RONDÔNIA: ROADS THAT LEAD TO DEVASTATION

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Estimates of deforestation in Amazonia vary widely, largely as a result of different criteria used in analyzing images from the different satellites. This debate does not change the fact that deforestation is a serious problem that requires the immediate definition of an effective preservation policy.

The deforestated area in Rondônia has been growing at an explosive rate. This acceleration was already obvious in 1986, when we published an article in this journal entitled 'Rondônia: sem florestas na próxima década' (*Ciência Hoje*, nº 19). In part, this phenomenon can be attributed to the massive migration of population in Rondônia. The World Bank-financed Polonoroeste Project paved the Marechal Rondon Highway (BR-364, Cuiabá-Porto Velho), greatly facilitating migration since September 1984. Migration is not the only factor: deforestation has been growing an even more dizzying pace than population. In other words, it's not only Rondônia's population that is growing, but the rate of deforestation per inhabitant — the average person who lives there has begun to clear more.

Faced with this, not only do we have to improve monitoring as a source of accurate information about the extent of deforestation, but we also need to better understand the phenomenon's underlying causes. Only this kind of analysis can allow a more realistic projection of future trends, whether the current plans are maintained or alternative strategies are adopted. This is also the only way making possible to identify effective measures to control the deforestation process.

The data on deforestation in Rondônia given by different satellites are quite conflicting; nevertheless, they give us an idea about the pace of the deforestation process (see 'The escalation of deforestation').

In interpreting the meaning of the deforestation data from Rondônia it is instructive to analyze the relationship between the growth of deforestation and the population of the state. What we find is that deforested area was growing more quickly than the population: from 1980 to 1985 the estate population grew at an exponential rate of 14.85% per year, but deforestation grew at the much higher rate of 24.8% per year (figure 2).

Another alarming fact is that deforestation has started to spread. This is appurent in AVHRR images from 1987 analyzed by J.-P. Malingreau, at the NASA, indicating that deforestation had already begun to spread along the BR-429 Highway that goes to Costa Marques, on Brazil's frontier with Bolivia (the route of this highway is shown on the map in figure 3). Until then, deforestation in the state had been concentrated along the BR-364 Highway (Cuiabá-Porto Velho) and the roads that connect the BR-364 with Guarajá-Mirim and Colorado. The Guaporé River valley — which takes up nearly half of Rondônia — had remained practically untouched prior to building the BR-429. The opening of this vast area to migration and deforestation is much more serious than would be felling the same amount of forest in the occupied area along the BR-364 Highway, because the likely to result is explosive and uncontrolled expansion of the process in the remainder of the state.

Both the diagnosis of problems and the prescription of countermeasures need be finely tailored to particular locations in the case of Rondônia. That is necessary because deforestation does not follow a uniform pattern, even within the bounds of the region covered by settlement projects. In fact, in some limited areas of these projects — more precisely in the oldest settlements — deforestation continues at a much slower pace, which is very different from the exponential pattern evident when one looks at the state as a whole.

An example of these areas is indicated on the map shown in figure 3. A square on the map, measuring 1/4 degree of latitude by 1/4 degree of longitude, has been delimited in the Cacoal area. In figure 4, we can see the growth of the deforested area in this square over the period from 1973 to 1980. The parallel vertical strips represent the deforested areas along the side roads located at intervals of 5 km to provide access to the 100 ha lots of the colonists. The curved area of felling that we see in the lower left hand corner of each square corresponds to the clearing along the BR-364 Highway.

Why does the increase of deforestation in the square that we showed — even though extremely rapid — not exhibit the exponential trend observed in the state as a whole? The reason is that throughout this area the lots had already been distributed to colonists by 1973, the beginning of the time series shown. The measurements therefore reflect the behavior of farmers who have already been settled, and do not include the effect of immigrants arriving in the virgin areas to establish new land-holdings.

