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Rebuilding the Brazilian rainforest: Agroforestry strategies for secondary forest succession☆

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A B S T R A C T

Does the adoption of agroforestry by small farmers in the Brazilian Amazon promote secondary forest succession on the degraded pastures and crop fields? New results from a small-scale farm agroforestry demonstration project, the Rondônia Agroforestry Pilot Project (RAPP) that began in 1992 are presented in this paper. In 1992, 242 farmers were surveyed by a stratified random sampling protocol, 50 of whom were selected to participate in the RAPP, constituting its experimental group. The remaining 191 farmers served as a control group. Farmers from both groups were re-surveyed in 2002 (after 10 years) and again in 2010 (after 18 years). Annual site visits to the experimental group farms were conducted from 1993 through 2003 to monitor agroforest plot development and management, and changes in pertinent socio-economic and household demographic characteristics such as household capacity, production systems, and social participation. Differences in property size, number of people permanently residing on the property, and social participation were found between the experimental and control group, with the experimental group having larger properties, more residents, and more participation in mutual aid associations. Control group farmers were also more reliant on cattle production (based on 2009 sales) despite having similar amounts of pasture as farmers in the experimental group. Within the experimental group, very few differences were found between farmers based on the type of agroforestry plot: timber, mixed or non-timber. Remote sensing analyses reveal long-term (10 years+) spectral differences in terms of the similarity to primary forest of both the agroforestry plots and the entire properties of the farms in this study. Experimental group farmers with mixed or timber-based agroforestry plots allowed more secondary forest succession to occur in and around their plots than farmers with non-timber plots. Although, on average, farm properties have become less spectrally similar to primary forest since 1992, properties with agroforestry plots tend to have more secondary succession and/or primary forest on their land in 2011. Several example properties are shown to illustrate the tendency of farmers with agroforestry plots to allow more secondary forest succession to occur on their land.

Introduction

Agroforestry and tropical forest succession

Socio-economic research articles on the role of agroforestry in promoting secondary forest succession were absent from Mercer and Miller's (1998) content review of the journal *Agroforestry Systems*, spanning 1982 to 1996. Since then this subject has entered into a broader scientific discourse on tropical agroforestry (e.g., Chowdhury, 2007; Ehiagbonare, 2006; JIRCAS, 2007; Lieberei & Gasparotto, 1998; Meza, Sabogal, & Jong, 2006; Raman, Mudappa, & Kapoor, 2009; Shono, Cadaweng, & Durst, 2007; Vieira, Holl, & Peneireiro, 2009). Agroforestry, defined as a "system of land use in which harvestable trees or shrubs are grown among or around crops or on pastureland" (Agroforestry, 2011) has evolved in numerous social and cultural contexts as a managed successional land cover to achieve fallow enrichment, secondary forest cover, riparian forestland rehabilitation, degraded forest recuperation or recovery, and agro-successional restoration. As a vehicle for

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promoting reforestation through managed secondary forest succession, research has also focused on the factors that influence farmers to adopt agroforestry practices (Smith, Dubois, Current, Lutz, & Clement, 1998; Warner, 1993; Yokota, Martin, & Siki, 2009). Related research has also explored the impacts of agroforestry and secondary forest succession on nutrient cycles (Sirois, Margolis, & Camiré, 1998), on biodiversity and wildlife populations (Bobo, Waltert, Fermon, Njokagbor, & Mühlenberg, 2006; Harvey & Haber, 1998; Letcher & Chazdon, 2009; Lozada, de Koning, Marché, Klein, & Tscharntke, 2006; Schulze et al., 2004), on atmospheric carbon sequestration (Castro, Sanchez-Azofeifa, & Rivard, 2003; Delaney, 1999; Fearnside & Guimarães, 1996; Lasco, Guillermo, Cruz, Bantayan, & Pulhin, 2004; Roshetko, Delaney, Hairiah, & Purnomosidhi, 2002; Schroth, D'Angelo, Teixeira, Haag, & Lieberei, 2002; Takimoto, Nair, & Nair, 2009; Wise & Cacho, 2011), and on agroforestry's contribution to rural household livelihood, not being limited to just income generation (Alavalapati & Nair, 2001; Barton, 1994; Budowski, 1980; Pattanayak & Mercer, 1998). As the research literature on agroforestry and its potential contribution to natural reforestation grows, questions remain regarding what types of agroforestry systems produce greater positive results in promoting secondary forest succession in the tropics.

