Integrating remote sensing, GIS and field surveys: the study of lot turnover, land concentration and land use in colonization areas

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Abstract. Colonization of new agricultural frontiers is associated with uncertain conditions for farmers, high rates of out-migration and deforestation. Lot turnover and concentration in settlement projects comprise one of the most pervasive problems facing actual development and conservation policies, combining intrinsically a wide range of socio-economic and environmental components. Such complexity poses new theoretical and methodological challenges on how to integrate different agents of land use decision-making in expanding frontiers. The goal of this paper is to present a multi-temporal approach to the study of land concentration in settlement projects, thus contributing toward integrative tools to the study of Land Cover Change in agricultural frontiers. It combines remotely-sensed imagery, field survey and secondary sources into a GIS structure, allowing land concentration and underlying socio-political forces to be studied. Our analysis includes land use allocation, distances to centers and settlement aging, at the household, cohort and settlement levels.

Key-words: Land use, land concentration, remote sensing, settlement projects, uso da terra, concentração de terras, sensoriamento remoto, projetos de assentamento.

1. Introduction

This paper deals with the dilemma between agrarian reform propositions and high rates of land concentration in settlement projects. A recent study on lot turnover and deforestation in the Brazilian Amazon showed *Gini* index increases ranging from 0.14 to 0.42 on 5 out of 6 settlement projects (states of Mato Grosso and Pará), along the 1981 – 1991 period (Campari, 2002), showing thus clear evidence of land concentration in these areas. Such problem brings also implications on patterns of land cover change (LCC), contributing substantially to increase deforestation rates. Our analysis on land concentration aims to contribute toward theoretical advances on land use /cover change studies, as well as on monitoring methods of the social impact of agrarian reform policies. We present a multi-temporal approach to the study of land re-concentration in settlement projects, thus contributing toward integrative tools for studying LCC in agrarian settlement areas.

The introductory section presents a background on the expansion of the agricultural frontier in Amazônia. The problem of lot turnover and land concentration is outlined, together with its significance for development and conservation initiatives. Next, we discuss some methodological approaches to the problem, including survey research and the use of remotely sensed imagery. This is illustrated with a cross-sectional study from a government-sponsored settlement project in the state of Acre, where strategies to integrate such methods through GIS tools and across different levels of analysis are presented. In the final section of this paper, we present some concluding remarks on how discussed methods capture variables identified on the literature review.

Lot turnover and land concentration are inter-related but distinct processes. We define lot turnover as the transference (through selling, exchange or other arrangements) of the farm lot from a family to another. In colonization settlements, it usually involves concession of use rights, through purchase receipts; while many lots are turned over as individual units, others are aggregated to neighboring lots to form a new, larger lot, picturing a process we call land concentration. In some cases, this process can be referred as re-concentration, that is, a previous large farm is divided into farm lots (e.g., during agrarian reform), and later purchased by a single owner, thus, re-concentration. Campari (2002) for instance, uses the term re-concentration for a range of situations following lot turnover. Two other equally relevant processes that can be addressed through the approach proposed here are lot abandonment and lot fragmentation (when the lot is subdivided into smaller units). The temporal (e.g. establishment, expansion, consolidation), spatial (e.g. extent of land cover change, land use allocation), contextual (e.g. settlement pattern, infra-structure, and ownership system) and environmental (e.g. topography, water) variables related to lot occupation, turnover and concentration, make this processes a prime application for integrating remote sensing, field research and GIS.

2. Lot turnover and land concentration: problem and significance

The goal of this section is to overview the literature on the issue while highlighting factors, variables and processes relevant to the study of lot turnover and land concentration.

Settlement and re-settlement of rural families constitutes a worldwide phenomenon characterized by inter- and intra-regional migration, and defining the expansion and dynamics of agricultural frontiers (Nelson, 1973; Whitten, 1987; Merrick, 1978). Migrants are usually drawn from landless families in more densely populated rural areas or by reasons linked to environmental events, such as prolonged drought (Moran, 1981; Wood and Carvalho 1988; Ozório de Almeida and Campari, 1995; Browder and Godfrey, 1997). These migrants are eager for a chance to work their own land as a pathway to prosperity (Ozório de Almeida and Campari, 1995). Sometimes, facilities to acquire land titles or to establish rights of use to land are offered by government programs (Moran, 1981; Smith 1982; Whitten, 1987). In other instances, such as spontaneous migration in Amazônia, settlers occupy public lands informally, and disputes with state enterprises have led to increasing social tension in the region (Sawyer, 1984; Schmink and Wood, 1992; Alston et al, 1995).