If we look still closer and consider individual lots — instead of examining a wider area within a settlement project — we will see deflorestation showing yet another pattern. Interviews in the Ouro Preto colonization

in Rondônia would be cancellation of these plans, as going ahead with the plan would stimulate the flow of migrants into the infertile valley of the Guaporé River. The many and various cost of such a project boggle the mind. And who would gain from it?

NUMBERED FIGURES (See *Amazônia* pp. 118-122)

Figure 1. The graph on the right shows the extent of deforested area in Rondônia, according to estimated based on data from the AVHRR sensor (corrected) and the LANDSAT satellite. The annual rates of deforestation estimated in the same way are shown on the left.

Right: Rondônia cleared area
Cleared area (km^2) Cleared area (% of the estate) Year
Left: Rondônia - rate of clearing from LANDSAT and corrected AVHRR data
Rate of clearing (km^2/year) year

Figure 2. Growth of population and of deforested area in Rondônia: felling is expanding at a more accelerated pace than the population. The broken line up to the year 1988 represents a linear projection based on the latest data available.

Population (thousand inhabitants) Deforested area (thousand km^2)
Deforested area (% of terrestrial area)

Figure 3. Map of Rondônia, with a square (1/4 degree of latitude x 1/4 degree of longitude) delimited in the Cacoal area — an area where colonization began in the early 1970s. The region has been deforested at a less intense pace than that observed in the state as a whole.

Figure 4. Deforestation series for 1/4 x 1/4 degree square (delimited in the Cacoal area) from 1973 to 1980. The series shows that in this area, where the land had already been distributed in lots when the surveys began, the forest was cut very quickly, but the pattern does not show the exponential trend displayed by data for the state as a whole.

Figure 5. Deforestation observed in a sample of 18 lots occupied by original owners.

Cumulative felling by original lot owners. Ouro Preto,
Cumulative area felled (Ha).
Time lot occupied (years).

Figure 6. The effects of colonist turnover on the rate of deforestation. Ouro Preto, Rondônia (1978-1981)

Felling/Lot/Year (Ha)
Original lot owners
Newcomers in first 4 years after arrival

Figure 7. Causal loop diagram of the relation between the construction of roads and deforestation. The sign (positive or negative) at the tip of each arrow indicates the expected direction of change in the item it points to if the item at the base of the arrow increases. Feedback loops — such as the positive loop between roads and population — are indicated by signs in parentheses.

Roads
Population Agricultural profitability Colonist turnover
Clearing per colonist
Deforestation (cumulative total)

NON-NUMBERED FIGURES (See *Amazônia* p. 116)

(p. 116). Burning in the Cujubim Colonization Project, August 1986.

FURTHER READING

FEARNSIDE P.M., 'The development of the Amazon rain forest: Priority problems for the formulation of guidelines', *Interciencia*, vol. 4, nº 6, p. 338-343, 1979.

FEARNSIDE P.M., 'Land clearing behaviour in small farmer settlement schemes in the Brazilian Amazon and its relation to human carrying capacity', in: A.C. Chadwick and S.L. Sutton (eds.) *Tropical Rain Forest: The Leeds Symposium*, Leeds Philosophical and Literary Society, Leeds, U.K., 335 p., 1984.

FEARNSIDE P.M., 'Deforestation and International Economic Development Projects in Brazilian Amazonia', *Conservation Biology*, vol. 1, nº 3, p. 214-221, 1987.

FEARNSIDE P.M., 'Causes of Deforestation in the Brazilian Amazon', in: R.F. Dickinson (ed.) *The Geophysiology of Amazonia: Vegetation and Climate Interactions*, John Wiley & Sons, New York, 526p., p. 37-61, 1987.

INSTITUTO DE PESQUISAS ESPACIAIS (INPE), *Avaliação da alteração da cobertura florestal na Amazônia Legal utilizando sensoriamento remoto orbital*, INPE, São José dos Campos, 1989.

