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Agricultural practices and biodiversity in cocoa production landscapes

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Abstract

Agricultural practices in cocoa cropping systems have been studied worldwide with a strong focus on production. Most of the attempts to improve cocoa production have been made through technical practice improvement only focused on the cocoa tree itself or the cocoa tree population within the plot. However, few approaches actually consider the cocoa field as it is most often cultivated worldwide, i.e. a complex association of species that include cocoa trees at different ages, but also fruit and timber trees as well as different species of lianas, mosses, orchids, bromeliads and shrubs. Moreover, most studies barely consider the existing interactions between one given cocoa cropping system and the other neighbouring systems, whether they are cocoa or non cocoa based, cultivated or non cultivated. As a result, the role of biodiversity in cocoa orchards and the role of cocoa orchards in environmental services such as biodiversity conservation are often unknown or not considered. We propose here a methodology for the study of biodiversity in cocoa production landscapes that takes into account three integration levels : (i) the plot (ii) the agroecological patterns, and (iii) the landscape. At the plot level, we studied i) physical characteristics of the vegetation structure including plant population density, strata location and light penetration, ii) local knowledge regarding uses of plants and animals, and iii) agricultural practices. Agroecological patterns are geographical structures composed of spatial patches characterized by specific ecological and social factors. We offer to build a typology of cocoa fields spatially localised taking into account their immediate neighbouring cropping systems. The patterns include a description of i) the nature of the systems (with or without cocoa) which have a common border with the cocoa field, and ii) the nature and intensity of biological interactions between the systems in the pattern. Finally, the territory level allows to integrate the functional and structural effects of the agroecological patterns and their interactions in the landscape. We suggest the need for an analysis of the interactions between these three integration levels to assess the environmental services provided by cocoa and other agroforestry systems in tropical landscapes.

Resúmen

Las prácticas agrícolas en sistemas de cultivo del cacao han sido estudiadas en todos los paises productores con un enfasis fuerte en la producción. La mayor parte de los intentos para mejorar la producción de cacao han sido realizados mediante el mejoramiento de las técnicas de manejo dirigidas solamente al árbol de cacao o a su población dentro de la parcela cultivada. Sin embargo, pocos estudios consideran el cacaotal tal como esta generalmente cultivado en la mayor parte de los paises productores, i.e. una asociación compleja de especies incluyendo árboles de cacao de edades diferentes, junto con frutales y maderables, asi como varias especies de lianas, musgos, orquídeas, bromelias y arbolitos. Además, aquellos estudios poco consideran las interacciones existentes entre un tipo de sistema de cultivo del cacao y los sistemas vecinos, que se basen en el cultivo de cacao o no, que sean cultivados o no. Como consecuencia, el papel de la biodiversidad en los cacaotales y el rol de los cacaotales para

proveer servicios ambientales tales como conservación de biodiversidad estan mal conocidos o poco considerados.
Proponemos una herramienta metodológica para evaluar la biodiversidad de territorios cultivados con cacao, incluyendo 3 niveles de integración : i)la parcela, ii) los patrones agro-ecológicos, y iii) el territorio. A nivel del cacaotal, caracterizamos i) las características físicas, ii) estructura de la vegetación, incluyendo densidades de las varias poblaciones de plantas asociadas, localización de estratas y penetración de la luz, iii) conocimientos y usos locales de plantas y animales, y iv) prácticas agrícolas. Los patrones agro-ecológicos son objetos geográficos compuestos de varios parches caracterizados por factores ecológicos y sociales específicos. Proponemos construir una tipologia de cacaotales localizados en el espacio junto con sus sistemas de cultivo o naturales vecinos. Los patrones podrían incluir una descripción de i) los tipos de sistemas (con o sin cacao) compartiendo un borde con el cacaotal estudiado, y ii) el tipo y la intensidad de las interacciones biológicas entre los diferentes sistemas del patrón. Finalmente, a nivel del territorio podemos integrar los efectos estructurales y funcionales de los patrones agro-ecológicos y sus interacciones en el paisaje. Con el fin de evaluar los servicios ambientales proveniente de sistemas agroforestales basados o no en el cultivo de cacao en paisajes tropicales, recalcamos la necesidad de un análisis de la interdependencia de estos 3 niveles de integración.

