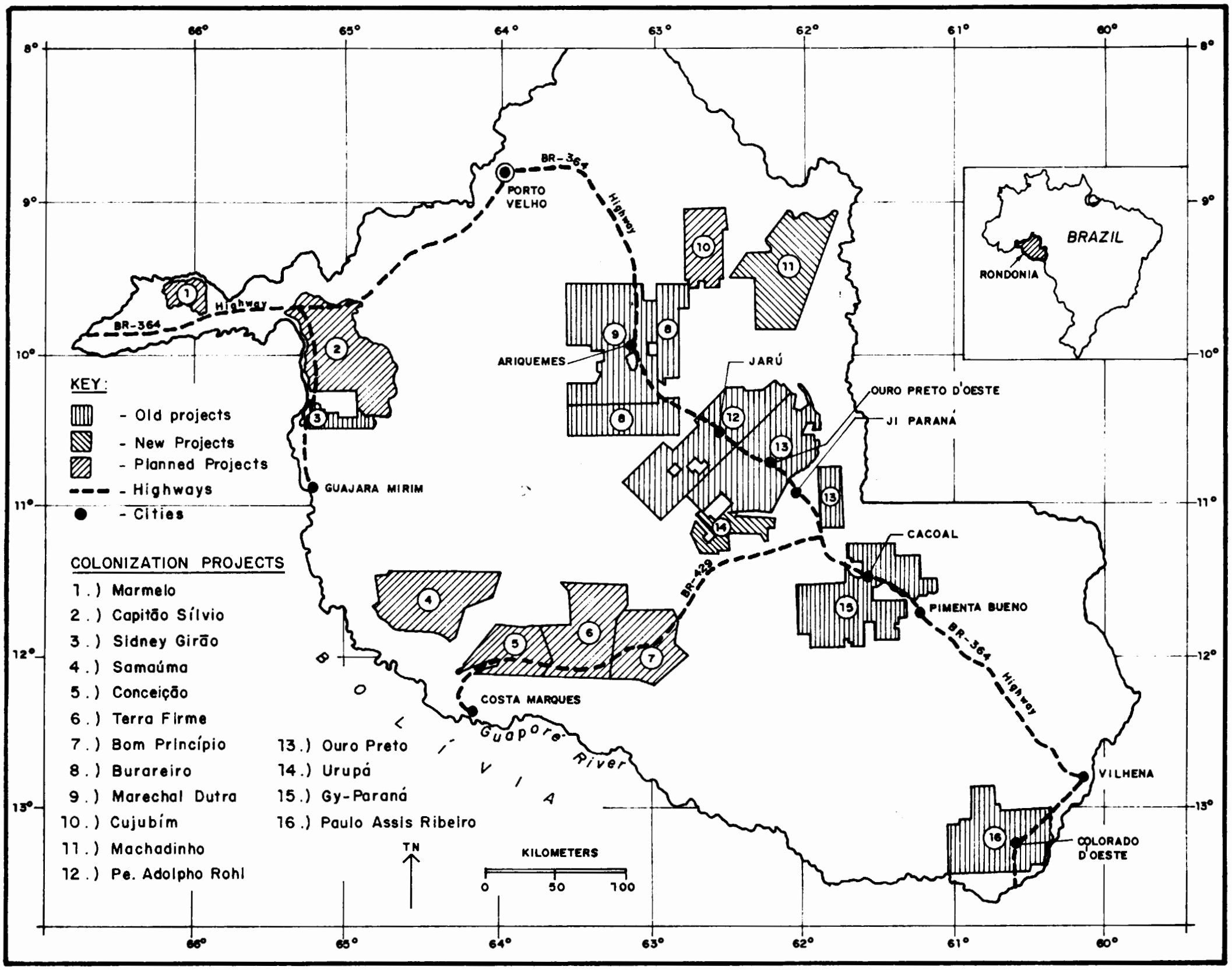


Figure 1. Locations of settlement areas in Rondônia.

these areas only after the decisions were made to implant the projects, exemplifies a pattern characterizing development throughout the Amazon region (see Fearnside, 1985a). Major projects are initiated by high-level decisions, restricting any research on environmental or other impacts to trying to minimize the ill effects of developments whose ultimate existence has already been decreed.