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The escalation of deforestation

While the data provided by different satellites are often inconsistent, it is essencial to identify the most reliable information and to perform the necessary corrections if we are to arrive at an adequate estimate of the deforestation taking place in Rondônia. However, whatever data source is used, the conclusion is always alarming: the deforested area is growing at a dizzying rate.

A report written by the Directorate of Remote Sensing of Brazil's National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais - INPE) as a contribution to the federal's 'Nossa Natureza' Program indicates that by 1988 a total of 30,046 km^2 of forest had been cleared in Rondônia. If we add to this value a proportional amount of clearing in the *cerrado* (scrubland) areas, we get a total of 31,623 km^2 (13% of the state). This correction assumes that only 25% of the *cerrado* area indicated on INPE's map is exposed to deforestation. The remainder is in two Amerindian reserves (the illegal deforestation detected so far on indigenous land is limited to forest areas). The estimate for clearing in the *cerrado* (989 km^2, with an adjustment for the area of state used in the INPE study) is conservative because of the widespread conversion of this type of vegetation to pasture and soybeans in the Vilhena area of eastern Rondônia. The INPE technicians based their study on LANDSAT satellite data.

However, INPE's estimate is not compatible with information derived from the AVHRR sensor, a piece of equipment carried by the NOAA-9 meteorological satellite. Although better correction coefficients may clear up this inconsistency in the future, we have no way to explain it at present. Data from AVHRR — interpreted by J.-P. Malingreau and C.J. Tucker at the National Aeronautics and Space Administration (NASA) in the USA — indicated that 39.000 km^2 (15.1% of Rondônia) had already been cleared by 1987. An image from 1985 interpreted by the same researchers had already indicated devastation of 27,658 km^2. A linear projection from AVHRR estimates for 1985 and 1987 indicates that by 1988 the total cleared would be 41,521 km^2 (17.1% of the state).

AVHRR produces images with a resolution of 1.1 km, which is much less accurate than the 30 m resolution of LANDSAT images. The estimates based on AVHRR are less reliable, and it is possible that the difference in the results is due to the difference between the sensors.

INPE presents as a reinforcement of its more optimistic evaluation an estimate made by the Brazilian Institute for the Environment and Renewable Natural Resources (Instituto Brasileiro de Meio Ambiente e Recursos Naturais Renováveis - IBAMA), indicating that deforestation had reached 22,913 km^2 by 1986. These data, according Roberto Pereira da Cunha, leader of the team at INPE that carried out the study, had been given to INPE by Fernando César Mesquita, then Director of IBAMA. Later, a technical report from the IBAMA explained that the data were referring to 1987 LANDSAT images rather than 1986 images; this makes the discrepancy still greater with the results based on the data from AVHRR.

It is plain that the data on deforestation in Rondônia are, to say the least, confusing. Part of the discrepancy among the different studies can be attributed to the upward or downward biases inherent in the methods used for each one. In a study done in 1986, G.M. Woodwell and co-workers, from the Woods Hole Research Center in the USA, concluded that AVHRR data, due to their long degree of resolution, should **under**-estimate deforestation in Rondônia by 2 - 18%. Later, uncertainty about how to best adjust for comparing LANDSAT and AVHRR images from different years led the same authors to conclude that it would be appropriate to use a correction factor of 1.0 (leaving the results unchanged). This research group continues to find good agreement between LANDSAT and AVHRR data, but now believes that AVHRR **over**-estimates deforestation.

Malingreau, Tucker and co-workers, who have published various estimates for Rondônia based on information from AVHRR, consider that it is not necessary to use a correction factor. On the other hand, David Skole at the University of New Hampshire, USA, calculated a correction factor of 18% to balance the over-estimation resulting from the course resolution of AVHRR. He compared data from images with 10 m resolution produced by the French satellite SPOT with data from the same images with their resolutions degrated to 1.1 km to simulate the level of detail detected by AVHRR.