Introduction

Agricultural practices in cocoa cropping systems have been studied worldwide with a strong focus on production. Most of the attempts to improve cocoa production have been made through technical practices improvement only focused on the cocoa tree itself or the cocoa tree population within the plot. However, few approaches consider the cocoa field as it is most often cultivated worldwide, i.e. a complex association of species that include cocoa trees at different ages, but also fruit and timber trees as well as different species of mistletoes, lianas, mosses, orchids, bromeliads and shrubs. Moreover, most studies are mainly focused on the cocoa plot and barely consider the existing biological interactions between one given cocoa cropping system and the other neighbouring cropping or natural systems. This is particularly true regarding the impact of these neighbouring systems on biodiversity. For instance, few data sustain that cocoa-based agroforestry systems (AFS) close to natural forest patches or tracts support substantially more diversity of forest birds and mammals than those isolated from natural habitats (Rice & Greenberg, 2000). Different hypotheses have been proposed, including that cacao farm may be population sinks for seasonal migrations of wild forest species, that they may provide a suboptimal buffer habitat that would promote population stability in the optimal forest habitat and finally that they might provide corridors or stepping stones of acceptable habitats for dispersing animals (Estrada & al., 1997). As a result, the interactions between biodiversity, including pests and diseases (Holdenrieder & al., 2004), and cocoa-based AFS need to be considered at scales beyond plot and up to the landscape level.

Methods

On one hand, more information is needed on the impact of cocoa cultivation landscape structure and composition on biodiversity (Schroth & Harvey, 2007). On the other hand, Leciak (2006) demonstrated that social aspects can be associated with ecological processes to show that :

a) the local management of biodiversity is based on three integration levels : (1) the relations with species, (2) the uses of ecosystems and (3) the landscape management of ecological patterns;

b) the interdependence between these integration scales, as well as the strong relations which link society with natural processes, demonstrate how biological diversity and its resilience capacities are maintained.

In the case of agroforestry systems, a multiscale approach is needed to determine how plant and animal diversity is influenced by different mosaic patterns of forest and agroforest areas (Faria & Baumgarten., 2007). As tree pathogens propagate according to heterogeneous spatial patterns of flow and isolation (Holdenrieder & al., 2004) and because cocoa-based AFS are the main source of income for millions of smallholders, cocoa pests and diseases were included in this approach and considered as part of the biodiversity of the system.

Following these authors, we propose here a methodology based on the integration of agronomy and ecology, and taking into account 3 geographical integration scales: (1) the plot (2) the agroecological patterns, and (3) the territory :

1 - At the plot level, main structural and disturbance parameters are characterized by : i) plot topographical structure (Altitude, form, size, slope and orientation), ii) vegetation structure inside the plot (plant richness, abundance and density, strata volumes and locations, light penetration), iii) local knowledge and uses of plants and animals, and iv) agricultural practices as disturbance factors.

2 - The agroecological patterns are geographical objects composed of spatial patches characterized by specific ecological and social factors. These patterns include the first level (plot of cocoa-based AFS) together with a description of i) the systems (natural or cultivated) which have a common border with the cocoa field, and ii) the nature and intensity of the biological interactions between the different systems in the pattern. Hence the patterns would constitute a typology of patches spatially localised and including a central cocoa-based AFS and its several neighbouring natural or cropping systems.

3- Finally, the functional and structural effects of the agroecological patterns and their interactions are integrated at the landscape level. This should contribute to evaluate both positive and negative impacts of biodiversity to cocoa-farm productivity within agroforestry landscapes.

Results and discussion

A pilot study was conducted in the cocoa growing area and indigenous reserve of Talamanca, Costa Rica. Figures 1 and 2 show two cocoa-based AFS patterns with strong differences in shape, size (measured with GPS), slopes and their orientations, human intervention intensity (disturbance), vegetation structure and diversity, and with very different neighboring systems.

Two samples were taken in each plot in order to integrate borders effects: one in the center of the plot, and one on the common border with another given cropping system.

These first results of an ongoing investigation project clearly show strong differences between cocoa-based AFS in terms of vegetation structure and diversity (Fig. 1). We hypothesize that these differences can be linked with differences of habitats for wildlife, pests and diseases. Finally, the strong contrast observed between the two plots in terms of surrounding systems and human disturbance (Fig. 2) shows the need to integrate local context parameters beyond the plot itself. As far as forests or conservation friendly systems, including their connectivity and continuity, are important factors for biological diversity conservation, as well as the intensity of practices are concerned, the neighboring systems should be considered together with the cocoa-based AFS and studied as agroecological patterns. We then need to analyze the relations between the components inside these patterns as well as the relations between the patterns and the landscape. These three integration scales are necessary steps to assess the environmental services provided by cocoa and other AFS in tropical landscapes.