Existing and Planned Colonization

Five Integrated Colonization Projects (PICLC) were begun during the 1970's — Ouro Preto (1970), Sidney Girão (1971), Gy Paraná (1973), Padre Adopho Rohl (1973), and Paulo Assis Ribeiro (1974)—followed by two Directed Settlement Projects (PADSC)—Burareiro (1974) and Marechal Dutra (1975) (Valverde *et al.*, 1979). PICLC provided more government services to the settlers than PADS. All of the settlement areas begun during the 1970s were composed predominantly of 100 ha lots with the exception of Burareiro, where 500 ha lots were sold through sealed tenders.

A second wave of settlement initiatives began with the Urupá colonization area, opened in 1982 and filled by 1984. In Urupá each colonist family was assigned 50 hectares (ha), half of which was located separately in a "block reserve" in compliance with Brazil's Forestry Code (Decree Law 4771 of 15 September 1965), which requires that 50% of the land remain in forest. The block reserve, like many other reserves in Rondônia, is already invaded by squatters (Fearnside and Ferreira, 1984). A "Forest Battalion" removed squatters in 1985, but many reinvasions have occurred since. In the projects implanted in the 1970's half of each lot was to be retained in forest by the individual colonist, although this requirement has never been enforced (see Fearnside, 1979a). In Machadinho, begun in 1984 and scheduled for completion by 1986, 60 ha is being distributed to each family, half in a block reserve. Cujubim, the next to be settled, has 100 ha per family, also half in a reserve. Bom Princípio (a FINSOCIAL project) and Terra Firme (which may be transferred from POLONOROESTE to FINSOCIAL) both have 100 ha per family with half in block reserves. The Conceição and Samaúma projects foresee

TABLE I

LAND CAPABILITY IN COLONIZATION PROJECTS IN RONDÔNIA
(PERCENT OF PROJECT AREA)

Capability group	Description	Paulo de Assis Ribeiro	OLD PROJECTS							NEW PROJECTS		
			Gy-Parana	Burareiro	Ouro Preto	Padre Adolfo Rohl	Marecha Dutra	Sidney Girao	Old Projects Subtotal	Urapa	Machadinho	New Project Subtotal
Group 1AB	Soils good for agriculture with low or medium inputs	92.90	44.05	42.66	36.99	29.19	17.31	0.00	42.08	43.86	7.15	15.17
Group 1C	Soils good for agriculture only with high inputs	0.00	3.10	15.99	18.49	10.60	39.02	0.00	13.77	47.49	57.79	55.54
Group 2	Soils fair for agriculture at one or more levels of input (low, medium or high)	0.00	14.16	28.17	17.57	46.94	30.43	86.09	24.44	0.00	7.36	5.75
Group 3	Soils "restricted" for agriculture at one or more levels of input	0.00	12.50	0.00	3.46	0.00	0.00	0.00	3.05	0.74	0.00	0.16
Group 4	Soils suitable for planted pasture	0.00	0.00	0.00	0.00	0.00	0.00	12.46	0.34	0.00	0.00	0.00
Group 5	Soils suitable for silviculture or natural pasture	2.77	14.78	0.00	0.00	0.00	0.00	0.00	3.32	0.00	0.00	0.00
Group 6	Unsuitable for use (other than forest)	4.32	11.41	13.17	23.49	13.28	13.24	1.45	12.99	7.91	27.70	23.38
	Areas of Projects (km^2)	3497.50	4510.00	2742.00	4011.75	3954.75	3659.00	622.00	22997.00	985.50	3528.00	4513.50

(Continued on next page)

100 ha lots. INCRA lot maps indicate an extension of the Samaúma project completely surrounding the Ocaia Amerindian reserve — similar juxtapositions of settlement projects and reserves have already lead to invasion of the Lourdes, Sete de Setembro and Aripuanã reserves in Rondônia (see Fearnside, 1983 for discussion of the relation of spatial arrangement of land uses and the viability of reserves). Plans for Capitão Silvio call for 100 ha per colonist family, while those for Marmelo call for 40 ha per family (both including reserve area). The total area of the planned projects is over one and one half times that of all existing projects, new or old.