The over-estimation inherent in AVHRR would be greater in Rondônia than in states such as Mato Grosso where large ranches predominate in deforested areas. The results in Rondônia would be biased upward by long narrow strips of deforestation that produce the 'fish bone' pattern evident in images of settlement areas occupied by small farmers. Deforestation with this pattern often has a width smaller than the resolution of the sensor, but not wide enough to trigger the entire 'pixel' (the small squares of which the images are composed) that covers the clearing.

The studies carried out on Rondônia using LANDSAT data from 1975, 1978, 1980, 1983 and 1988 also produced biased results, but in the opposite direction. Instead of a computer analysis of digital tapes, all of these estimates were based on manual interpretation of paper photographic images. Manual interpretation tends to under-estimate the area of small clearings: the errors become larger as the scale of the images increases. The studies with images from 1975 and 1978 used a scale of 1:500,000, while the later studies used a scale of 1:250,000. We do not yet have ways of correcting for the biases inherent in the manual method. The resolution of the sensors also differs: the estimates through 1983 used the multispectral scanner (MSS) with a resolution of 80 m, while estimates for more recent years use the thematic mapper, with a resolution of 30 m.

The graphs in figure 1 allow comparison of LANDSAT and AVHRR estimates for the rate and extent of deforestation in Rondônia. More information will be necessary to analyze the discrepancy between INPE's estimate for the extent of deforestation by 1988 and that based on data from the AVHRR. With respect to the rate of deforestation, however, the value of 4,042 km^2/year derived from the latest AVHRR data is most congruent with the general trend. Assuming this as the rate, we can calculate that the deforested area by 1989 would total about 35,700 km^2, which represents 14.7% of the state.

project, where the government settled farmers in 100 ha lots, showed an interesting phenomenon. In lots that had been occupied by only one owner over a period of ten years, the deforested areas increased in a linear fashion over the first six years. However, after the sixth year — as can be seen in figure 5 — what we observe is that deforestation continued, but much more slowly, tapering

off to form a plateau.

In this case a sample of 18 lots was considered. This same trend is evident in a larger sample of original owners (30 lots) with data on cumulative deforestation through the ninth year of occupation.

And what happens when the lots pass to other hands? When a lot is sold in an area that already has access roads, the new owner generally acts in a way similar to what his predecessor did when he first occupied the virgin lot: with greater financial resources and a different cultural background, this second owner starts to deforest nearly twice as much per year as do long-established original colonists (figure 6). Consequently, the cycle is repeated: for several years rapid linear growth in the deforested area occurs, again followed by a plateau.

There are still other factors that cause farmers to intensify their deforestation activity. One of these is easier access to the lots when the roads are opened or improved. Road access causes the value of the lots to increase abruptly. This leads to sale of the lots, with the consequence that we have shown. However, even if a colonist does not sell his lot, he changes his behaviour with the improvement of access. The ability to market products more easily makes agricultural activities more profitable, and the farmer starts to fell at a faster rate.

Opening or improving roads also causes deforestation to increase because it makes planting pasture more attractive, in that the resale value of the lots increases. Pasture serves as a means of safeguarding against squatters.

At present the growth of deforestation in the state as a whole appears to be determined mainly by immigration, reinforced by factors like the increase in land values due to improvement of access. In the future, however, the behavior of the population already settled in the region will assume a greater relative importance. Other reasons to expect a future decrease (but not interruption) of deforestation include the lower quality of the available soil, the difficulty or impossibility of access to the remaining unoccupied lands and the finite capacity of the states from which immigrants are coming to expel population at ever-increasing rates. We also need to consider the decrease in the relative attractiveness of Amazonia after this frontier of "lands without owners" is closed, as well as the limited availability of capital, petroleum and other inputs that would be necessary if the rate of deforestation were to continue do increase rapidly. However, it is unlikely that deforestation could be stopped before the complete felling of the region's forest, unless a far-reaching government program is firmly implemented, based on knowledge of what occurs in the field.