Neoclassical dual migration models state that migration responds to differential expected incomes between origin and destiny (Todaro 1980). Alternatively, migration choices are made based on the increase in human capital stock to be provided in the arriving site, once income differentials alone might not explain variation regarding migration decisions (Massey et al, 1994; van Wey, 2001). Population studies in the Amazon region found that migration is followed by high rates of occupational changes (Browder and Godfrey, 1997: 260). In the rural sector around new settlements, where risks of crop and market failure are high, migrants seek off-farm employment as an insurance against income shortfalls (Moran 1981; Ozório de Almeida and Campari, 1995). In the frontier setting of the Amazon, however, wage labor markets do not advance at the same rate as expansion of the peasant economy (Sawyer, 1984).

Relocation of settlers, along with incentives for large-scale farmers is a major force shaping land use and land cover change in the Brazilian Amazon. This holds both for both areas of spontaneous migration, where expelled peasants move towards the expanding frontier (Schmink and Wood, 1992; Alston et al, 1995), and in government sponsored settlement projects (Moran, 1981; Smith, 1982; Mahar 1989; Ozório de Almeida and Campari, 1995). A large percentage of families end up abandoning their plots or selling them to nearby urban merchants or to large cattle ranchers, and have either migrated into local urban centers or relocated to new settlement fronts (Ozório de Almeida and Campari, 1995; Schmink and Wood, 1992; Alston et al, 1995).

Some of the major factors leading to high turnover rates in many of those settlement projects include the lack of all-weather roads (Nelson, 1973, Moran 1990), poor selection criteria of settlers by government agents (Moran 1981:146), and the overall lack of environmental baseline studies and institutional support (Moran, 1981; Smith, 1982; Fearnside, 1986). Others found that the lack of property rights of pioneer settlers in spontaneous migration fronts, such as South of Pará State, made them vulnerable to be expelled by ranchers, who claimed the land as their own (Schmink and Wood, 1992). Alternatively, ranchers buy untitled land already deforested, and obtain later land titles to it (Alston et al, 1995). As frontiers develop, rents for land tend to be much higher than returns to labor, and settlers are encouraged to sell their land and move on (Ozório de Almeida and Campari, 1995). Since crop harvest and commercialization can be seldom compared to financial returns to land as frontiers develop, the process of selling lots and moving forward has been shown as an livelihood strategy employed by many smallholders in face of the conditions they experience in most Amazonian settlement projects (Campari, 2002). This author moves further on exploring the relationship between lot turnover and deforestation, by challenging the hypothesis that lot turnover by colonists comprises the inexorable driving force of deforestation processes in the Amazon (ibid, 2002). As he points out, this process is far more complex than previously thought, especially given that his data show “successful” colonists (the ones that remain on their assigned lots) engaging on higher rates of deforestation, when compared to migrating colonists.

In the Transamazon colonization scheme, access to basic services such as health and credit was initially good. The quality of these services decreased, however, after an unplanned increase in the flux of in-migration overrun government’s capacity to deliver basic services (Moran, 1984:292). Poor soils, steepness, malaria and commercialization problems contributed to aggravate the problem. Lot abandonment rates along the Transamazon were reported to be around 30% in the first decade and continued to climb in the second decade of settlement (Moran, 1993:59). A recent study shows that lot turnover rates in this region have been closely correlated with soil quality and with time of arrival at the frontier (Moran et al, 2002).

Lot turnover rates have been also high in the state of Acre, Western Amazônia. Pedro Peixoto Colonization Project, for example, established in 1979 and the largest settlement project of the state, has 9,174 INCRA[1] registers expedited for a total of 4,225 lots, pointing to the accentuated turnover rate in course in this settlement (ZEE, 1999a). As for Rondônia, very high rates of lot abandonment during early stages of settlement were reported, especially in regions severely attacked by malaria (Martine, 1990). Dropout rates up to 95% in the first two years were observed in colonization projects in Bolivia, as for example in Alto Beni (Nelson, 1973).