The World Bank has suggested reducing the lot size in projects in Rondônia in order to accomodate more families in the same areas. Advantages in discouraging cattle pasture have also been emphasized (Goodland, 1985). Settlers in Rondônia do not practice shifting cultivation where land is left fallow in woody secondary forest for a sufficient period to regenerate soil quality. Rather, most deforested land is cultivated in annual crops for only 1-2 years, after which it is converted to cattle pasture (which degrades within a decade). While planners might imagine that farmer families cultivating annual crops in plots of approximately 2 ha could theoretically maintain a sustainable shifting cultivation cycle within the 50 usable hectares of a 100 ha lot, the conversion to pasture results in an unsustainable system in most of the area regardless of lot size. The rapidly increasing number of landless migrants entering Rondônia since the BR-364 Highway was paved make policy changes likely to reduce lot sizes. According to the Rondônia State Secretariat of Agriculture, 15,000 families entered Rondônia during the first three months of 1985, and the number of families awaiting settlement totaled 50,000 by July 1985 (E. S. A. Lopes, personal communication, 1985).

Soil Capability

The soils in the area to be colonized by the new projects can be judged by comparison with soils in existing colonization areas. Except for one project (Sidney Girão), all of the five "old" areas contain more fertile soils than do more recently initiated projects — Urupá and Machadinho — or the six

TABLE I

LAND CAPABILITY IN COLONIZATION PROJECTS IN RONDÔNIA
(PERCENT OF PROJECT AREA)
(Continued)

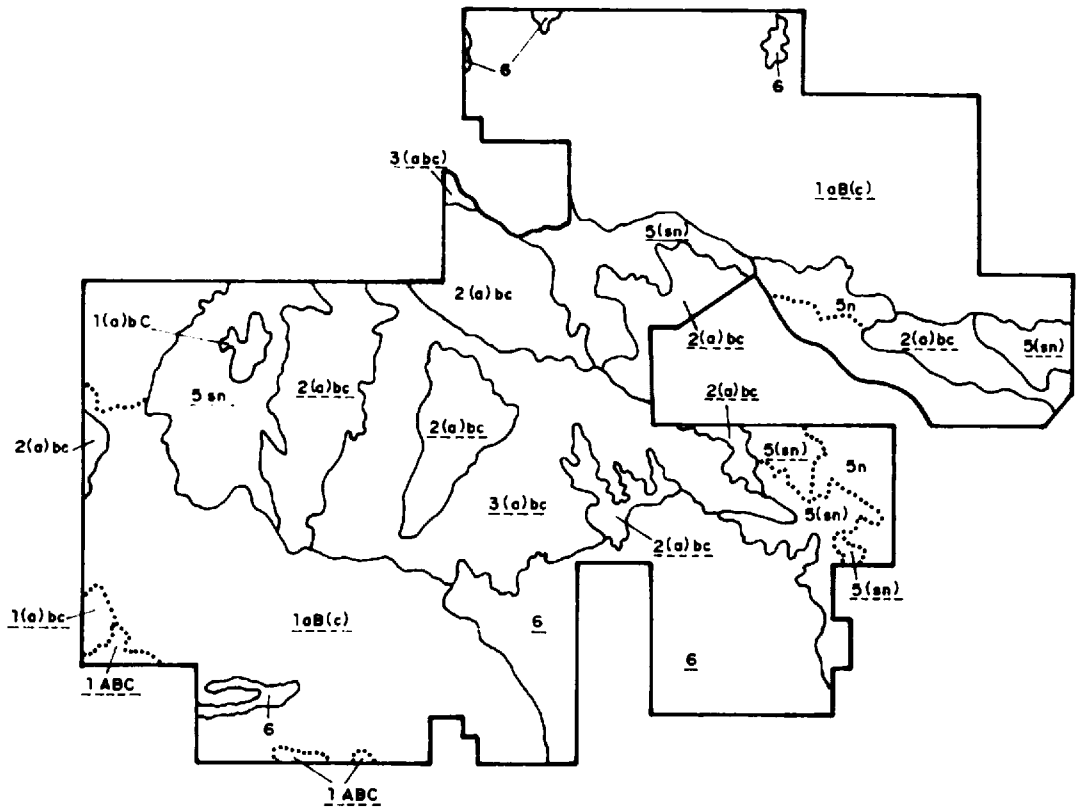
PLANNED PROJECTS									
Samauma	Capitao Silvio	Bom Prin-cipio	Terra Firme	Concei-ção	Cujubim	Marmelo	Plannned Projects Sub-Total	Area of land quality (km^2)	Percent of total area
0.38	0.28	0.00	0.00	0.00	0.00	0.00	0.13	10380.75	24.47
80.09	73.32	93.08	72.61	56.68	39.86	13.67	69.64	16062.00	37.86
0.00	4.72	0.00	0.00	0.00	59.41	66.79	9.54	7303.25	17.21
0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.08	721.75	1.70
0.55	10.93	0.00	3.15	0.00	0.74	0.00	3.52	602.75	1.42
14.48	0.00	6.36	15.00	4.68	0.00	0.00	6.82	1781.00	4.20
4.50	10.74	0.00	9.24	38.64	0.00	19.54	10.28	5575.75	13.14
2316.00	3688.75	2130.00	3137.50	1617.50	1427.00	600.00	14916.75	42427.25	100.00