Rondônia's ever more rapid deforestation cannot be expressed appropriately by any single algebraic formula, such as an exponential equation. Neither can we expect that its eventual slowing will follow the smooth and symmetric trajectory of a logistic (S-shaped) curve. Computer simulation would be the best way to analyze the complex interaction of factors affecting the process. To have and idea which factors are involved and the relationships among them it is necessary to examine more closely some cases of deforestation that have been occuring in Amazonia.

One must look for the primary causes of this phenomenon in places far away from Amazonia. In fact, the changes that have occured in the agricultural patterns in southern Brazil in the last 20 years are strongly reflected in the occupation of Amazonia. With the expansion of soybean plantations, for every 12 workers employed in the previous agricultural system there were 11 who were unable to find work in the new production system. Expansion for the sugar-cane plantations — encouraged by the government for the alcohol production — also expelled small farmers from their lands. Replacement of coffee, which makes intense use of manual labor, by mechanized crops such as wheat (a switch that has been sped both by damage from frosts and by the relatively unfavorable price of coffee in comparison with soybeans and other crops) swelled the flood of immigrants leaving for Amazon still more.

In Amazon itself the most evident forces fostering this process are land speculation, the magnifying effect of cattle pasture on the impact of even a sparse population, and the positive feedback relationship between road construction and population growth (see 'A floresta pode acabar?', *Ciência Hoje* nº 10).

The profits from agricultural production, added to those coming from speculation and from the various kinds of government subsidies, made deforestation financially very atttractive. Many small farmers come to the region to make their fortunes as commercial farmers. However, they gradually see that speculation yields much bigger profits as their neighbors sell their lots at prices that exceed the return obtained from years of hard work. In this way, agriculture becomes a means of paying living expenses while the farmer waits an opportunity to sell his land at a good profit and move on to a more distant frontier.

Generally, colonists see these sales as a compensation for improvements on their lands, rather than speculation. Large ranchers are probably more likely to start their activities in the region with speculation in mind, but they too are careful to refer to themselves as 'producers' rather than as mere speculators.

As mentioned above, deforestation grows through a positive feedback process — a vicious cycle that leads to exponential changes. For example, the construction of roads is closely connected to the rate of immigration: more and better roads attract more immigrants, while the increase of population justifies the construction and improvements of roads.

These relationships can be represented in the causal loop diagram shown in figure 7, in which the arrows indicate the influence of each item on the others. We can see that roads represent a key item, both because of their connection with the growth of the population and through their influence on the area that each farmer deforests. In the diagram, 'deforestation' can be obtained by multiplying the 'clearing per colonist' by the size of the 'population', that is, the number of farmers.

The key role of opening and improving roads indicates this as the most sensitive point on which to concentrate efforts intended to slow deforestation. This factor, which has a heavy impact on the rate of deforestation, would be relatively ease to control: road construction depends exclusively on government decisions, instead of on the thousands of individual decisions made by farmers, squatters and speculators that determine the fate of a forest after a road is opened or paved.

The future of felling in the rainforest depends on a complex system of interacting factors. We can expect deforestation to be stimulated by forces like the positive feedback relationship between road construction and forest felling, to stimulate deforestation, while factors like the growing importance of the resident population in relation to the arrival of migrants probably will contribute to slowing (but no stopping) the process. Everything indicates that deforestation will accelerate in the coming years.

The poor quality of the soil under the remaining forest in Rondônia is sufficient justification in itself for not opening more roads (see 'Distribuição de solos pobres na colonização de Rondônia', *Ciência Hoje* nº 33). The plan to pave the BR-429 Highway in the Guaporé River valley, if put into practice, will unleash a surge of deforestation that will be difficult to control in an area without agricultural potential. A good start for a preservation policy for the rest of the forest