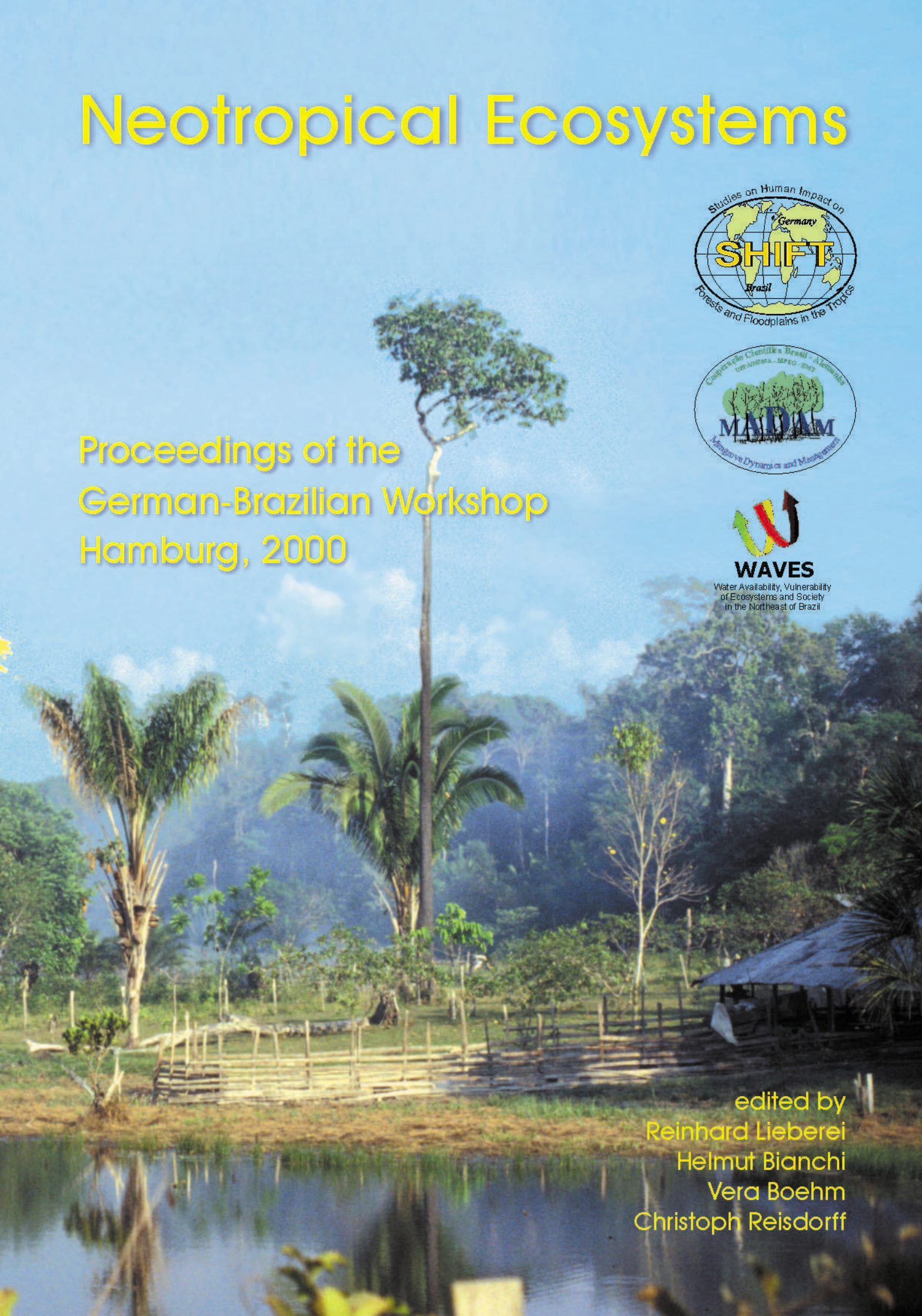
Neotropical Ecosystems



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WAVES
Water Availability, Vulnerability of Ecosystems and Society in the Northeast of Brazil

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Integration of Information on Fallow Systems toward Supporting Public Policies