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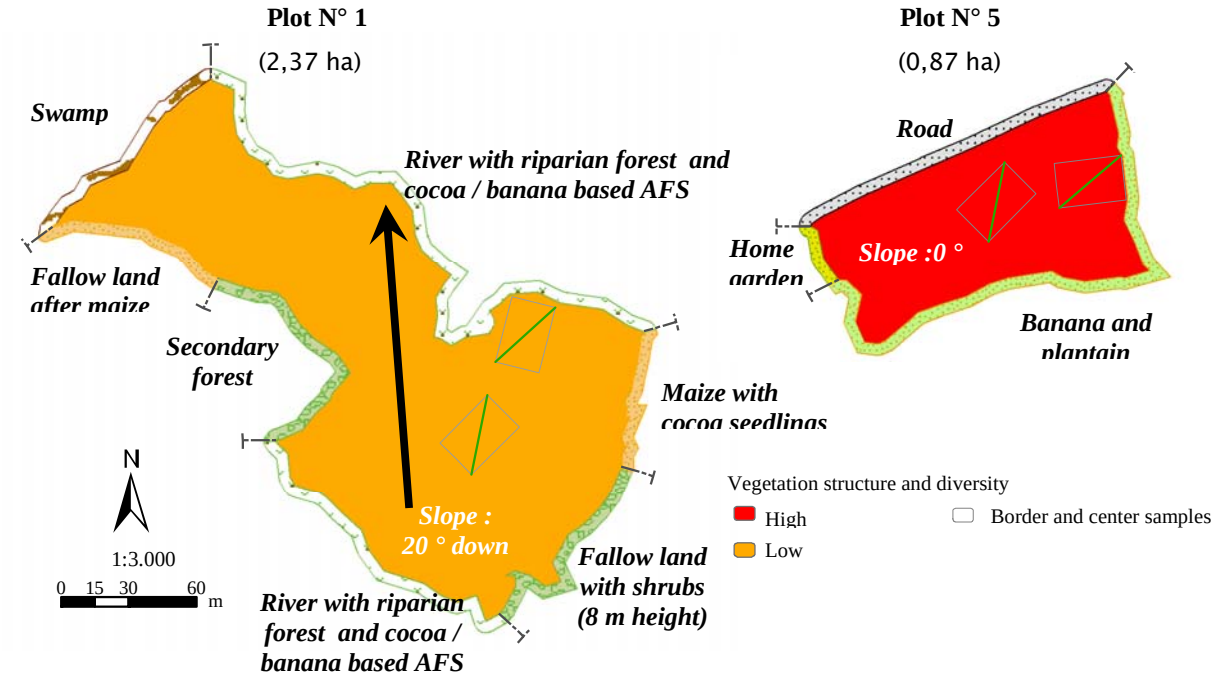

Figure 1. Agro-ecological patterns for two cocoa-based AFS with vegetation structure & diversity index.

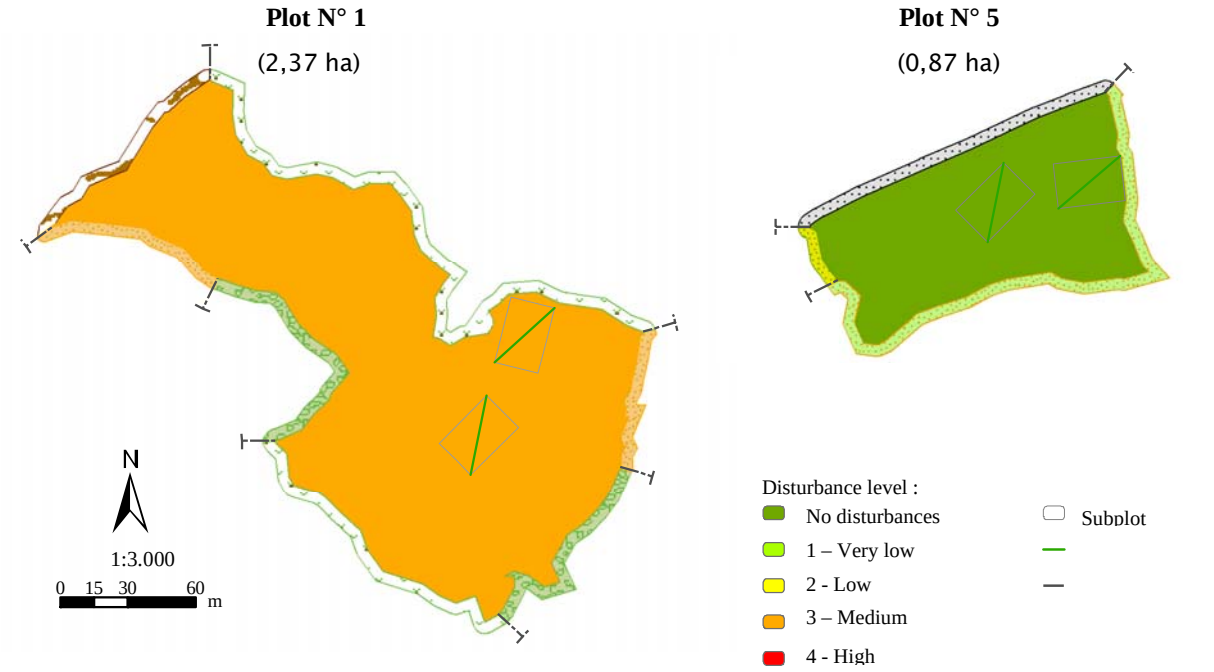

Figure 2. Agro-ecological patterns for two cocoa-based AFS with vegetation structure (border systems) and disturbance index (central cocoa-based AFS).