Migration histories of individual settlers have been found to be one of the best predictors of agricultural performance in the Transamazon frontier (Moran, 1981:91), thus influencing turnover. Farmers involved in entrepreneurial activities, such as commercialization, transportation, or intensive agriculture experienced normally a single migration event. Conversely, subsistence and wage-labor oriented farmers have been correlated with multiple migrations (ibid: 92), and with high likelihood of selling their land and turn exclusively to wage-labor, or beginning anew in another frontier (ibid:158).

[1] INCRA – National Institute for Colonization and Agrarian Reform

Lot turnover and concentration problems might be rooted on conditions of uncertainty present in settlement projects. Uncertainty is endogenous to land use decision-making, particularly in expanding frontiers. Forest conversion to pasture might respond, for example, to the lack of enforcement of property rights (Schmink and Wood, 1992; Ozório de Almeida and Campari, 1995; Alston et al, 1995) and difficult access to markets (Moran 1981; Sawyer, 1984; Ozório de Almeida and Campari, 1995). On the other hand, farmers might respond to income uncertainties by seeking larger households and by investing in subsistence strategies (Wilk, 1991), by buying more land (Hecht 1993), investing in cattle (Mertens et al, 2002), by different types of labor contracts (Ortiz, 1990), or by contracting credit for investments in agriculture (Chibnik, 1994).

3. Methods for studying land concentration along with LCC

This paper aims at contributing to an emerging literature to study lot turnover and land concentration, and its correlations with patterns of LCC. Given the salience of this issue to the study of deforestation and agricultural frontier dynamics, some authors have already presented their contribution, in a way that the actual range of possibilities allows us to choose more appropriate strategies according to research goals. An important contribution comes from Campari's (2002) work on exploring the complexity inherent to lot turnover and deforestation processes, in 6 different colonization projects. By combining survey research with remotely sensed imagery and secondary information gathered with colonization agencies, Campari identifies rates of deforestation along cumulative distributions on farm sizes, and uses indicators such as *Gini* indexes to depict land concentration during the time-frame chosen on his analysis (1981-1991).

While such meso-scale approach provides significant understanding of major interactions shaping lot turnover and deforestation trends, micro-level approaches might throw additional light on forces shaping land use dynamics at the household level, which underlie observed land cover changes. This allows for further derivation of spatially explicit correlation matrices between land concentration indexes and drivers of land use change. Examples of such factors include cultural background of colonizing families, environmental variables such as soil quality and water availability, and differential connectivity of lots to markets (which is not only a function of settlement aging, but also a function of spatial variability on road quality).

Land ownership and time of settlement are initially investigated through secondary sources provided by the agencies responsible for settlement implementation, support and regulation. This role is often played by INCRA, the Brazilian agency responsible for colonization and agrarian reform. INCRA holds a detailed database (SIPRA) on settlers' information. It might also provide property grids for settlements, as well as historical records on its' implementation and evolution.

Examples of approaches to study land use dynamics at the farm-lot level are proposed, for instance, by McCracken et al (1999), Brondizio et al (2002), and Moran et al (2002), whose work rely on integrating multi-temporal remote sensing data, socio-demographic and land use surveys within a GIS spatial framework, including layers of property systems and forms of ownership. Land cover transitions from multi-temporal remote sensing data allow identification of changes at the level of lots, groups of lots, and the settlement as a whole. They have used demographic concepts such as cohort, age and period effects to study and test for the role of endogenous and exogenous variables underlying land cover change and land use choices.

4. Land concentration and LCC in an agrarian settlement: illustrating an analytical strategy

The case presented here is PAD Humaitá, which was established in 1981 in the State of Acre, in an area over 60,000 ha and relatively close to the state capital. The settlement design consists of a radial road network[2] around a central village, and originally was divided in 945 lots (ZEE, 1999a:38). The settlement is currently undergoing its second generation stage, which means that, after 23 years of occupation, original settlers' descendents are as important as their parents or more, in taking place as active actors shaping lots' dynamics, including LUCC and lot turnover, concentration and fragmentation processes. The settlement is considered "emancipated" by INCRA, meaning that most lots have been officially titled by this agency.

