People and Environment in Amazonia: The LBA Experience and Other Perspectives

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Amazonia is the arena for an ongoing extraordinary transformation of nature and society. This process of change can be depicted in many ways and by various disciplines, with emphasis on the biosphere or the atmosphere, as demonstrated by the Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA). However, the human factors behind environmental change should not be neglected. This chapter introduces the section on people and environment in the region proposing an examination of the human dimensions of land use and land cover change from the LBA experience and other perspectives. As a basis for this approach, we provide a brief review on related topics and insights about opportunities for integrative research. Selected findings produced by LBA projects are highlighted and a synthetic view on research gaps, analytical gaps, data gaps, and policy implications of human dimension research in Amazonia is presented.

1. MOTIVATIONS

The chapters in this section of the book examine a variety of human impacts on ecosystems, landscapes, and regions as a consequence of different processes occurring in Amazonia, for example, deforestation and land use change [*Alves et al.*, this volume; *Brondizio et al.*, this volume], selective logging [*Asner et al.*, this volume], fire occurrences [*Schroeder et al.*, this volume], the expansion of intensive agriculture and ranching [*Walker et al.*, this volume], road building, and development [*Pfaff et al.*, this volume]. Scenarios of future Amazonian landscapes built with simulation models are also discussed [*Perz et al.*, this volume]. Assuming the current transformation of nature and society in Amazonia as an interactive process, this chapter proposes a broad examination of the human dimensions of land use and land cover change from the Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) and other perspectives. One way to approach this theme is to take the major scientific questions posed by LBA and identify situations where the human perspective is implicated, for example, when human agents are responsible, directly or indirectly, for changes in land use and land cover. Another way might be to examine the epistemology behind LBA to understand the role of science, and scientists, in formulating the mix of articulated disciplines and questions. A third way could be to examine biophysical dimensions, the climate change drivers, and their impacts on human society.

Our goals are not to enumerate all these options but to present how a human-centered perspective came to be part of LBA and what insights we have gained to date from that perspective. The next section will focus on the major

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questions proposed for LBA and why a human dimension was inherent, and indeed necessary, given how these questions were formulated. Our focus is on the human dimensions of land use and land cover change because it was under this topic that the substantive work on human dimensions was originally developed within LBA science.

2. AN OVERVIEW ON THE HUMAN DIMENSION RESEARCH IN LBA

Taking the two fundamental questions of LBA, to understand how Amazonia functions as a regional system and how changes in land use, land cover, and climate might affect its functioning, it is evident that one could not answer these two questions by examining only the biophysical systems. At the center of change in Amazonia is the fact that the region is experiencing migration and settlement, high rates of deforestation and logging, the development of roads and urban centers, and land use intensification. These changes in land use and land cover will have an impact on Amazonia's long-term functioning. People are the agents of change, the agents that disturb the system, and also the ones that will suffer the consequences of such disturbance. LBA has learned to address how human-driven land use change affected land cover and how climate variability has been influenced by human changes in land cover and ecosystem functioning.

People are a major force in the biosphere (and the atmosphere), but human actions are mediated by human institutions at a variety of scales, from local, to regional, to national, and international. It is not simply individuals or households, which act upon the environment of Amazonia; it is also government, nongovernmental organizations, and other forms of organized groups. These groups do not always work in concert. They differ in their goals, and how these conflicting goals play out is part of human dimension research.

Soon after its inception, LBA leading investigators recognized the need to develop a human dimension research agenda within the program. As with the International Geosphere-Biosphere Programme (IGBP), which realized in 1988 that it needed to invite social scientists to help understand the human drivers of global change, LBA became concerned early with the impact of environmental changes on people and of people on the environment. To explore this required social science, the challenge was how to include this human dimension expertise in an effective way, given that the original LBA questions were not conceived with this perspective in mind and were drawn up without social scientists' participation. The original formulation involved climatologists, biogeochemists, hydrologists, ecologists, and other biophysical scientists. As the LBA research progressed, the need for understanding the human dimensions of change in Amazonia became so evident that even sensitivities to the theme by the Brazilian government, related to policy issues, were overcome, leading to recognized progress in articulating the natural and the social sciences [*Batistella et al.*, 2008].

