A Biophysical Approach to the Environmental Services by Land-Use Systems Assessment; Functional Biodiversity in Tropical Agroforestry Systems (The Case of Tomé-Acú Community, Northern Brazil)

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Abstract

Currently, the environmental services concept and its assessment seems the most appropriate approach to estimate, evaluate, conserve and in general make environmental use sustainable. The most well known environmental services are water purification and carbon sequestration. However, there are knowledge gaps. In the case of biodiversity, for example, evaluation has mostly been based on quantitative or qualitative studies of individuals and functional groups.

We suggest functional biodiversity as an indicator of the sustainability of land-use systems, as it is closely related to the variability, resilience and dynamics of ecosystems.

The application of the Criteria & Indicators (C&I) approach addresses this intention, operationalizing the functions involved in three main clusters: productive, ecological and operational through the definition of a sufficient number of indicators to represent the most relevant interactions. Such indicators are mainly process based and underline the impact of human intervention on ecosystems.

In this framework, the objective of this research is to assess the factors influencing the biophysical processes that determine the capabilities of agroforestry systems to maintain functional biodiversity, underlining the importance of the management factor to make them more productive and sustainable.

The data collecting methods include: ecological field studies, interviews, secondary sources review supported by remote sensing approaches. The units of analysis are agroforestry plots in small farmer properties; data processing is supported by multi-criteria protocols: work-shops at different levels of target groups and specialized software (CIMAT2.0). The results will be used to develop a model of the agroforestry systems for deeper understanding and to support decision making by the farmers.

Keywords: Agroforestry Systems, Biophysical assessment, Criteria & Indicators, Environmental Services, Functional Biodiversity, Tropics

1. Antecedents

Environmental management, like most of human activities in current times is progressively covered by the **market-based approach**, in the aim to make more "efficient" and "rational" the judgements and decisions related. The product of this elucidation is the concept of **environmental services** and its executive branch the **payment of environmental services (PES)** based on biophysical assessment, generally biophysical, and compensation mechanisms, generally economic.

2. Biodiversity conservation by Agroforestry Systems

As other land-use-management paradigms agroforestry has been considered as an option for biodiversity conservation. Its comparative **advantages** against other technical alternatives lean on three basic issues: 1. Its higher structural diversity, 2. Its higher dynamic of natural succession, and 3. The reduction of deforestation as outcome of its implementation [Coleman, 1994; Kang *et al.*, 1994; Michon *et al.*, 1986; Sánchez, 1995; Gallina *et al.*, 1996 cit. by Krishnamurthy and Avila, 1999; Shoenerberger, 1993; Bates, 1999].

Some examples are found in the study of the ability of **home-gardens** to maintain a high inter and intra-specific diversity and constant yields [Krishnamurthy and Avila, 1999]; the **agroforests** that emulate the structure and functionality of natural forests, integrating many species neither spatial nor temporal static arrangements [Mary, 1986 cit. by Torquebiau, 1993; Torquebiau, 1993; Michon and de Foresta, 1999]; and **buffer strips** around intangible zones, offering the best simulation option without affecting the production functions [Kangeyama & Reis, 1989].

3. Functional Biodiversity

Given the ampleness of the concept of biodiversity, **many approaches** were developed; the most integrative considers three big points of view: as a concept, as a measurable entity and as a social and political construct [Gaston, 1996a cited by Acharya, 1999].

The biophysical approach defines three levels of study: **genetic, species** and **ecosystem**, and although it's rather complex for some purposes it is not applicable so some complementary approaches were suggested: **identification of keystone, flagship, umbrella,** or **indicator** species [Heywood, 1994 cited by Acharya, 1999], or organizing the species according to their **degree of threat**: endangered, rare, vulnerable, etc. [IUCN n/d URL] or in operational clusters like **compositional, structural** and **functional** biodiversity [Noss, 1990a cited by Acharya, 1999].

> *"... Composition, structure and function... determine, and in fact constitute, the biodiversity of an area. Composition has to do with the identity and variety with elements in a collection, and includes species lists and measures of species diversity and genetic diversity. Structure is the physical organization or pattern of a system, from habitat complexity as measured within communities to the pattern of patches and other elements at a landscape scale. Function involves ecological and evolutionary processes, including gene flow, disturbances and nutrient cycling" [Noss, 1990b]*

Functional biodiversity basis in the heterogeneity and dynamism of the community components and the feedback of the biophysical and socioeconomic variation, consequently assign more weight on components that provide sustainability to the system through the encouragement and intensification of the processes [Altieri and Nicholls, 1999 cit. by Altieri, n/d, URL]. In the case of anthropogenic systems should be special remarks on the generation of useful outputs.

4. Conceptual and methodological tools

4.1. Scope of data collection

The study is carried out in three operation levels: parcel, region and landscape; and considers three study areas: ecological functions, productive functions (biophysical and socioeconomic) and operational functions.