The temporal series of remote sensing images is composed of two Landsat MSS images (1975, 1985), three Landsat TM images (1986, 1992, 1996) and three Landsat ETM+ images (1999, 2002 and 2003). These images serve on the one hand to derive transition matrices of LCC and on the other hand to assist as a land use recall during interviews with farmers. A 1983 INCRA digitized property grid is overlaid to these images, helping thus to analyze land use strategies and land cover change taking place during this time frame, at the levels of farm lots, cohorts of farm lots (representing farmers arriving at the same time period), and settlement. The inherent idea on calculating LCC at the cohort level is that it allows testing for the role of household aging on LCC. Given the time-line of this colonization setting, and the availability of remote-sensing imagery relatively free of clouds for the region, the cohorts of settlers are established as follows: a) Cohort 1 - farmers arriving before 1986; b) Cohort 2 - farmers arriving between 1986 and 1992; and c) Cohort 3 - farmers arriving from 1992-1999.

Sampling strategy - Based on the overlay of property grid, road network and multi-temporal remote sensing, the sampling of lots for interviews may be stratified according to distances of lots to urban centers, and performed on all roads of the settlement (every road of the settlement has at least one sampled lot). This allows for lots to be sampled in closest or furthest conditions along each road. Distance and connectivity to urban centers is an important component to the study of land use trajectories, and are hypothesized to influence spatial distribution of the land concentration process. Sample size may vary according to the type of settlement and research goals. The sampling distribution may be proportional to the number of lots originally present on each road of the settlement, and randomized along road segments. Each segment represents a class of distance of a group of lots to the nearest village or urban center.

Image classification - Landsat scenes of 1975, 1986, 1992, 1999 and 2003 are classified according to the predominant land cover features encountered: agriculture, pasture, secondary re-growth in two stages, forest, water, density urban, clouds and shadow. We use images (color composite print-outs, unsupervised classification) for fieldwork interviews and use interviews to gather training samples for image classification. Multi-temporal images are used during land use history interviews. Training samples are collected at interviewed properties. A mixed strategy is used for image classification, starting with a detailed unsupervised classification (ISODATA algorithm – ERDAS software), which highlights spectral diversity in the whole footprint. Farmers inform land use history for the sites that are part of the interview sample. This information is translated into training samples, which assign spectral signatures to land cover features, to be used for supervised classification. "Ground-truthing" is performed with a GPS device to compare classification results to actual

[2] in contrast to other INCRA settlement projects comprising the fishbone road network design (as described in Moran, 1981), or to the road network following the watershed drainage system (as described in Batistella, 2001).

land cover features, pointing to necessary corrections. Unsupervised and supervised classifications are used iteratively to produce more accurate and refined (smaller number of classes) classifications as the process goes on.

Matrices of LCC highlight changes (direction and extent of LCC) on land cover classes taking place from one time period to the next. Once INCRA digitized property grid is overlaid to the classified scenes, a GIS technique (Zonal Statistics - Arc GIS – ESRI) calculates the areas of each class for all lots of the settlement at different time-periods. Next, with the help of a relational database, rates of land cover change are calculated for each of these lots, for the time-periods representing cohorts of arriving settlers (before 1986, from 1986 to 1992, and from 1992 to 1999). A database obtained from INCRA contains the time of settlement of each farm-lot, and is used to place lots into respective cohorts. Last, rates of LCC encompassing the same periods will be calculated for lots of the same cohort, and for the whole settlement. Following fieldwork, individual lots are aggregated as concentrated properties when necessary.

Distance measurements are calculated through *network analysis*, a GIS technique based on a set of rules that regulate network flux through a vector-based surface (Burrough and McDonell, 1998). The road network of Humaitá settlement was digitized using INCRA's 1983 property grid overlaid to the Landsat 2003 scene. Survey data on road quality and transportation costs are used to determine the average speed allowed by road conditions at different segments of the network. Next, the *network analyst* procedure of Arc GIS (ESRI) will calculate the **time-distance** from each sampled lot to the main local market, Rio Branco, based on these average speeds.

Another factor that needs to be considered is that land use decisions of farmers are constrained by the biophysical environment (Moran et al 2001). Better quality soils allow for a more diversified set of crops, while access to water reduces risks of crop failure. Therefore, these variables need to be controlled for, by including them into the model. Soil quality and access to water are both part of the survey. Farmers were asked to describe the predominant types of soil in their lot[3], as well as sources of water for agriculture and domestic use.