planned areas (Cujubim, Samaúma, Bom Princípio, Terra Firme, Capitão Silvio, and Marmelo). Sidney Girão, the exception to the rule of more fertile soils in older projects, is a special case for geopolitical reasons. The project was implanted outside of the zone of fertile soils in order to secure the area near Brazil's border with Bolivia (Mueller, 1980). Sidney Girão was unable to retain sufficient population to fill the project's lots until long after all of the other projects in Rondônia were overflowing with disappointed land-seekers. The poor results were even officially recognized as being due to the low soil fertility of the area (Valverde *et al.*, 1979; Mueller, 1980). The case of Sidney Girão should serve as a warning to planners intent on promoting colonization schemes on poor soils.

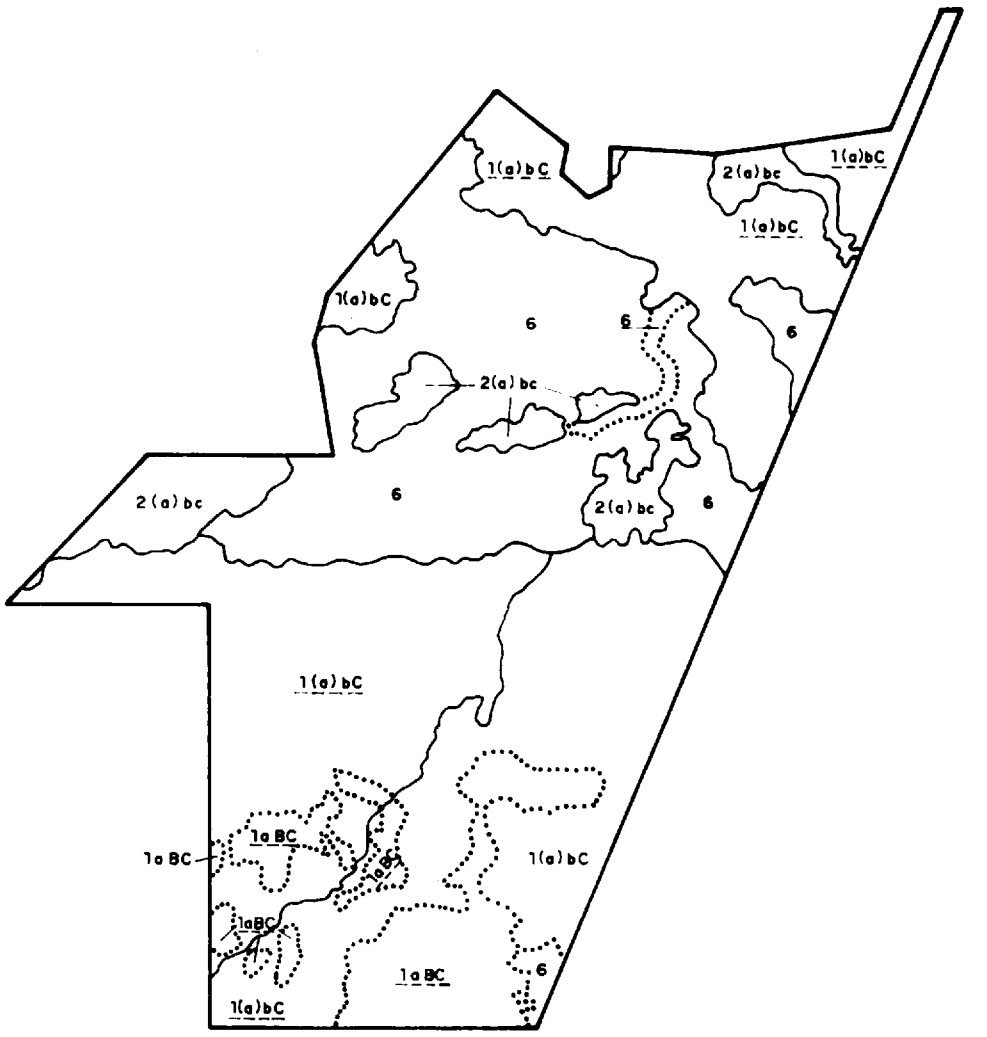
Areas in each land capability class were estimated from the 1:500,000 scale EMBRAPA map by superimposing a 1 mm x 1 mm grid over the maps and counting the squares with at least 50% of their area within each map unit. The boundaries of the projects used were those of the State Commission for Rural Planning (Brazil, CEPA-RO, 1983). The areas of the projects derived in this way (Table I) vary slightly from those reported by INCRA (Brazil, Ministério da Agricultura, INCRA-CEER, 1983).