Four strategies were adopted to develop the human dimension component of LBA. First, efforts were made to find ad hoc partnerships to jointly formulate scientific questions reflecting the social processes behind land use and land cover change and the impacts of environmental change upon human health. Second, efforts were made to examine the policy implications of LBA for human resources, education, and training, particularly with regard to how it might affect the sustainable development of the region and the role of the state in such development. Third, LBA sought to strengthen the bridges with the social sciences, by inviting social scientists to join its Scientific Steering Committee and later developing programmatic initiatives that were inclusive of social science questions [see *Lahsen*, 2002; *Alves et al.*, 2004; *Schor*, 2005; *Alves*, 2007a, 2007b, 2008; *Egler and Ibañez*, 2007]. Finally, in the context of the transition to the second phase of LBA, a number of initiatives were taken to bring decision makers and stakeholders to present and discuss scientific findings and new integrative questions.

Among the relevant results was a bibliographic study to review the scientific production during the 1990s in the region, with a focus on four major themes: populations, ethnic and cultural representations; agropastoral and extractive activities; industrial activities; and urban networks [*Becker*, 2007a]. The search found a reasonable amount of work in the social sciences, both in regional institutions, and outside the region. It revealed considerable depth in research on sociopolitical issues, particularly on modernization and social change, the expansion of the agropastoral frontier in the period 1960–1985, the impact of the current frontier expansion, and of new dynamics of regional change. The greatest amount of debate in the literature focused on land use, particularly the use of forest resources, the impacts of cattle ranching, extractivism, and the different ways, some of them predatory, of land appropriation dominating the region. Other areas of considerable debate in the literature deal with deforestation, logging, and forest management and, more recently, urban development in the region as an alternative to rural living. The study identified some major topics for future research: the need for more attention to intraregional migration, the potential and limitations of various forms of production, and the role of cities and networks promoting regional development and change.

Another key initiative to foster the integration of social sciences in LBA was the workshop "The Human Dimensions of Environmental Change and LBA," held in May 2004. It was a singular opportunity to address three main concerns about the importance of social sciences to LBA: (1) human dimensions of environmental change in Amazonia, including the identification of research gaps and analytical tools to conduct such research; (2) data availability and quality; and (3) policy making. The workshop represented a rare chance for articulation among LBA and social scientists, allowing the formulation of research questions, not addressed in the original LBA scientific plan. A collection of selected papers produced by this workshop can be found in the work of *Costa et al.* [2007]. The workshop emphasized knowledge gaps and the need for new analytical data and tools of interest to LBA, particularly related to issues of sustainability. Table 1 synthesizes the outcomes of the workshop. Far from being a complete picture, it offers a possible path for future initiatives integrating social and natural sciences in Amazonia.

3. HUMAN AND BIOPHYSICAL DIMENSIONS OF LAND USE AND LAND COVER CHANGE IN AMAZONIA: SELECTED FINDINGS AND OTHER PERSPECTIVES

A variety of relevant topics were posed by LBA scientists and contributors to the discussion of human dimensions

Table 1. Research Gaps, Analytical Gaps, Data Gaps, and Policy Implications of Human Dimension Research in Amazonia