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Abstract

The rotational slash-and-burn agricultural system, largely dependent on the duration of the fallow period to restore the productivity of the land, is still extensively practiced by small land holders in the Northeastern Pará State, Brazil. Clear signs of agronomic and ecological failure of this system have been represented by consistently decreasing crop yields, fallow period shortening, and structural and compositional depletion of the natural recovering vegetation (capoeira). The SHIFT-capoeira research project (ENV-25) has been developing and introducing fire-free alternative management practices such as (i) the enrichment of the capoeira vegetation to improve biomass production and nutrient recovery/fixation, (ii) use of a bush-chopper that allow the mulching (instead of burning) of the biomass, (iii) mulch management/fertilization for optimal weed control and crop absorption of stocked nutrients, and (iv) crop rotation/association/cultivation techniques that are, on the one hand, adapted to fire-free agricultural production, and on the other, more suited to fulfil the household as well as the commercial needs of the farmers. The focus of this study is the evaluation of the contribution of these management alternatives for the sustainability of the agricultural activity developed by the small land holders in Northeastern Pará, with special reference to the non-monetary gains in terms of ecological function restoration and natural resources conservation afforded by fire-free management practices. The final purpose of the research effort is to draw indications of public policies directed to improving the efficacy of the development programs dedicated to the small land-holders of the region.

Keywords

Fire-free agriculture, Mulching, Sustainable agriculture, Energy analysis, Environmental assessment

1 Introduction

Similarly to virtually all old colonization areas in the Brazilian Amazon, the agricultural occupation of the Northeastern Pará State region is based on staple crops grown in soils prepared by the slash-and-burn of the secondary forests (known as capoeiras). Following a short (typically one year) productive period, the area is abandoned for vegetation regeneration, and new areas covered with secondary forest are slashed-and-burned, completing the shifting cultivation cycle. This essentially small holder subsistence production system, totally dependent on the vegetation fallow to recover and store nutrients and improve soil fertility, persisted in relative balance while a low demographic pressure and particular market conditions allowed fallow periods of 12 up to 20 years and more, a situation no longer present in the region. The marked occupation process underway since the early 1970s, allied to an increased market insertion in recent years, has brought about an intensification of land use and a shortening of the fallow period to as little as three years. Such a period is insufficient for soil fertility restoration, and clear signs of failure of this traditional agricultural system are represented by yields consistently lower than the State average for the main crops, and the inviability of growing some staple crops such as rice and beans. Additionally, general environmental quality degradation of the area is attested by the high rate of deforestation and forest burning, while the economic stagnation entraps the farmers and their families in a cycle of poverty and helplessness.

Results obtained to date under the research project "Secondary Forest and Fallow Vegetation in the Eastern Amazon Region – Function and Management (ENV-25) point out that the technological alternatives to be sought in order to revert the socioeconomic and environmental collapse of the small land holder agriculture in the region must involve fire-free management of the fallow vegetation, coupled with innovative biomass mulching procedures, and crop rotation/association techniques (Brienza Jr. et al., 1998; Denich et al., 1998; Kato et al., 1998a, b; Metzger et al., 1998; Silva Jr. et al., 1998). Specifically, the alternative agricultural system proposed involves, for every five-year production period, three sets of management procedures, namely:

(i) slash-and-mulch (as opposed to slash-and-burn) the secondary vegetation, a process made possible by the

introduction of a tractor-driven biomass chopper (TRITUCAP);

(ii) secondary vegetation enrichment with fast-growing, nitrogen-fixing tree species, to improve biomass accumulation for mulching and additional charcoal/-firewood/timber production; and

(iii) early (post-mulching) soil fertilization coupled with crop rotation/association that allow the development of one additional harvest cycle per five-year period.

The fire-free agricultural management system can bring about, on the one hand, economic improvements to the farmers, for it results in agricultural intensification and harvest diversification; and on the other, the system can ameliorate environmental quality and natural resources conservation, resulting in important social benefits to the local communities. These advantages are due to the possibility of cultivating the land for two consecutive years instead of only one, followed by just three fallow years instead of four or five. Besides, the enriched secondary forest yields usable wood materials, being also economically attractive, while the conventional slash-and-burn system remains unproductive during the fallow period.