Table I compares the land use capability ratings of the existing and planned projects. The 31 land capability classes represented in the project areas have been summarized in major groups, arranged in the table in decreasing order of fertility. The projects are classified into "old", "new" and "planned", and within these categories are arranged in order of decreasing percentage of soils rated good for agriculture with low or medium inputs (or, in the absence of any such soil, in decreasing order of the percentage of soils good for agriculture only with high inputs). Land capability maps of representative "old", "new" and "planned" settlement areas are shown in Figure 2.

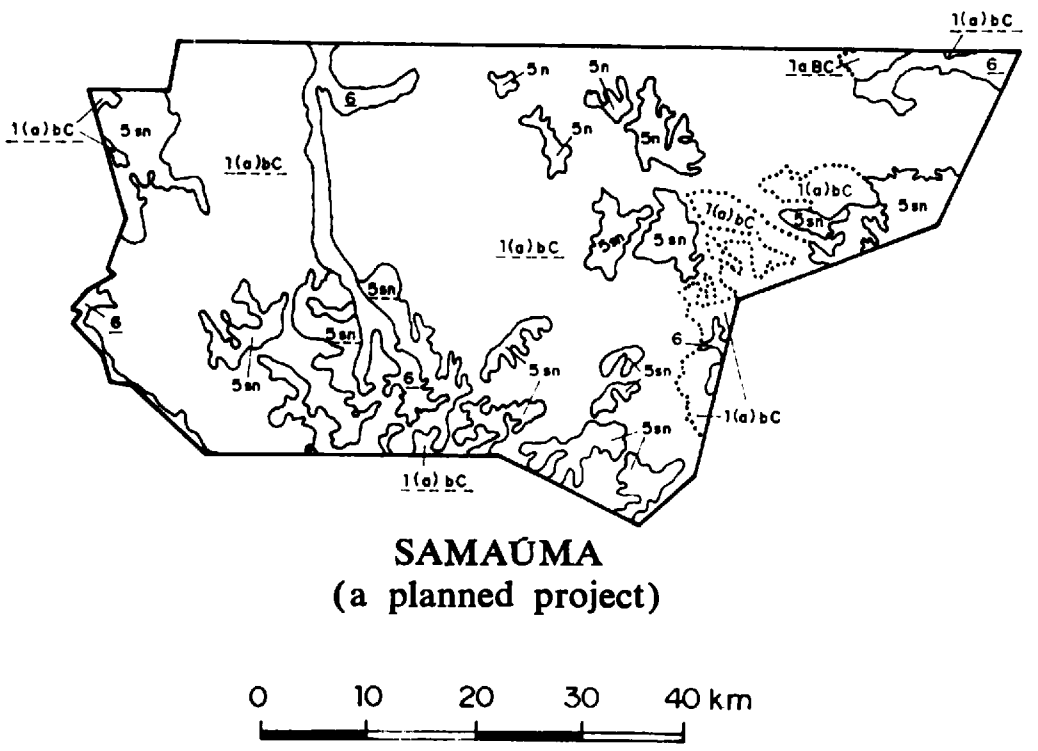
The criteria used by EMBRAPA in classifying land capability as "good", "fair", "restricted", or "unsuitable" appear to be the same as those used by Projeto RADAMBRASIL (Brazil, Ministério das Minas e Energia, DNPM, Projeto RADAMBRASIL, 1978: Vol. 16, pp. 375-87). Classifications are made for agricultural use with high, medium or low inputs, for pasture, and for silviculture. Table II summarizes the classifica-