Topics	Institutions and Governance	Logistics and Regional Development	Production Systems	Populational Mobility	Urbanization	Land Use/Cover Changes (LUCC)
Research gaps	Role and weight of institutions; Public/private relations; Links between markets and the State	Differentiation of territorial units; Links with institutions	Urban and rural linkages	Inter-regional/ intraregional patterns; Linkages with all other topics (e.g., LUCC)	Urban typology; Linkages between urban infrastructure and all other topics (e.g., LUCC)	Regional patterns for deforestation and abandonment dynamics; Linkages between agricultural production and LUCC (e.g., intensification, degradation); New occupation fronts
Analytical gaps	Sociology of action	Network analysis	Environmental valuation; Regional accounting; Production functions; Data integration	Spatially explicit models	Tools for characterization of urban areas	Multiscale analysis assessments of land use expansion and concentration; Intra-annual classification of crops and pastures; Analysis based on land parcels and agrarian structure
Data gaps	Case studies	Land zoning data; Census data (including census-tract level)	Environmental, social, and economic variables; Census data (including census-tract level)	Intramunicipal data (mostly from field work)	Data for periods between censuses	Deforestation data from the 1970s; Intra-annual remote sensing data; Agricultural production data; Land tenure data
Implications for policy making	Assessment of institutional lack and efficiency	Infrastructure and urban planning; Land zoning	Land zoning; Institutional building	Job creation; Infrastructure and urban planning	Infrastructure and urban planning	Land zoning and planning; Deforestation control

of Amazonian environmental changes. The economic questions, for example, their relation with deforestation and other social and environmental dimensions, have revealed multitiered processes and highlighted the limitations of data gaps, analytical gaps, and incomplete knowledge [*Perz et al.*, this volume]. The main challenges still reflect the need to balance economic development and nature conservation, including the difficulties of ensuring sustainability through market integration. In addition to these difficulties, the agrarian situation represents distinct opportunities and limitations for actors [*Costa*, 2007a; *Walker et al.*, this volume; *Brondizio et al.*, this volume]. As a consequence, some areas show emerging production systems, while others maintain their business as usual [*Costa*, 2007b].

The contrast between macroeconomic approaches and case studies at local scales remains an important source of discussion. This emerges from the research about land use patterns and processes at various scales and from the challenge of multiscale integration, as revealed by the chapters of this section of the book. Two different problems can be recognized: (1) understanding the system functioning as a regional entity, a well-known challenge of scale integration within LBA [*LBA*, 1996; *Nobre et al.*, 2001] and (2) identifying and comparing different locations, looking for understanding of social processes with higher or lower chances of environmental and economic sustainability [*Batistella and Moran*, 2005].

Logistics and regional development are closely related with the economic system, but one can also find connections with other dimensions, particularly with geopolitics and policy making. *Becker* [2007b] emphasizes the singular dynamics referring to the soybean phenomenon in Amazonian frontiers, its production chains, its impact on the organization of actors, mainly due to the different roles of smallholders and largeholders, and policies related to infrastructure development. *Walker et al.* [this volume] discuss policies that created the preconditions for modern Amazonian agriculture as well as describing cattle ranching and soybean market settings and trajectories of expansion.

The role of roads and networks to provide access to resources and markets has also been highlighted [*Pfaff et al.*, this volume]. These artificial landscape corridors should be considered in territorial planning, land zoning, and geopolitics. However, the differentiation of land units and institutional arrangements is far from being achieved.

Moreover, understanding population mobility and strategies of occupation through the region will expose complex trajectories [*Hogan et al.*, 2008]. In recent years, the population in Amazonia has grown increasingly urbanized, but the consequences of patterns and processes of urbanization to land use and land cover change remain a research topic to be developed.

The questions addressing land use and land cover change in Amazonia are central to LBA as they articulate with most of the research components of the experiment (Figure 1). However, some scientific gaps remain. For example, knowledge is still incomplete about the regional patterns of deforestation and land abandonment, the identification and quantification of land use intensification and land degradation processes, and the immediate tracking of new fronts of occupation [*Alves*, 2001].

Data gaps include deforestation assessments for dates before the 1970s, remote sensing seasonal data, regional and local data about the agrarian structure and agropastoral production. Without these inputs, it is virtually impossible to carry out comprehensive multiscale analyses, intra-annual classifications of agricultural and pasture lands, as well as studies based on land parcels. These issues have clear policy implications, particularly for land zoning and deforestation monitoring.