One additional benefit of the fire-free management system is the possibility for the farmer to adjust the agricultural calendar more efficiently, for the dependency on the dry season for burning the biomass is eliminated. Hence, the farmer can choose the best planting period based on agricultural (rather than strictly climatic) terms, improving crop productivity and workload distribution throughout the growing season.

There are also drawbacks associated with the fire-free management system. Most of the benefits are manifested in the long run, and are only partially perceived in monetary terms. The system involves higher costs due to the mechanic mulching operation and fertilizer application, needed to compensate the delayed release of nutrients from the mulch (as compared with the prompt nutrient release from the ashes). The research challenge resides in assessing the balance between the environmental and social (as well as some private) benefits, and the private costs to the farmer, of the fire-free agricultural management system proposed by the SHIFT-Capoeira (ENV-25) project.

The objective of this study is to account, on a common basis, the overall advantages and shortcomings of the fire-free agricultural management system proposed for the small land holders in Eastern Pará, and to contribute orientation for public policies that may foster those practices that improve the sustainable development of the region.

1.1 Sustainability assessment

Three dimensions of consideration must be taken into consideration in order to assess the contribution of the fire-free management practices to the sustainability of the small land holders in Eastern Pará, namely the economic, the social, and the ecological dimensions.

The economic dimension presents well-accepted valuation methods, mostly based on income and monetary balance of the production process. Such methods, however, are less than appropriate for certain considerations, for example when the goods and services obtained from the production process are not directly inserted into the formal market, or when the inputs for production are obtained free-of-charge directly from nature, such as natural soil fertility. In order to avoid conceptual conflicts between the sustainability assessment between dimensions, in the present study cash-flow analysis will be proceeded to the evaluation of the economic contribution of the fire-free management practices.

The social dimension involves the improvement in quality of life brought about by the technology, the equitable partition of the benefits in the community, the participation of women in the production and appropriation of wealth, the educational and cultural development of the community, etc., all of which are assessed by appropriate indicators, preferrably diverse from those related to income and monetary balance evaluation.

Many options are presently available for the study of the ecological dimension of sustainability. The system's ecology valuation of solar energy fluxes (Odum, 1996) is one of such methods especially appropriate for the assessment of the fire-free management practices under consideration. This method accounts for all solar energy fluxes associated with the production process (the energy memory), and converts the energy balances directly into indices of sustainability. This environmental accounting methodology is the core of the present sustainability evaluation of the fire-free management practices.

2 Materials and Methods

Three basic steps are involved in the sustainability assessment based on energy memory accounting:

i. overall system delimitation, energy sources identification, system's compartment definition, and energy fluxes characterization;

ii. compartment and fluxes energy memory quantification, and

iii. formulation and resolution of sustainability indices.

