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Adoption and development of integrated crop–livestock–forestry systems in Mato Grosso, Brazil

Juliana Gil *, Matthias Siebold, Thomas Berger

Department of Land Use Economics in the Tropics and Subtropics, University of Hohenheim, Wollgrasweg 43, 235-70599 Stuttgart, Germany

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ABSTRACT

By combining crop, livestock and/or forestry activities in the same area, integrated systems (IS) can increase organic matter content in the soil – which favors biomass production and allows for higher livestock stocking rates in pasturelands. The implementation of IS is therefore seen as a promising strategy for sustainable agricultural intensification in Brazil, particularly in Mato Grosso state (MT). However, despite the benefits associated with IS and incentives offered by the federal government to stimulate their dissemination, little is known about these systems or the challenges to implement them, and only a limited number of farmers have adopted IS so far. This paper presents a comprehensive assessment of all IS identified in Mato Grosso by 2012/13, which were mapped and described in terms of their main technical and non-technical features. These findings were combined with farm survey data set to provide a detailed account of the various technologies currently being disseminated, their individual diffusion levels and potential adoption constraints. Results generated through qualitative and quantitative research methods give an overview of IS' state of the art, reveal farmer perception of such technology and offer insights into the prospects for low-carbon agriculture in the region. The study's major findings are that IS are present in more than 40 of the 141 municipalities of MT, and the vast majority (89%) involve only crop and livestock. Farmers have adopted three different crop–livestock configurations, depending on their production strategy. Cultural aspects play a major role in farmer decisions to adopt IS, credit provision has not been relevant for IS adoption, and a broader dissemination of IS may occur as land transitions continue.

1. Introduction

More than any other country in the world, Brazil faces the challenge of balancing agricultural production and environmental protection. As a major player in the world agricultural market, it is expected to satisfy a significant share of the global demand for food and energy in the coming decades, while also needing to ensure that agricultural expansion will not threaten its forest lands (Nepstad et al., 2009; Godfray et al., 2010; Arvor et al., 2012). In an effort to prevent further deforestation and optimize land use as a whole, the Federal Government of Brazil is adopting measures to direct the expansion of pasture and crops towards already deforested areas and promote agricultural practices that can intensify production sustainably.

Integrated systems (IS) deserve to be highlighted within this context as a very promising strategy to achieve such goals. By combining crop, livestock and/or forestry activities in the same area, they may be able to increase fertility and organic matter content in the soil. This favors biomass production and allows for higher stocking rates in pasturelands (Bungenstab, 2012; Carvalho et al., 2014). Such increase in the system's total productivity represents a direct advantage for farmers if it can be translated into higher economic return and soil conservation over the longer run. In fact, both individual farmers and the society as a whole can benefit from IS given that the maintenance of soil fertility is critical for the conservation of natural resources and provision of environmental services (Lemaire et al., 2014; Salton et al., 2014).

The assessment of indirect impacts of IS adoption is a complex task at the landscape and regional levels, especially when it comes to the prevention of deforestation due to land use intensification in already cleared areas. Most recent studies agree that intensification spares land under certain assumptions (Cohn et al., 2014; Nepstad et al., 2014; Strassburg et al., 2014) and recognize that the

* Corresponding author. Tel.: +49 711 459 24116; fax: +49 711 459 24248.
E-mail address: julianagil@uni-hohenheim.de (J. Gil).

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effect of agricultural intensification practices (including IS) may differ in frontier regions (Byerlee et al., 2014). Still, the consensus among experts is that IS could help prevent further deforestation (Balbino et al., 2011; Bonaudo et al., 2014).

Integrated systems may include annual and/or perennial crops, different tree species, and several spatial arrangements. Planting densities, field operations and the frequency of rotation between crops and grasses also vary. Such heterogeneity means that farm surveys are not suited to measure the rates at which carbon accumulation occurs in specific IS. Nonetheless, it has already been suggested by literature based on field trials that these systems can contribute to the increase in carbon stocks in the soils (Cerri et al., 2010; Carvalho et al., 2014; Piva et al., 2014; Silva et al., 2014).

When compared with the well-known "agroforestry systems" though, IS usually involve more intense field operations and lower species-diversity. In this sense, IS are relatively similar to conventional agricultural systems in terms of low labor-intensity and high output levels, which makes them a realistic alternative in areas where large-scale commercial agriculture is already in place.