Several initiatives within LBA addressed changes in land use and land cover. Considering only LBA-Ecology, a NASA-funded program on terrestrial ecology, there were 38 projects under this research component (Figure 1). These projects used a variety of perspectives, as illustrated by Figure 2. On the other hand, only five projects addressed human dimensions of Amazonian change (Figure 3).

In general, progress was made in understanding the relationship between certain types of land use and forest conversion, in particular, with regard to logging, cattle ranching, and small agriculture. Also of late, there has been progress in understanding the dynamics of conversion to mechanized soybean production, the transformation of land from forest matrices to agropastoral production centered landscapes, and the dynamics of fire in their relation to altered regions through selective logging and other land uses. The expansion of intensive agriculture, the impact of roads and networks on deforestation, and scenario developments also produced relevant results through LBA. Chapters in this section present findings and considerations on these matters.

Some aspects deserve special attention when examining the biophysical and human dimensions of land use and land cover change in Amazonia. Differences in soil quality, for example, explain much of the variance in the rates of secondary succession, in crop choices, and persistence of farmers on the rural properties [*Moran et al.*, 2000]. This finding highlights that we cannot overlook soil quality assessment as a key variable that makes a real difference in social and environmental outcomes. Farmers with high quality soils were able to persist on their properties despite ups and downs of the economy over a 30-year period. When these soils were located favorably to markets, this advantage further multiplies. These differences in soil quality are particularly no-

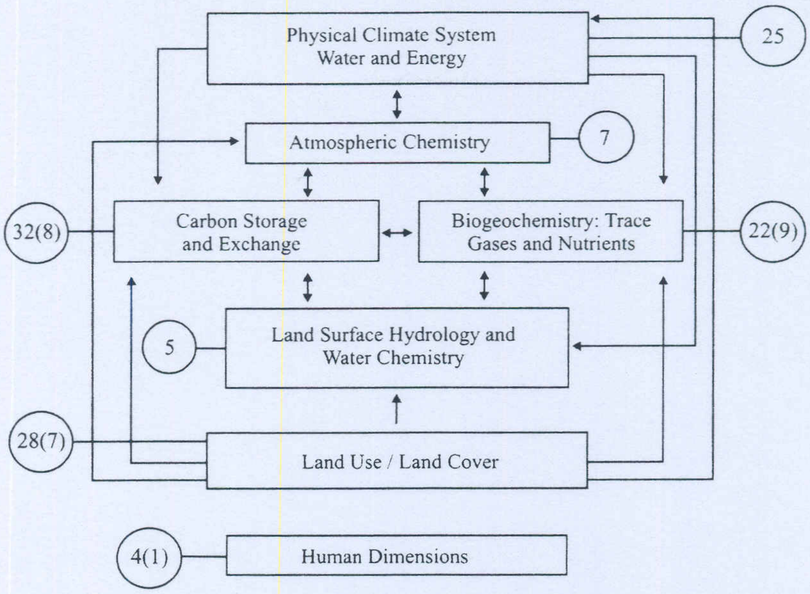

Figure 1. Number of projects by research component of LBA-ECO (the projects funded during the phase of synthesis and integration are in parentheses).

table when we compare results across regions [*Tucker et al.*, 1998]. In interregional comparisons, biophysical factors are often more explanatory than human factors, and broad differences in agricultural potential are more likely to be considered by policy makers, thereby further enhancing the natural effect of biophysical differences.

However, the use and management of land better explains the differences in the rate of secondary succession and agriculture intensification when we compare locations within a region [*Moran and Brondizio*, 1998]. This is not surprising, as the detailed knowledge of a given property allows differences in management to be used in explanation. These