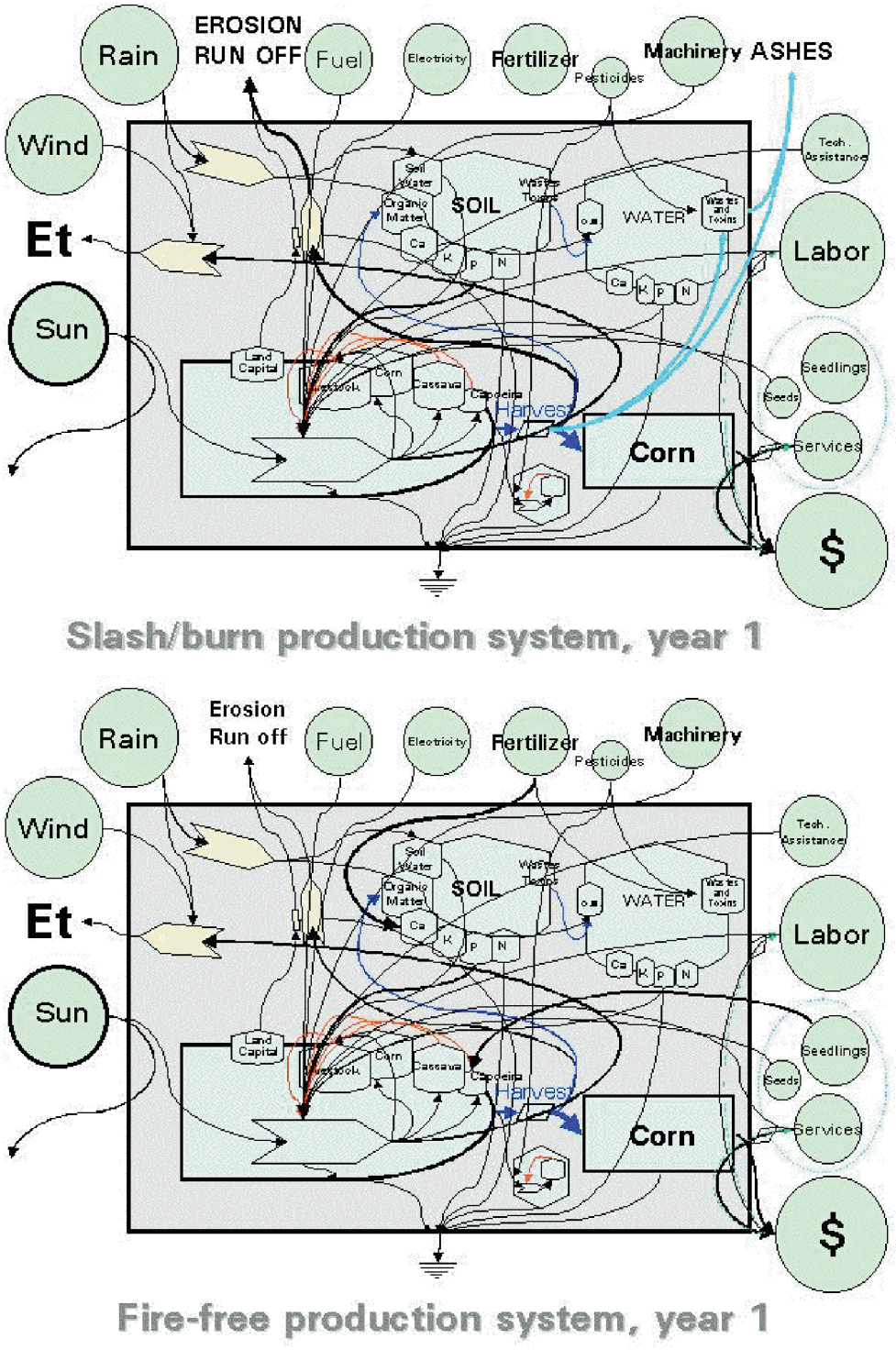

Fig. 1: System diagrams for the first year of the slash-and-burn and the fire-free agricultural production systems of small landholders of Eastern Pará.

Additionally, for the specific case of the present study in which most of the needed data has already been collected, a Delphi-type questionnaire will be filled by the project's participating researchers, in order to gather and organize the existing information.

This paper reports on the system delimitation and characterization for both the slash-and-burn and the fire-free management practices for a five-year production cycle, the formulation of preliminary sustainability indices appropriate for the systems under consideration, and the