Land use decisions of households are examined based on separate linear regression models, where the dependent variables comprise proportions[4] of land in annuals, perennials, pasture, forest, ponds and secondary re-growth, by the time of the survey. Explanatory variables include time-distance to urban centers, time of settlement, socio-economic (such as labor force, age, income, education, size of the lot, participation in farmer unions and land tenure), cultural (ethnicity, agricultural background) and environmental (soil quality, topography and water availability) factors. Additionally, measurements of land concentration, such as the number of lots owned by each farmer, might be included as an explanatory variable, when time-specific information on the lot concentration process is available. Alternatively, separate regressions might be performed for concentrated properties, thus highlighting differences on drivers of LCC between the latter and non-concentrated ones.

5. Land concentration and LCC – concluding remarks

Our literature review pointed to several factors that are relevant to the study of land concentration in settlement projects. Here, we want to review how these factors are captured by the methods discussed above. Given the micro-level nature of surveys conducted with farmers, it is possible to explore a wide range of variables that theory shows are relevant to

[3] Time and funding constraints do not allow for detailed soil sampling.
[4] This proportion is calculated by dividing the estimations of land use types (a combination of survey data with remote sensing classification outputs) by total area of the lot.

the land concentration process. Life histories of households, for example, together with characteristics of the lot, land allocation and sources of income might help us understand adaptive strategies that were useful on dealing with uncertainties and constraints common to the environment of expanding agricultural frontiers. These strategies were shown to be important on understanding rates and patterns of lot turnover and land concentration. Other variables affecting settlement projects as a whole, such as governmental policies and services, infra-structure and prices of crops, might be collected through archival research and interviews with representatives of governmental agencies. Differential perceptions and responses to such factors by households, however, add another layer of complexity to the theme, but might be important on explaining settlement structure in relation to lot ownership.

Multi-temporal remote sensing images, when combined with property grids and road networks through GIS layers, provide us the opportunity to analyze land cover patterns and trends at different levels (e.g. level of lots, cohorts of lots and the whole settlement). When combined to interviews, substantial information on the dynamics of land use allocation and thus strategies of livelihood is added, helping our understanding of trajectories that are linked to lot turnover and concentration.

The identification of lot turnover/concentration rates and patterns, combined to the characterization of such processes along the lifetime of settlement projects, is important as a feedback for future colonization programs, and one essential for reaching the goals of agrarian reform. Remote sensing and GIS technologies, when combined with research at the property level, show an enormous range of possibilities of contributing toward better monitoring and reversing such processes. Integrative efforts across disciplines are proving an effective manner to achieve such goals.

6. Bibliography

Alston, L., Libecap, G.D., and Schneider, R., 1995. Property Rights and the Preconditions of Markets: The Case of the Amazon Frontier. Journal of Institutional and Theoretical Economics, 151(1): 89-107.

Batistella, M, 2001. Landscape fragmentation and land-cover dynamics in Rondonia Brazilian Amazon. PhD dissertation. S. of Public and Environmental Affairs, Indiana University.

Brondizio, E., S. McCracken, E.F. Moran, A.D. Siqueira, D. Nelson, and C. Rodriguez-Pedraza, 2002. The Colonist Footprint: Towards a conceptual framework of deforestation trajectories among small farmers in Frontier Amazonia. In: *Land Use and Deforestation in the Amazon*. C. Wood et al. (eds.) Gainesville, University of Florida Press.

Browder, J., and Godfrey, B., 1997. Rainforest cities: urbanization, development, and globalization of the Brazilian Amazon. New York: Columbia University Press.

Burrough, P.A., and McDonell, R.A., 1998. Principles of Geographical Information Systems. Spatial Information Systems and Geostatistics. Oxford University Press.

Campari, J. de S., 2002. Challenging the Turnover Hypothesis of Amazon Deforestation: Evidence from Colonization Projects in Brazil. PhD Dissertation, The University of Texas at Austin.

Chibnik, M., 1994. Risky Rivers: The Economics and Politics of Floodplain Farming in Amazonia. The University of Arizona Press.

Fearnside, P. M. (1986). Human carrying capacity of the Brazilian rainforest. New York, Columbia University Press, 293p.

Hecht, S. B. (1993). The logic of livestock and deforestation in Amazonia. *Bioscience*, 43(10):687-695.

INPE, 2004. Annual rates of deforestation in the Amazon. Instituto Nacional de Pesquisas Espaciais. http://www.obt.inpe.br/prodes/prodes_analogico.htm

Mahar, D.J., 1989. Government Policies and Deforestation in Brazil's Amazon Region. Washington DC, World Bank.