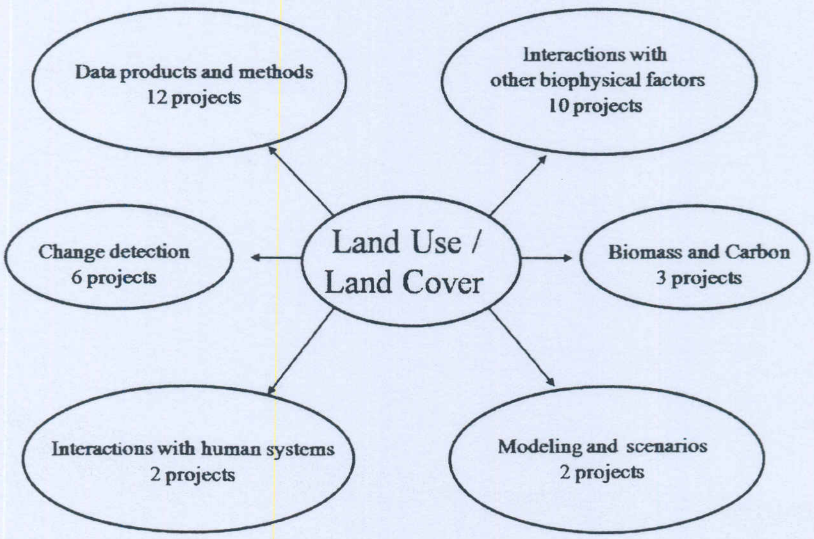

Figure 2. Research themes for projects under the component "Land Use and Land Cover" of LBA-ECO.

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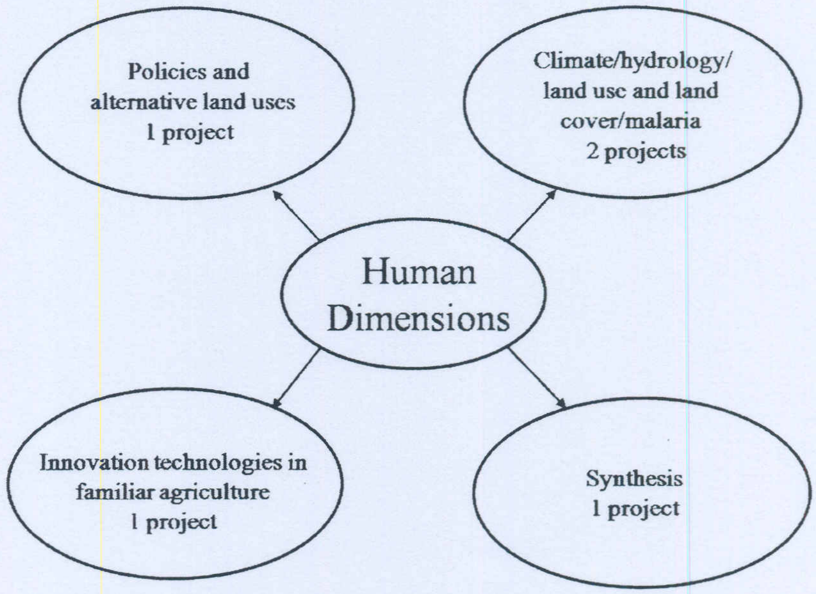

Figure 3. Research themes for projects under the component "Human Dimensions" of LBA-ECO.

differences are commonly left out in aggregate analyses, where farmers may at best be treated as small or large, rather than having inherent different qualities in their stewardship of the land.

Monitoring land cover change in Amazonia has evolved significantly during the last decade. Stages of secondary succession can now be associated with spatial and spectral patterns that can be captured via analysis of remote sensed images, and further, can be used to estimate biomass and carbon, as well as to infer cycles of production [*Moran et al.*, 1994; *Lu et al.*, 2005]. Spectral mixture analysis and classifiers using spatial, spectral, and textural information are better able to capture the heterogeneity of landscapes with greater accuracy [*Lu et al.*, 2004].

Classification of successional forest stages remains a challenging task because of the lack of sharp distinctions between adjacent stages and confusion between early successional forest stages with degraded pasture and advanced successional forest stages with perennial plantations and agroforestry. Accurate classification of these land covers and associated biomass estimation has become a significant factor in reducing the uncertainty of carbon emission and sequestration [*Zarin et al.*, 2005; *Neeff et al.*, 2006].

