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Socioeconomic and environmental assessment of biodiesel crops on family farming systems in Brazil

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ABSTRACT

In Brazil, local agricultural research agendas are increasingly challenged by the search for sustainable biodiesel crop options for family farmers, especially under semi-arid conditions. The aim of this paper is to explore the suitability of different biodiesel crops (i.e. soybean, castor bean and sunflower) through a set of environmental and socioeconomic indicators in a semi-arid (Montes Claros) and a more humid (Chapada Gaúcha) municipality in the state of Minas Gerais, southeast Brazil. A technical coefficient generator (TechnoGIN) was used to assess current (maize, beans, soybean and grass seed) and alternative (castor bean and sunflower) crops grown with current and alternative production techniques. The quantification of the inputs and outputs was based on farm surveys, expert knowledge, literature and field experiments. Although castor bean and sunflower are economically competitive with maize in Montes Claros, feed and labour requirements may hinder farmers' adoption. In Chapada Gaúcha, the double cropping system soybean/sunflower presented small economic gains when compared to soybean; it also increased nitrogen losses and biocide residues. We conclude that the scope for alternative and sustainable biodiesel crops on family farms is limited. Their economic benefits are small or absent, while their introduction can lead to higher environmental impacts and there may be trade-offs with food and feed availability at the farm level.

1. Introduction

Worldwide, biofuels have become one of the most dynamic and rapidly growing sectors of the global energy economy (UN, 2007; Scragg, 2009; Tomes et al., 2010). There is increasing recognition that biofuel production can offer opportunities for countries to meet reduction of greenhouse gas emission targets, while empowering farmers through the generation of jobs and income in rural communities (Hazell and Pachauri, 2006; FAO, 2008).

Biofuel initiatives in Brazil have recently targeted biodiesel as a way of combining renewable energy production with rural poverty reduction. A national program for production and use of biodiesel was created in 2004 framed by a set of regulations based on mandatory blending of biodiesel with fossil diesel (Brasil, 2005). Expectations on further expansion of the mandatory blending policy, from the present 5%, led to a fast development of the biodiesel industrial production capacity which is able to supply two and a half times the current demand (Ubrabio, 2010; MME, 2012b). One of the main features of the policy is the inclusion of family farmers as feedstock suppliers to the biodiesel industry. Biodiesel producers who comply with feedstock supply from family farmers (Appendix S1) are granted a social fuel stamp, which implies tax exemptions and selling preference at biodiesel auctions (MDA, 2011).

Although the number of family farmers engaged in biodiesel crop production increased over the last five years, reaching over 100,000 families in 2010, biodiesel crop options are still narrow as 95% of the feedstock supplied is soybean. Soybean farmers are concentrated in the South and Central-West Brazilian regions; together they account for 91% of the feedstock supplied. The semi-arid Northeast region, on the other hand, has the highest concentration of family farms in the country (50%) and is responsible for only 5% of the total biodiesel feedstock acquisitions (MDA, 2011). Furthermore, this region has an agricultural GDP per capita that is seven times smaller than in the South and Central-West of Brazil (IBGE, 2006).

The Brazilian biodiesel policy is currently challenged by the search for alternative biodiesel crops that combine high oil productivity with better suitability for less endowed farmers, especially under semi-arid conditions. This strategy aims to increase oil production per area, thus positively affecting the energy balance of the production activity, and at the same time increasing family farms'

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engagement. To be effective in engaging many family farms and increasing oil production in the near future (ca. 5 years), such crops should be compatible with the current farming systems (i.e. cropping sequence, labour and capital availability) plus well-established agronomic and management information for their cultivation should be available. Eligible biodiesel crops should then be assessed in combination with different production techniques and in terms of environmental and socioeconomic indicators. One way of improving knowledge regarding the complex relationship between agricultural production, environment and economy is through integrated quantitative methods and tools. These methods allow exploration of suitable production activities taking into account farmers' objectives, resource availability and technical feasibility (de Wit et al., 1980; Hengsdijk and van Ittersum, 2002). This would complement the existing literature assessing the feasibility of biodiesel production on family farms in Brazil, much of which is qualitative in nature (Abramovay and Magalhães, 2008; César and Batalha, 2010; Garcez and Vianna, 2009; Hall et al., 2011; Padula et al., 2012; Watanabe and Zylbersztajn, 2012). Such analysis is based on the description of production activities under specific biophysical and technological conditions in terms of inputs and outputs which are known as technical coefficients (Hengsdijk et al., 1999; Ponsioen et al., 2006). Inputs may include external nutrients, biocides and labour which together with the outputs can be expressed in their own physical units, and in monetary units. Besides crop production, outputs may include socioeconomic and environmental indicators such as labour use efficiency, cost–benefit ratios, nutrient losses and biocide residue (van Ittersum and Rabbinge, 1997). Moreover, although there are a number of studies that explore the agroecological potential of biodiesel crop options (Aranda-Rickert et al., 2011; Baldwin and Cossar, 2009; Dhyani et al., 2011; Zheljazkov et al., 2008), limited work has been done towards the integrated analysis of socioeconomic and environmental aspects of crop activities under different environmental conditions and technology levels. Finally, the importance of research that supports systematic analyses at more than one hierarchical level (e.g. field and farm level) cannot be understated (Volk and Ewert, 2011).