4.2. Data analysis

4.2.1. Multi Criteria Analysis (MCA)

It is a series of methods designed to give an integrative approach to interdisciplinary problems, including different sources of data, different expert positions and different groups of interest. Its main advantages are: a. covers a great range of inputs and outputs addressed under different perspectives, b. allows the analysis of qualitative and quantitative data, c. involves the participation of multiple interest groups and try to achieve their agreement and d. the analysis may be interactive with the assessments (feedback mechanism) [DTLR, n/d; Mendoza & Macoun, 1999]

Chart 1. Steps for data collection, integration and analysis
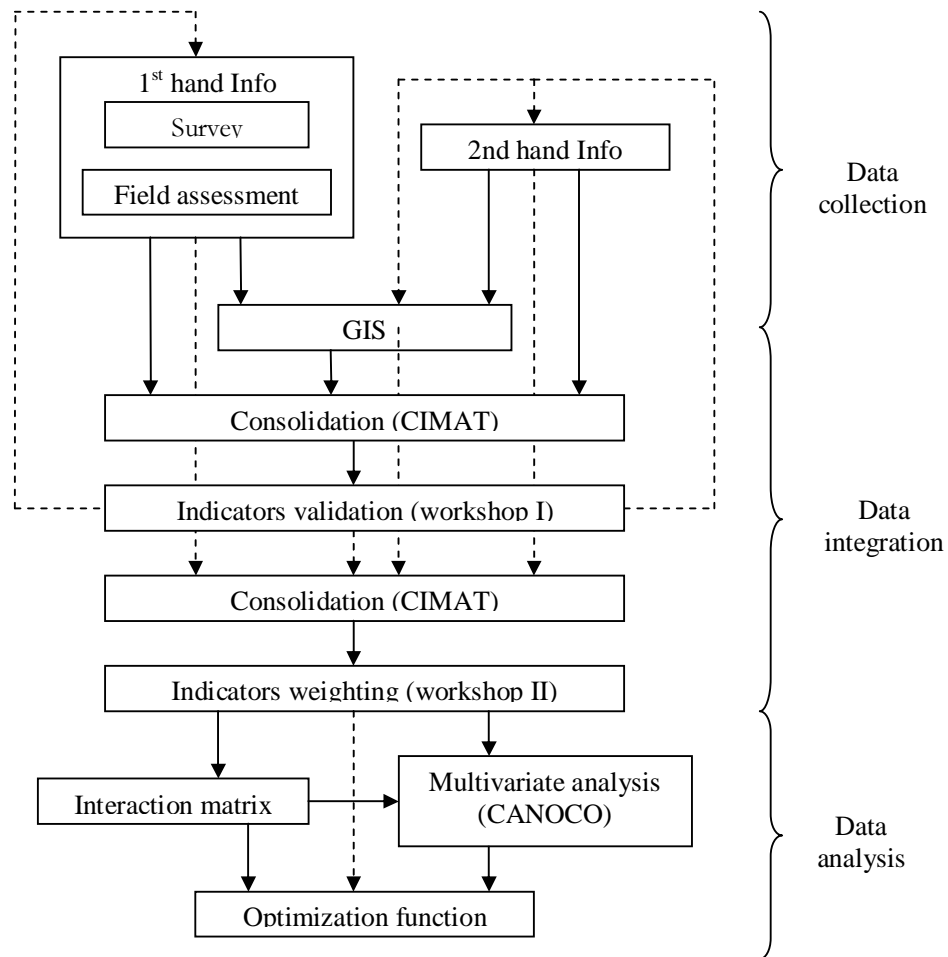
Criteria and Indicators concept and terminology, through a series of methodological steps allow the understanding of the ecology and resilience of the systems, grouping the factors according to the complexity levels in the successive steps: Principles, Criteria, Indicators (and Verifiers) [CIFOR C&I team, 1999; Mendoza e Macoun, 1999; ITTO, 1998 and Ritchie *et al.*, 2000 cited by Prasad, 2002; Prasad, 2002].

CIMAT (*Criteria and Indicators Modification and Adaptation Tool*), it is a specific software that allows the creation, modification, on-site assessment and navigation of criteria and indicator (C&I) sets. Even CIMAT has been developed by CIFOR (Center of International Forestry Research) to the evaluation of forest systems, its structure makes it feasible to apply to different conditions where the C&I approach is considered, assisting in the construction of hierarchies and consequently the ranking and rating processes [CIMAT, 2000].

4.2.2. Multivariate Analysis (MVA)

Multivariate methods focuses on interaction of different factors coincident in the same moment and space, and how they influence among each other on the "direction of the outputs" [Walker, n/d]. In spite its results are not categorical determine the influence spots or trends where one wants to go via other type of analysis or even investigations.

CANOCO (*Canonical Community Ordination*) it is a software designed for the analysis of ecological communities, applying techniques that relate the communities qualities composition to its environmental conditions, allows the detection of key factors and design of alternative scenarios in response to inputs change. [ter Braak & Smilauer, 2002].

5. Hypotheses, approaches and objectives

Agroforestry systems maintain functional biodiversity in a degree that maintain the production and environment processes in sustainable levels.