This is the case of Mato Grosso, a Brazilian state lying within the "Arc of deforestation", where agriculture is rapidly expanding. At the same time, local livestock production systems are highly land-intensive and have low stocking rates, which contribute to increasing overall land pressure and land-use change (IMEA, 2010a; Cohn et al., 2011; Alves-Pinto et al., 2013). Considering that Mato Grosso is the main cattle and soya producer in the country and lies adjacent to the most dense portion of the Amazon forest, the adoption of IS there could help to achieve both environmental protection and development of more efficient and sustainable agriculture. Additionally, IS could contribute to the rehabilitation of degraded pasturelands, which already accounted for more than 1.6 million ha in Mato Grosso in 2006 (IBGE) and release carbon into the atmosphere (Silva et al., 2004; Fearnside et al., 2009; Batlle-Bayer et al., 2010; Carvalho et al., 2010).

For all these reasons, IS are one of the six practices eligible for credit under the so-called "ABC Plan" – a major initiative of the Brazilian federal government aimed at reducing greenhouse gas (GHG) emissions from the agricultural sector. Launched in 2010 at the 15th Conference of the Parties to the UN Framework Convention on Climate Change, the Plan is part of the country's national policy for climate change, which sets a voluntary GHG emission reduction target of 36.1–38.9% of the total emissions projected by 2020. Specifically concerning IS, the goal is to double the area currently cultivated, reaching approximately 4 million ha and preventing the release of about 20 million tons of carbon dioxide equivalent into the atmosphere (CNA, 2012).

Still, in spite of all incentives and benefits associated with IS, adoption by local farmers remains low and use of the credit lines offered through the ABC Plan is still limited. Even though it is important to consider the recent nature of the ABC Plan and to recognize that the number of agricultural loans issued by the banks has increased substantially over the past year, most of these loans are concentrated in Southern Brazil and target practices other than IS (Observatório ABC, 2013).

According to the latest official agricultural census (IBGE, 2006), only 357,006 ha were occupied with agroforestry systems in MT (less than 1% of the state's 33,450,060 ha of agriculture) and official statistics on IS are not yet available. Especially in the state of Mato Grosso, research is lacking on the extent of existing IS, where they are located, their economic and environmental inputs and impacts, and the challenges associated with their implementation.

This paper seeks to contribute to a deeper understanding of integrated systems in Mato Grosso and to offer insights into their potential dissemination by mapping and describing pioneer initiatives, assessing how farmers perceive this new technology and identifying determinants of adoption. It is organized in five sections. Section 2 describes the study site and the conceptual framework behind the questionnaire applied to farmers. Section 3 presents survey results obtained through the comparison of farmers' socio-economic profiles and the characteristics of farming systems related to all main aspects of the study. These include the IS strategies found in MT, farm and farmer characteristics, soils and other biophysical environmental factors, farmer technological profiles, legal status of the rural property, production data, challenges of IS implementation, credit availability, and farmer exposure to information,. Section 4 discusses these results and some policy implications, highlights the impacts of IS on the environment (and vice-versa) as perceived by farmers, and then answers whether any of the factors listed above represents a barrier to a broader dissemination of IS and/or to the consolidation of low-carbon agricultural systems in the region. Finally, Section 5 concludes the discussion and highlights further research avenues on integrated agricultural systems that were identified with the study.

2. Material and methods

Since specific IS data are not yet available, we initiated the study by identifying all IS adopters in the state of Mato Grosso by contacting unions, professional associations, rural extension services and consultants in every municipality of Mato Grosso state. A comprehensive questionnaire was designed and pilot-tested together with local experts, and then administered to both IS adopters and non-adopters (all interviews were conducted by the first author). Networks of trust had to be developed in order to access sensitive and/or confidential information on land tenure, credit and environmental liability issues. Such data are often unavailable due to their strategic nature or even because they reveal poor law enforcement.

All four types of IS defined in the "National Policy for Integrated Crop–Livestock–Forestry Systems", established by the Federal Law n. 12805/2013, were considered for this study:

- iCL – crop–livestock systems (i.e., integrated production of grains, grasses and animals);
- iLF – livestock–forestry systems (i.e., integrated production of grasses, animals and trees);
- iCF – crop–forestry systems (i.e., integrated production of grains and trees); and
- iCLF – crop–livestock–forestry systems (i.e., integrated production of trees, grains, grasses and animals).

In order to assess the influence of biophysical environmental factors on the adoption of IS, quantitative data were collected on the location of farms using IS, and qualitative data were collected within those farms on locations where IS were more likely to be practiced. In both cases, this evidence was reported by farmers themselves, based on questions about whether they thought that the soil on their properties was adequate for the cultivation of certain species, as well as whether IS would be an interesting option in selected locations.

The assessment of the influence of IS adoption on the biophysical environment, on the other hand, is less straightforward. As most integrated systems are new in Mato Grosso, treatment/control evidence of their environmental impacts is still lacking. Nevertheless, data on before/after management practices of farms were collected where IS are adopted and not adopted (including information on stocking rates and basic field operations, e.g., fertilizer applications). As already mentioned in the introduction, the literature contains strong evidence linking several of