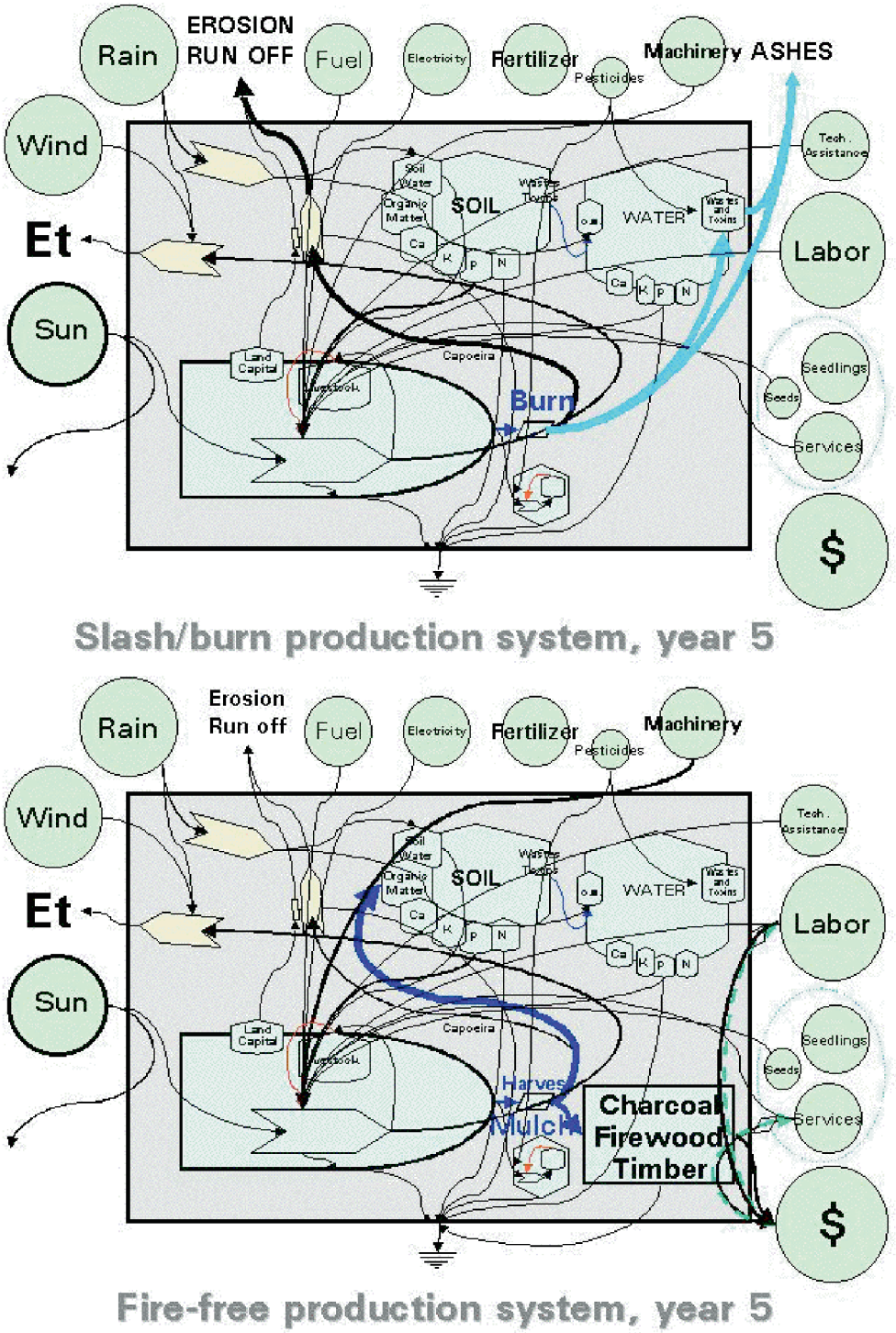

Fig. 2: System diagrams for the fifth year of the slash-and-burn and the fire-free agricultural production systems of small landholders of Eastern Pará.

composition of an automated spreadsheet for the resolution of the devised sustainability indices. This preliminary system evaluation framework constitutes the basis for composing the Delphi questionnaire that will provide the data, as well as the analytical structure, for resolving the sustainability indices.

3 Results and Discussion

The first step for the energy memory sustainability assessment of both the conventional slash-and-burn and the proposed fire-free agricultural production systems under consideration was the overall system delimitation and

characterization. The energy memory assessment involves the drawing up of diagrams using systems symbology, as explained in detail by ODUM (1996). These diagrams can then be translated into computer simulation programs, or as the present case, into automated spreadsheets.

Several assumptions and limitations must be defined in order to compose "typical systems" upon which the assessment framework can be drawn, for subsequent resolution with data collected from actual field studies. Specifically for the systems under consideration, the main definitions are as follows:

i. The system is driven by energy inputs from natural sources and man-made resources, expressed in the systems diagrams as circles;
ii. The main energy fluxes are directed toward production (expressed as Et-evapotranspiration) and losses (mainly erosion and ashes);
iii. Auto-catalytic processes (positive feedback) occur between the production and natural resources compartments;
iv. Money (flux expressed by dashed lines) is exchanged for the harvest (yield) to pay for labor, services, and man-made resources;
v. The main differences between the production systems studied are in the losses and production-natural resources compartments.

The typical system diagrams for the first management year of the slash-and-burn and the fire-free agricultural production systems studied is presented in Fig. 1.

Essentially, the system comparisons show that for the first production year, the losses associated with the slash-and-burn management practices are much larger (erosion, run off, and ashes), while the fire-free production system demands additional inputs in the form of fertilizers (to compensate for the immobilization of nutrients in the mulch) and seedlings (for enriching the secondary vegetation). The main product of both management systems is corn.