The objective of this paper is to explore current and alternative oil crops and their management through a set of environmental and socioeconomic indicators in two locations of Southeast Brazil. In this assessment, a semi-arid municipality, Montes Claros, and a more humid municipality, Chapada Gaúcha, of Minas Gerais state, were studied. Alternative production activities (biodiesel crops) and techniques were assessed against current – not so intensive in the use of machinery, biocide, and fertiliser – production techniques of maize (*Zea mays* L.) and beans (*Phaseolus vulgaris* L.) in Montes Claros and the more intensive production techniques of soybean (*Glycine max* L.) and grass seed (*Brachiaria* spp.) in Chapada Gaúcha. Findings from this analysis can produce useful knowledge for farmers and scientists on promising opportunities and major constraints of biodiesel crops under different production techniques. In addition, the outcomes of the assessment of different biodiesel crops under contrasting socioeconomic and agroecological conditions may help to provide insights for policy makers as to the overall evaluation of the biodiesel policy in Brazil. Finally, the proposed integrated analysis aims to generate a coherent field-level information package (technical coefficients) that will enable farm level studies (Leite et al., 2014b), thus contributing to further insights into the effects of biodiesel crop cultivation when farmers' resources (land, labour, capital) and objectives (i.e. profit maximisation, food self-sufficiency) are taken into account. Although this study focuses on the assessment of indicators that are relevant to the uptake of biodiesel crops by family farmers, we acknowledge there are other important indicators, such as GHG emissions and net energy production, when it comes to the overall sustainability evaluation of biofuel production.

In this study the selected methodological approach and technical coefficient generator are generic and can also be applied to other regions.

2. Materials and methods

The description of key terminology used in this study is summarised in Table 1.

2.1. Modelling approach

The exploration of agroecological and socioeconomic sustainability of current and alternative production activities requires a comprehensive compilation of their inputs and outputs. It means that all inputs (i.e. labour, biocides, fertilisers and input costs) and outputs (i.e. yield levels and nutrient losses) associated with a particular crop with a specific production technique and land unit have to be quantified. A comprehensive database was built based on information on current and alternative production activities from which different production activities can be assessed through the various possible combinations of crops, production techniques and land units. To generate such combinations and calculate the inputs and outputs a computer program (TechnoGIN) was used. TechnoGIN (Ponsioen et al., 2006) is a technical coefficient generator which allows for the quantification of inputs and outputs of a large number of current and alternative production activities. Although TechnoGIN was first developed for Ilocos Norte, Philippines (Ponsioen et al., 2003), it has recently been re-designed as a more generic and flexible tool for further applications in other regions of Asia and Africa (Patil et al., 2014; Reidsma et al., 2012; Wolf et al., 2004).

The input and output coefficients of current production activities in TechnoGIN are based on survey data. Alternative production activities, however, are quantified based on knowledge of the biophysical processes of plant and animal production, technical recommendations and land use related objectives following the so called design criteria (Hengsdijk and van Ittersum, 2002). For these activities, target yields were based on crop models (potential and water limited yields), field crop experiments (rain fed and irrigated), expert knowledge and literature. Inputs were determined using the so called target-oriented approach, i.e., seeking the technically optimum combination of inputs to realise the target yield level (van Ittersum and Rabbinge, 1997).

Table 1
Summary of the terminology used in the quantification of crop activities.

Terminology	Description
Production level	Level of primary output per unit area
Land unit	Relatively homogenous area in terms of landscape, soil characteristics and climate conditions
Production technique	A set of agronomic inputs required to realise a particular output level
Production activity	Crop or crop rotation cultivated on a particular land unit and characterised by a specific production technique
Current production activity	Production activity characterised by actual farmers' management in terms of crop choices and technology adoption
Alternative production activity	Production activities technically feasible but not yet widely applied by farmers
Target oriented approach	Technical optimal combination of inputs to realise a particular output level or production level
Technical coefficients	Input and output coefficients of a production activity

Source: van Ittersum and Rabbinge (1997) and Hengsdijk et al. (1999).