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The demise of swidden-fallow agriculture in an Atlantic Rainforest region: Implications for farmers' livelihood and conservation

Alfredo C. Fantini[a,*], Eliane Bauer[b], Cassio M. de Valois[c], Ilyas Siddique[a]

[a] Departamento de Fitotecnia, Universidade Federal de Santa Catarina, CP 476, 88040-900 Florianópolis, SC, Brazil
[b] Fundação Municipal do Meio Ambiente de Florianópolis, R. Felipe Schmidt 1320, 88010-002 Florianópolis, SC, Brazil
[c] Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina Rod. Admar Gonzaga 1347, 88034-901 Florianópolis, SC, Brazil

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ABSTRACT

The Brazilian Atlantic Forest is widely recognized for its high levels of biodiversity and endemism. Its vast region concentrates also a large number of small farmers, who historically have been practicing swidden-fallow cultivation. Globally, there is contradictory evidence of the current fate of this traditional, integrated agricultural system, and the new land uses may have a strong impact on farmers' livelihoods and ecosystem conservation. In this study, we assessed the land cover and land use change in a watershed where slash-and-burn cultivation was prevalent, aiming at understanding the drivers of change and discussing past and possible future impacts, including the perception of farmers on the drivers of land use change. We combined information gathered from interviews with 15 key informant farmers and from the analysis of remote sensing images for the years 1957, 1978 and 2011. Swidden-fallow cultivation has declined steadily since the 1950s. Part of the land was abandoned and forest succession was allowed to occur, increasing the total forest area; an apparently positive outcome. However, conversion to pastures and *Eucalyptus* plantations not only used much of the open land but also converted successional forests through deforestation, based on remote sensing. The willingness of farmers to grow more *Eucalyptus* and raise more cattle further increases concerns about the prospect for conservation. Our approach, combining remote sensing-based land change quantification and interviews, revealed to be complementary, allowing a better understanding of the past and possible future scenarios for the land use dynamics.

1. Introduction

Swidden-fallow cultivation has been fundamental to the livelihoods of millions of people all over the tropical world (Mukul and Herbohn, 2016; van Vliet et al., 2013) and there is much recognition of the ingenuity of this millenary agricultural system (Chazdon, 2014; Kleinmann et al., 1995). Swidden-fallow landscapes are characterized by an intricate mosaic of secondary forests, managed to variable degrees for multiple products and services, and are intentionally and multifunctionally integrated with the usually short-lived annual cropping phase on the same land management units and have therefore been considered agroforestry (Denevan et al., 1984). Nonetheless, swidden-fallow cultivation has also been referred to as obsolete and even criminalized almost everywhere (Padoch and Pinedo-Vasquez, 2010). Many studies have pointed out detrimental consequences of swidden cultivation on forest diversity (e.g. Gibson et al., 2011; Bihn et al., 2010; Lawrence, 2004) and on soil physical properties and fertility (Thomaz, 2013; Rodenburg et al., 2003; Ribeiro Filho et al., 2015). However, some degree of detrimental effects is not surprising as almost all of such studies compared environmental characteristics of swidden systems with undisturbed forests (Mukul and Herbohn, 2016).

There has been, however, a growing interest in swidden-fallow cultivation in recent years, with the publication of a strong body of literature on the theme as special features in journals (van Vliet et al., 2013, 2012; Mertz et al., 2009) as well as books (Chazdon, 2014; Cairns 2015, 2010; Delang and Li, 2013). On the one hand, swidden-fallow cultivation remains a safety net or the only alternative to sustain the complex socioeconomic and cultural structure of many communities of poor farmers in the tropics (Adams et al., 2013; Peroni and Hanazaki, 2002; Cramb et al., 2009). On the other hand, the mosaic of secondary forests that dominates swidden-fallow landscapes is now recognized to harbor a significant portion of the regional biodiversity, including endemic species, and to generate important ecosystem services (Delang and Li, 2013; Andrade and Rubio-Torgler, 1994; Chazdon et al., 2009; Dent and Wright, 2009; Guariguata and Ostertag, 2001; Brown and Lugo, 1990; Oliveira, 2008). Nonetheless, the warnings brought by the literature on the importance of conserving the socioeconomic and ecological value of swidden-fallow systems have not yet been translated

* Corresponding author.
E-mail addresses: alfredo.fantini@ufsc.br (A.C. Fantini), eliane_bauer@yahoo.com.br (E. Bauer), cassiomdv@hotmail.com (C.M. de Valois), ilyas.s@ufsc.br (I. Siddique).

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into effective policies.

As a general rule, farmers who practice swidden-fallow agriculture do not receive any incentive to keep doing so or to improve their traditional systems, and are left to rely on their own commitment and resources. By maintaining swidden agriculture on marginal lands, these farmers reveal their ability to adapt to the continuous dynamic of complex internal and external pressures. While such complexity confers resilience to the system (van Vliet et al., 2012; Begossi, 1998), it has also prompted change. For example, when presented with specific opportunities or coerced, farmers tend to move towards stronger integration into the Market (Li et al., 2014; Cramb et al., 2009; Pedroso et al., 2009; Dove, 1983). In other cases, the dynamic demographic structure of the communities and important new sources of revenue from part time employment in urban centers or government pensions cause a labor shortage for cultivation (Adams et al., 2013; Bauer et al., 2015; Pedroso et al., 2009). This process, in turn, has been suggested to drive net forest recovery, resulting in a forest transition (Keenan et al., 2015). However, the assumptions of the forest transition hypothesis are called into question by the rapidly increasing demand for agricultural products by urban populations and distant markets (Perfecto and Vandermeer, 2010) and the associated international displacement of deforestation (Meyfroidt et al., 2010). Furthermore, the theoretical gains in biodiversity conservation based on net increases in forest cover may not actually be attained due to widely increasing fractions of industrial tree monocultures of total 'forest' cover, which lack many of the social and ecological benefits of secondary forests (Chazdon et al., 2016). For instance, forestry plantations dominated by monocultures account for 25–100% of 'forest' gain in countries experiencing forest transition (Sloan and Sayer, 2015). Despite the increasing availability of forest cover data, the policy relevance of predictions in forest cover is limited if disconnected from the motivations of land use decision makers. Indeed, we know little about why swidden-fallow cultivation has resisted as the main pillar of livelihoods in some regions, while it has declined or changed in others (van Vliet et al., 2012; Mukul and Herbohn, 2016).