But:

- There are many scientific references about the virtues of agroforestry systems to maintain biodiversity -most based on pre-conceptions-, but they were not demonstrated conclusively.
- There is no consensus about how biodiversity should be assessed in agro-ecosystems and even worse: which biodiversity approach should be taken into account.

Thus we try to demonstrate:

- The abundance and richness of species in a system would be highly related with the intensification of processes evolved on it.
- The intensification of the ecosystem functionality, should imply the intensification of the production processes and consequently the increase of yields and by-products.

Then, the objective of this research is:

To assess the factors that influence in the biophysical processes that determine the agroforestry system capabilities to maintain functional biodiversity (case study: municipality of Tomé-Açu, Pará State, Northern Brazil); underlining the management as a key factor in the aim to improve the systems toward to make them more productive and sustainable.

And to achieve that we should:

- To define a methodology based on multicriteria analysis and consequently a set of criteria and indicators for its evaluation.
- To define an AFS optimization management model, in order to encourage its functional biodiversity.

6. Preliminary results

Definition of C&I set. For the biophysical evaluation of AFS in general and for its functional biodiversity assessment in particular. Such set is refined successively according to the following filters: a. Its conceptual re-evaluation, b. Consultation with experts, and c. Workshops with stakeholders. The election of the criteria will be according to: its representativity, application feasibility, flexibility for extrapolation, degree of integration, etc.

Chart 2. Principles (analysis group): integration and its integration in the operationalization of functional biodiversity evaluation
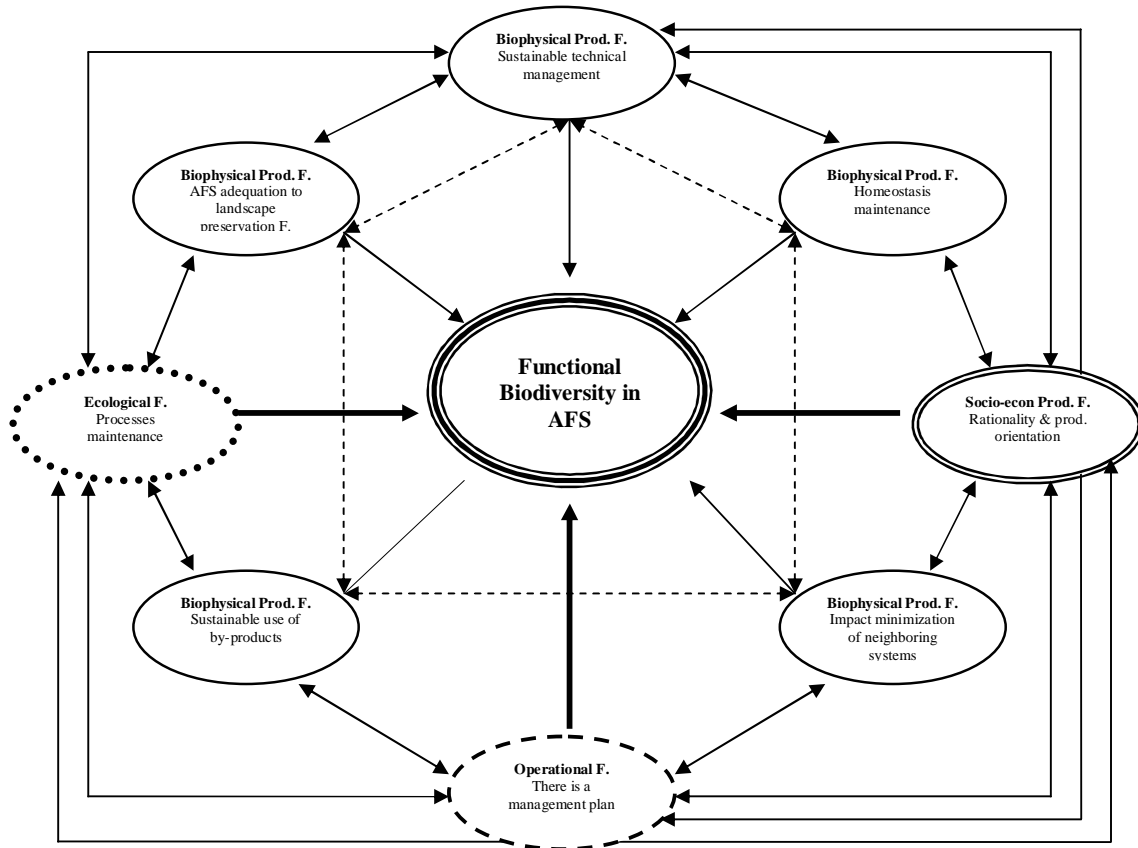
Interactive model. That considers the definition of inter-relations, ranks and rates assignation for every stage of analysis, especially on the "first-hard data" indicators and verifiers set developed.

The interactive model and the sustainable use index (CIMAT output) should give us in one hand the understanding of processes and indication of key factors, on which the successive steps should stress: multivariate analysis (CANOCO) and the generation of a sensitivity model, which would drive us to the finding of equilibrium between production and environmental services generation.

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