GY PARANÁ
(an old project)



MACHADINHO
(a new project)



SAMAÚMA
(a planned project)

Figure 2. Land quality maps of representative old, new and planned settlement projects. Old projects have better soils. May codes: Numbers indicate groups (explained in Table I); letters indicate managements type: A = low inputs (manual labor, no fertilizers;) B = medium inputs (manual or animal labor, some fertilizers and biocides), C = high inputs (mechanization, heavy fertilization); P = planted pasture; S = silviculture, N = natural pasture. Indications of suitability: Capital letter = good; lower case without parentthesis = fair; lower case wtih parenthesis = poor; No letter appearing = unsuitable. Underlining: dashed = some poorer soils also occur in the association; solid = some better soils also occur in the association. Source: Brazil, CEA-RD, 1983.

tions for the low and medium input agricultural systems.

The low input management system refers to "traditional" agriculture without capital inputs, using only manual labor and simple hand tools except for "some animal traction for light agricultural implements". This is slash-and-burn agriculture with intervening fallow periods of unspecified length.

The medium input system is described as requiring a "reasonable level of technical knowledge", use of animal traction and manual labor, and "reasonable quantities of fertilizers and lime", which are "usually much less than the quantities recommended on the basis of research". The qualification is explicitly made that "colonization of these areas should not be promoted, on the basis of the land capabilities interpreted under this system, unless fertilizers are available and their appliaction is viable" (Brazil, Ministério das Minas e Energia, DNPM, Projeto RADAMBRASIL, 1978: Vol. 16, p. 381).

The high input system requires "sufficient capital to maintain and improve the condition of the land and crops", requires the use of agricultural machinery, and "maximum use of research results" including fertilizer application recommendations. Colonists cannot be expected to fertilize at these high levels; most colonists do not even, in practice, fertilize at the lower levels expected under the medium input system. The declared function of colonization as a means of alleviating rural proverty is inconsistent with the use of soils which require high capital inputs in order to sustain production.

The land capability classifications are made based on the degree of limitation from five sources: low soil fertility, water deficit, impeded drainage, erosion hazard, and impediments to agricultural mechanization. The mechanization criteria are only applied to classifications for the high input system. Restrictions for each criterion are rated "none", "light", "moderate", "strong", or "very strong". [1]

In interpreting the EMBRAPA soil capability classification presented in Figure 2 and Table I it should be remembered that some of the suggested land uses are overly optimistic in view of the agricultural results obtained in Amazonia in recent years. The practice of recommending cattle pasture for low-fertility soils (Group 4) is questionable, since pasture production declines rapidly

due to decreasing availability of phosphorus in the soil, together with soil compaction and weed invasion (Fearnside, 1979b, 1980; Hecht, 1983, 1984). Silviculture on very poor soils (Group 5) can also have unsatisfactory results, as has occurred on the poorest soils of the Jari Project (Fearnside and Rankin, 1980, 1982, 1985).

Land capability maps indicating the "suitability" of vast areas for uses requiring deforestation must be interpreted with caution. They should not be taken to mean that forest conversions of this magnitude should be promoted. Deforested areas in Rondônia were increasing at a greater than linear rate through the year 1983 — the time of the latest available satellite-based survey, which was prior to the migration surge spurred by paving the BR-364 Highway (Fearnside and Salati, 1985). Environmental costs of deforestation are significant and are linked to the scale of the developments (Fearnside, 1985b, c; Salati and Vose, 1984). Planners would be wise to guarantee that a much larger share of the total land area is retained in forest than that implied by land capability maps such as those used here.

The decline in soil quality in new and planned projects is evident in Figure 3. Because the Urupá project includes an area of good soil, the average percentage of area rated "good" at the lowest input level rises very slightly in new as compared to old projects, but still leaves over 90% of the land in less than optimal soil categories. The percentage of land of reasonable quality declines steadily from old to new to planned projects. The amount of land in the planned projects rated "good" for agriculture at low or medium input levels is an insignificant 0.13%. Since the landless migrants to be settled in these projects cannot afford the heavy fertilization and other inputs required for arable farming in the poorer soil, their agricultural efforts are likely to fail.