In the Brazilian Mata Atlântica region, swidden-fallow cultivation is millenary (Dean, 1995), locally known as *roça de toco* (Fantini and Siminski, 2016), and the longest phase of the swidden-fallow cultivation cycle, the secondary forests, still prevail all across the landscapes. This is indirect evidence of the overwhelming importance of this land use system until recently. In the Southern Mata Atlântica, where our study took place, 95% of the remaining vegetation is a mosaic of secondary forests (Vibrans et al., 2012). Swidden cultivation is fading out rapidly in the region (Alarcon et al., 2011; Siminski and Fantini, 2010; Zuchiwschi et al., 2010). As an important reason, previous studies have pointed to environmental regulations (Brasil, 2012, 2006) restricting the clearing of secondary forests (Pedroso et al., 2008; Siminski and Fantini, 2010, 2007).

It is possible that part of the fallows in the region will never be cleared again. But significant land use intensification through monocultures like palms, bananas, even-aged tree plantations and pastures (Adams et al., 2013; Pedroso et al., 2008) are likely to continue, with their respective, significant social, economic and environmental impacts.

The studied watershed is typical of the southern coast of the Atlantic forest, where farms are small (up to 25 ha) and both swidden cultivation and remaining forests are mostly confined to poor soils of the hill. In addition to the harsh conditions faced by farmers, the high population density of the region and the proximity to markets will likely exert a strong pressure on this land use. The watershed is also representative of the Atlantic forest region with respect to the widespread monoculture plantation of exotic tree species as well as increasing cattle raising, which is demanding conversion of more land to pastures.

The introduction of the analysis of remote sensing images has helped to quantify the speed and direction of past land use changes (Lira et al., 2012; Hurni et al., 2013; Teixeira et al., 2009). However, more interdisciplinary studies have improved the understanding of the problem-situation by combining analysis of images with ground data collected through interviews and other participatory research tools as well as from tertiary sources (Adams et al., 2013; Chi et al., 2013). In our study, we applied a similar approach, but specifically linked quantitative land use change data with farmers' motivations, concerns and expectations for land use change, in order to integrate a bottom up practitioners' perspective yet to be reflected in land use policy across many tropical countries. Our objective was to identify what drivers the farmers view as important to have guided their decision-making on land use in the last decades and, especially their expectation regarding swidden-fallow cultivation as well as their intended land use transitions for the near future. Such knowledge may be the basis for the formulation of a much-needed policy on land use and resources conservation for the Mata Atlântica region, one that takes into account the socio-environmental array of elements that carved the regional landscape.

2. Methods

2.1. Study area

The study was done in the watershed of São Mateus (27°23′S to 27°28′S; 48°44′W to 48°49′W), located in the municipality of Biguaçu, 30 km from the center of the capital of Santa Catarina State, Southern Brazil (Fig. 1). Part of the 38.4 km^2 of the basin is flat terrain with elevation of 20 m a.s.l. The larger portion of its surface is located on the hillsides of the Serra do Mar, with elevations up to 586 m a.s.l. and slopes predominantly above 30%.

Soils are predominantly red yellow Argissolo (corresponding to Ultisol in the U.S.D.A. Soil Taxonomy (Soil Survey Staff, 1994), with low fertility and widespread rock outcrops. The climate of the region is classified as Cfa (meso thermal humid with hot summer), with an annual average temperature of 20.5 °C and annual average rainfall of 1588 mm (INMET, 2009). The original vegetation was subtropical Dense Rainforest within the Atlantic Forest or Mata Atlântica (Veloso et al., 1991).

European colonization of the area started around 1816 (Soares, 1988), and now mainly Portuguese and Germans, but also some Africans represent the main ethnic groups. By 2009, the watershed comprised 234 farms, 80% of which are smaller than 20 ha.

2.2. Data collection and analysis

Data collection for this study included the processing and analysis of remote sensing images as well as participatory research methods. Remote sensing data were gathered from aerial photographs for the years 1957, 1978, and 2011. Aerial photographs from 1957 and 1978 (scale 1:25,000) were digitalized with a resolution of 900 dpi, georeferenced and orthorectified using ILWIS software. For the year 2011, orthophotos (scale 1:10,000) in digital format, with a resolution of 0.39 m, were already available. The orthophotos were then imported into ArcGIS software and combined into a mosaic (one for each date).

Land use/cover classification included five categories: mature or advanced secondary forest, early secondary forest, crop field, pasture, and even-aged forest. On-screen vectorization in the ArcMap Editor module was used to bind the polygons of each use/cover class. An optical stereoscopy was used to help differentiate advanced from early secondary forests on aerial photographs. The high resolution of the 2011 orthoimage was crucial to help interpret the images from 1957 and 1978. Ground truthing based on frequent fieldwork in the study watershed helped accurate classification. However, based on the aerial photos for 1957 and 1978, mature forest and advanced secondary forest could not be accurately differentiated, so we merged these two land covers into a single category. We concentrated the land use analysis on the hillside portion (equivalent to 80% of the basin), where swidden-fallow agriculture is practiced. The flat area of the basin is covered with