Similar diagrams were drawn for the whole production cycle (five years), and the main contrasts between the systems in a yearly basis are as follows:

System comparison, year two – The secondary vegetation growth in the slash-and-burn system is slow and poor, due to negative effects of fire. As a consequence, erosion and run off fluxes (losses) are larger, and cassava is the only product. In the fire-free management, the enriched secondary vegetation accumulates more biomass, and contributes additional nitrogen from fixation by introduced leguminous trees. A positive feedback is established between the large organic matter production by the vegetation and the soil. As a consequence of this increased nutrient flux, a new corn crop can be harvest, adding to the cassava production.

System comparison, year three – The recovery of the secondary vegetation in the slash-and-burn system is still slower and of lower quality, losses (erosion and run off) remain larger, and there is no marketable production, the system is stagnant. The enriched secondary vegetation of the fire-free system continues to grow faster and contribute nitrogen and organic matter to soil, and there is a final harvest of cassava.

System comparison, year four – The slash-and-burn system continues stagnated, with poor secondary vegetation recovery. The fire-free production system continues to contribute more nitrogen and organic matter to soil, but marketable production ceases.

System comparison, year five – The fallow period is completed and the systems are converted to cultivation. The burning operation of the slash-and-burn system causes significant losses of nutrients (ashes) and soil (erosion/run off), resulting in water contamination. There is no marketable production for the third year in a row. The mulching operation of the fire-free system requires inputs of fuels and machinery, and result in a large flux of nutrients from the vegetation to the soil (contributing to curtail erosion/run off losses). There is a strong market insertion of products harvested from the secondary vegetation, such as charcoal/firewood/timber (Fig. 2).

Assuming that these systems diagrams represent the typical management practices under consideration, sustainability assessment spreadsheets were formulated to receive the data to be gathered with the application of the Delphi questionnaire (a research phase still in progress, to be reported later). The spreadsheets were composed by management system (slash-and-burn and fire-free) in a yearly basis, and express the amount of every input (including natural resource sources) and product associated with each system in its appropriate unit, followed by the coefficient to transform this unit to the corresponding energy unit (solar energy joules) used in the energy memory calculations. These offered preliminary "transformity" coefficients were obtained from the literature, and will be appropriately adjusted with data obtained during the next phase of the research.

The spreadsheet was automated in such a way that once the actual amount of each input or product is entered in its designed cell, the corresponding result is expressed in the sustainability index section of the spreadsheet. Four recommended sustainability indices were included so far

(ULGIATI, 1995), and additional ones may be devised as the study progresses.

The investment ratio index expresses the proportion of the overall system's energy memory that is contributed by manmade effort (i.e. investment + services/system throughput). This index represents the economic dynamics of the production system, tnamely the relationship between the system studied and the market economy. Also, it is a measure of the dependency of the management practice on inputs that must be brought from outside.

The yield ratio index expresses the proportion of the overall system's energy memory contributed by nature (i.e. all sources/all man-made inputs). The yield ratio is a measure of the system's efficiency in harvesting and processing the energy available.

The non-renewable/renewable index expresses the burden imposed by the production system onto the natural resources, and can be used to point out the need for alternative sources for energy and materials needed for production.

The empower density index is a measure of the overall energy load of the system, representing its carrying capacity, and serving well for comparing contrasting management practices.

These composed system diagrams and their derived spreadsheets form the basis for determining the data that must be gathered from the projects documentation and from the researchers files, in order to proceed with the actual assessments of sustainability of the slash-and-burn and the proposed fire-free management practices in Eastern Pará. The next research step then comprises distributing the questionnaires and reviewing the literature of projects to fill in the blanks of the spreadsheets, and obtain the first actual assessments that will guide the validation of the method and the comparison of the studied production systems.

4 Conclusion

No matter how departed from the established market perspective of conventional economic analysis, the results of this proposed alternative sustainability assessment framework may contribute to accomplish two main objectives of the research, (i) to educate farmers and decision makers to value natural resources at least as much as the imported man-made inputs for production, and (ii) to focus the arguments for a more equitable priority distribution between exploitation and conservation of natural resources and the productive capacity of nature.

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