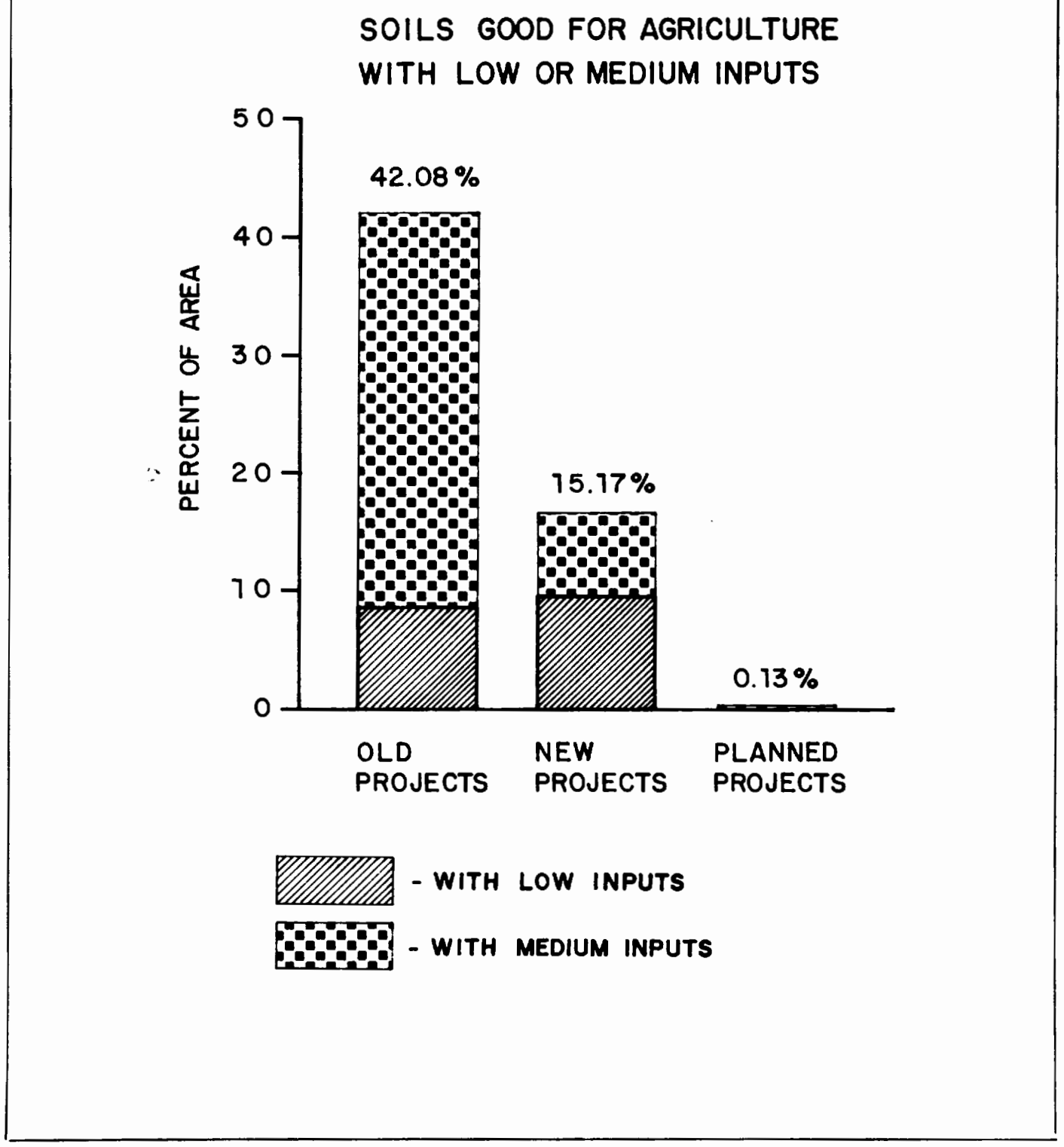


Figure 3. Percentage of soils rated "good" for agriculture with low or medium inputs (open bars). Shaded portion is for area rated "good" with low inputs (old projects = 8.58% new projects = planned projects = 0.00%. The declining share of better soils bodes poorly for agriculture in planned projects.