Integration of remote sensing and geographic information systems allows the evaluation and mapping of soil erosion risk in a large area. When high-quality topographic and climate data are not available, a surface cover index based purely on remote-sensing data is useful to evaluate and map the potential land degradation risks caused by deforesta and associated soil erosion in Brazilian Amazonia [*Lu et* 2007].

Vegetation change detection has long been regarded challenge, especially in the moist tropical regions. Hy approaches combining image differencing and postcla fication comparison are promising in detecting vegeta change trajectories, especially for vegetation gain and [*Lu et al.*, 2008].

The search for quantitative methods to analyze and scribe the structure of landscapes has also become a h priority. Land use and land cover issues are at the core this perspective, due to their intricate dynamics and c sequences in landscape structure and function. Landsc fragmentation is the process whereby a landscape ma is progressively subdivided into smaller and more isola patches, mainly as a result of human land use activities. design of Amazonian settlements affects the structure landscapes and the processes of fragmentation. Orthogo settlement structure (such as the classic fishbone patte found in Rondônia) produce greater forest fragmentat have lesser spatial complexity, and less interspersion betw landscape classes than settlements designed as a functio topographic variability. The design based on topogra plays an important role in maintaining or increasing fo interior habitat relative to the entire landscape area, low ing the impact of forest fragmentation on the occurrence distribution of organisms. The maintenance of large patc of forest reserves also play an important role in maintaining lower levels of fragmentation [*Batistella et al.*, 2003; *Batistella and Brondizio*, 2004].

The policy implications of such considerations are crucial for further initiatives regarding settlement implementation. Development and conservation strategies can be informed by the results achieved, but regional dynamics and local context should be taken into account to avoid political failures. The path for a reasonable conceptual approach explaining the heterogeneous processes of colonization in Amazonia is far from achieved, but analyses of landscape structure and function can provide a unique way to understand the spatial characteristics of Amazonian land change.

Land tenure, type of settlement, the developmental cycles, period and cohort effects also affect patterns of land use and land cover [*McCracken et al.*, 1999]. The cohort effect, for example, persists despite period effects, i.e., events such as tight credit, hyperinflation, and other macroeconomic forces affect the magnitude but not the overall trajectory of deforestation [*Evans et al.*, 2001]. On the other hand, the conservation of relatively large areas of forest within human settlements is more effective if dependent on institutions' self-organization relative to the needs of the population and to demarcating areas of reserve with rights given to local people vested in its protection [*Batistella*, 2001].

The understanding of human and environment interactions, in particular, the role of cohort, age, period effects, external capital, and household processes upon land cover trajectories in colonization areas, has progressed [*Walker et al.*, 2000; *Brondizio et al.*, 2002]. Among other initiatives, agent-based models incorporate household demographics and labor arrangements, land cover and allocation, soil quality and crop productivity, and spatial features of the farm lot [*Deadman et al.*, 2004].

However, the role of social variables to understand the dynamics of land use and land cover in Amazonia is still poorly explored. Social studies rarely investigate the outcomes in terms of land change, and land use/land cover assessments rarely include the social dimensions of land change [*Turner et al.*, 2004]. This research gap reveals an opportunity for future studies about the human-environment interactions in the region.

4. CONCLUDING REMARKS

The following seven chapters discuss human and biophysical dimensions of land use and land cover change in Amazonia assuming that the understanding of changes in Amazonian landscapes and regions depend on documentation of alterations in land cover and trajectories of land use. These land changes are intriguing processes to investigate, as they produce relevant environmental outcomes and social feedbacks, such as land appropriation and conflicts, agricultural production systems, and human-dominated landscapes. The spatial nature of human-environment interactions in Amazonia brings up issues of scale and levels of analyses, providing opportunities for the study of spatially explicit processes, such as tropical deforestation and its impacts from region to household. The chapters in this section of the book provide a general picture about the accomplishments and limitations of this integrative research and also indicate promising grounds for future studies.

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