Massey, D.S., J. Arango, G. Hugo, A. Kouaouci, A. Pellegrino, and J.E.Taylor, 1994. An Evaluation of International Migration Theory: the North-American Case. Population and Development Review 20:699-751.

Martine, George, 1990. Rondônia and the Fate of Small Producers. In: Goodman and Hall (eds), The Future of Amazonia: Destruction or Sustainable Development? St. Martin's Press New York.

McCracken, S., Brondizio, E.S., Nelson, D., Moran, E.F., Siqueira, A.D., and Rodriguez-Pedraza, C., 1999. Remote Sensing and GIS at Famr Property Level: Demography and Deforestation in the Brazilian Amazon. Photogrammetric Engineering and Remote Sensing 65(11):1311-1320.

Merrick, T.W., 1978. Fertility and land availability in rural Brazil. Demography, 15(3):321-336.

Mertens, B., Poccard-Chapuis, R., Piketty, M.G., Lacques, A.E., Venturieri, A., 2002. Crossing spatial analysis and livestock economics to understand deforestation processes in the Brazilian Amazon: the case of São Félix do Xingú in South Pará. Agricultural Economics 27:269-294.

Moran, E.F., 1981. Developing the Amazon. Bloomington: Indiana University Press.

Moran, E.F., 1984. Colonization in the Transamazon and Rondônia. In: Schmink, M., and Wood, C., *Frontier Expansion in Amazonia*. University of Florida Press. Gainesville.

Moran , E.F., 1990. Private and Public Colonization Schemes in Amazonia. In: Goodman and Hall (eds), The *Future of Amazonia: Destruction or Sustainable Development?* St. Martin's Press New York.

Moran, E.F., 1993. Through Amazonian Eyes: The Human Ecology of Amazonian Populations. University of Iowa Press.

Moran, E.F., S.D. McCracken, and E.S. Brondizio, 2001. The Developmental Cycle of Domestic Groups and its Impact on Deforestation Rates in the Amazon. Paper presented at the Population Association of America, annual meeting, Washington D.C., March 29, 2000.

Moran, E.F., E.S. Brondizio, and S. McCracken, 2002. Trajectories of Land Use: Soils, Succession, and Crop Choice. In: *Land Use and Deforestation in the Amazon*. C. Wood, et al. (eds.) Gainesville: University of Florida Press.

Nelson, M., 1973. The Development of Tropical Lands. Baltimore: John Hopkins University Press.

Ozório de Almeida, A. and J. Campari, 1995. Sustainable Settlement in the Brazilian Amazon. New York: Oxford University Press.

Ortiz, Sutti, 1990. Uncertainty Reducing Strategies and Unsteady States: Labor Contracts in Coffee Agriculture. In: Elizabeth Cashdan (ed), Risk and Uncertainty in Tribal and Peasant Economies; Westview University Press.

Sawyer, D., 1984. Frontier Expansion and Retraction in Brazil. In: Schmink, M., and Wood, C.: Frontier Expansion in Amazonia. University of Florida Press. Gainesville. 180-203.

Schmink, M., and Wood, C., 1992. Contested frontiers in Amazonia. New York: Columbia University Press.

Smith, N., 1982. Rainforest Corridors: The Transamazon Colonization Scheme. Berkeley: University of California Press.

Todaro, M.P., 1980. Migration and the Labor-market in developping countries. Journal of Economic Literature 21(1): 137-139

Van Wey, L.K., 2001. A Comparative Study of Migration in Mexico and Thailand. PhD Thesis, Sociology, University of North Carolina Hill.

Whitten, A., 1987. Indonesia's Transmigration Program and its Role in the Loss of Tropical Rain Forests. Conservation Biology, 1(3): 239-246.

Wilk, R., 1991. Household Ecology: Economic Change and Domestic Life Among the Kekchi Maya in Belize. The University of Arizona Press.

Wood, C. and Carvalho, J.A. de, 1988. The Demography of Inequality in Brazil. Cambridge: Cambridge University Press.

ZEE, 1999a. Zoneamento Ecologico-Econômico do Estado do Acre – Estrutura Fundiária. Secretaria do Meio Ambiente do Estado do Acre, Governo do Estado.