Rondônia Agroforestry Pilot Project

This paper updates selected findings of the Rondônia Agroforestry Pilot Project (RAPP), an on-farm experimental agroforestry demonstration project involving small-scale farmers in the southwestern Brazilian Amazon state of Rondônia over an 18 year (1992–2010) period (Browder & Pedlowski, 2000; Browder, Wynne, & Pedlowski, 2005; Summers, Browder, & Pedlowski, 2004). One of the long-term research questions that the RAPP sought to address was: Is successful agroforestry a catalyst to secondary forest succession that might encourage reforestation of degraded lands on small farms in the Amazon? And, more specifically, does the type of agroforestry system (non-timber, mixed, or timber-based) adopted influence the likelihood that a farmer will manage degraded land for secondary forest regrowth as previously hypothesized (Browder et al., 2005)? Furthermore, are there socio-economic household characteristics that might predict secondary forest succession based on agroforestry?

Considerable differentiation in the spectral signatures from satellite images of the RAPP planting sites and their immediate surroundings were noticed over time. In some cases, farmers had allowed secondary forest vegetation to subsume their agroforest plots and in others, farmers had more carefully managed their plots sites to minimize secondary vegetation. The spectral differentiation within the experimental group led the principal investigators to speculate about socio-economic factors that might influence these spatial patterns. They hypothesized that three variables, for which household level survey data were available, might contribute to a better understanding of these patterns, as follows: (1) Household capacity of the control and experimental groups (number of working age adults living and working on the farm and the size of the farm area). The greater the household capacity the more likely a household might be to pursue a more labor intensive non-timber or mixed agroforestry experiment. (2) Dominant farming strategy pursued by the experimental farmers (area devoted to perennial cropping, annual cropping, and cattle). The more area in perennial cropping the more likely a farmer would exhibit a tendency to manage crops for annual harvest and income leading to a non-timber agroforestry preference. (3) Associational activities of control and experimental groups (farmer participation in mutual aid associations and rural workers unions). Farmers more active in these associations would be more likely to innovate and adopt agroforestry experimentally because of the greater network of technical information and mutual support such participation provides.

From these questions and observations the research objectives for this paper, enumerated below, emerged – to assess the potential impact of agroforestry adoption on secondary forest succession and primary forest conservation.

Objectives

In this paper, both 2010 land owner survey results and contemporaneous remote sensing analyses were used to address the following research questions:

1) Are there any significant differences in socio-economic characteristics between:
   a) The experimental group of agroforestry adopters ($n = 31$) and the control group of non-adopters ($n = 39$) included in the 2010 survey?
   b) The three different sub-groups of agroforestry adopters; timber, non-timber, and mixed, in the experimental group?
2) Are there any significant spectral differences in land cover in and around the agroforestry plots between the sub-groups of agroforestry adopters in the experimental group that might indicate a positive synergy between agroforestry demonstration plots and subsequent secondary forest succession?
3) Are there any significant differences in the amount of remnant primary forest cover on the properties in the project's experimental and control groups that might indicate a potential natural forest conservation effect of agroforestry adoption?

Study sites

Both control and experimental groups were drawn from the same rural population of family farmers who had migrated to Rondônia between 1980 and 1985 and settled in the project's two study sites, the *municipios* (counties) of Nova União and Alto Paraiso. The largest proportion of these farmers originated in the South and Southeast regions of Brazil, most having worked as sharecroppers and tenant farmers on coffee plantations. With the progressive government-sponsored conversion from coffee to soybean production beginning in the mid-1960s this rural population became progressively displaced from their traditional livelihoods and the government actively encouraged their migration to Rondônia as part of a larger regional development and resettlement program called The Northwest Region Development Plan (POLONOROESTE) (Browder & Godfrey, 1997; pp. 164–175). The farming strategies pursued by these new homesteaders in Rondônia typically followed a similar pattern: Small-scale forest clearing and planting of annual crops (corn, rice, beans) and a small area of perennial crops (usually coffee and cacao). Small livestock and eventually milk cattle, then beef cattle were added over time. For various reasons, several patterns of socio-economic and land use differentiation began to emerge leading some unsuccessful farmers to sell all or part of their properties, whilst more successful neighbors enlarged their holdings (for a more detailed examination, see Browder, 1994). The causes of these parallel processes of property subdivision and enlargement and how they correlated to changes in land cover, land use, household income, and numerous other household level socio-economic and demographic characteristics within the context of leading theories of frontier expansion are presented elsewhere (Browder et al., 2008). Suffice it to say that the study sites and their rural populations surveyed were