Conclusions and Implications for Scientists and Policy Makers

The decision-making process in use in Rondônia, as elsewhere in the Brazilian Amazon, gives inadequate weight to long-term effects, and even to medium-or short-term human impact. Among the conclusions that follow from the case of the inauspicious colonization plans in Rondônia is the need to restructure the decision-making process so that agronomic, environmental and human aspects of any proposed development are evaluated early in the decision process. The evaluations must be prior, not only to the physical initiation of the public works involved, but also to the taking of any decision on eventual realization of the overall development schemes in question.

The magnitude of the gap between official hopes and likely outcomes for the planned projects indicates that decision-makers in Rondônia might be well advised to reconsider the decisions made, even if at some cost. A retraction of this type is under consideration in the case of Marmelo, the project with the least promising soil of all. However, the location of this project on the route of the Porto Velho-Rio Branco Highway insures that pressure to settle the area will be intense, since a loan to finance paving this road was approved by the Interamerican Development Bank in 1985. Work on improving the highway has already begun.

The poor soils of the colonization projects now being initiated — when compared with those of most of the earlier projects — reflect the fact that the best agricultural land has already been claimed. It is a common phenomenon in the humid tropics that the first settlers in an area claim the best land. Subsequent waves of settlers, when no more good land is available, do the

TABLE II

LAND SUITABILITY CATEGORIES LOW AND MEDIUM INPUT SYSTEMS

CLASSIFICATION	LIMITS TO CLIMATICALLY ADAPTED CROPS	LOW INPUT SYSTEM		MEDIUM INPUT SYSTEM	
		YIELDS IN FIRST YEARS	YIELDS IN SUBSEQUENT YEARS	YIELDS	RESTRICTIONS
Good	none or slight	good in first 20 years	gradual decline after 20 years	good yields are maintained	all easily removed
Fair	light to moderate	good in first 10 years	medium in 10 subsequent years	good, with failures due to weather not more than once every 5 years	one or more cannot be totally or partially removed
Restricted	moderate to strong	medium during "first years"	rapid decrease within 10 years	medium, crop failures every 1-5 years	one or more cannot be removed, or can be partially removed with intensive improvements
Unsuitable	very strong	low or very low from the beginning	——	sustained production economically unviable	one or more cannot be removed

Source: Condensed from Brazil, Ministério das Minas e Energia, DNPM, Projeto RADAMBRASIL (1978: Vol. 16, pp. 375-387).

greatest damage. Roads and other infrastructure implanted for the first settlements facilitate the subsequent waves of migration. Political pressure generated by the presence of migrants then leads to implanting additional roads and settlement schemes, despite poor prospects. These events are not unpredictable.

Understanding the processes of settlement, deforestation and land use change is one of the areas in which scientists can contribute important information to planning. Other areas include estimation of human carrying capacity, consequences of conversions to different land uses, and the functioning of potentially sustainable agricultural and forest exploitation systems (Fearnside, 1979a, 1986). While research to obtain better information on these subjects should be a high priority, already available information is sufficient to identify many likely ill effects of current development policies.

The need to face the finite limits of agricultural land resources in Rondônia, as elsewhere, can be expected to become ever more apparent. An end to population absorption and frontier expansion will inevitably come

about, either through the force of natural environmental limitations or through conscious human decisions. The decision-making process that can best be expected to minimize the human problems surrounding the transition must include evaluations of costs and benefits prior to commitments to any given development scheme.[2]

NOTES

1. Restriction from low soil fertility, for example, is considered "none to light" if base saturation is over 50%, aluminum saturation is under 50%, the sum of exchangeable bases is over 3 meq/100 g of air dried soil, and electrical conductivity of the soil solution is under 4 mohms/cm at 25°C. Erosion hazard is rated in accord with the slope of the terrain, with an adjustment in cases of soils with low permeability. In permeable soil, erosion hazard is rated "none" if the terrain is "about level", in which case 10-20 years of agricultural production are expected with no erosion; "light" for 2-6% slope with agricultural use expected to remove 25-75% of the soil's A horizon in 10-20 years; "moderate" for 6-13% slope with all of the A horizon expected to be removed in 10-20 years; "strong" for 25-50% slope, and "very strong" for slopes over 50%.

2. I thank E. Levy for counting the map squares and J. G. Gunn and J. M. Robinson for comments on the manuscript. Funds are from the science and technology component of POLONOROESTE.

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