Artículos

TECHNICAL EFFICIENCY IN LAND USE FOR SOYBEAN CROPPING BY SMALL FARMS EVIDENCES FROM NORTHERN MATO GROSSO, BRAZIL

Eficiencia técnica en el uso de la tierra para el cultivo de soja por pequeñas granjas: Evidencias del norte de Mato Grosso, Brasil

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Abstract: We aimed to analyze the efficiency of small farmers in Mato Grosso that crop soybean. Data Envelopment Analysis (DEA) method was employed and we identified factors effecting efficiency with a logit model. Results demonstrated that only few farmers are efficient in soybean cropping because this production is based in economies of scale due to the high costs involved in the technological package. Two main practices were identified to reduce small farmers dependence of economies of scale: the costs funding with contracts between farmers and tradings and the acquisition of used machinery or contracts of services in substitution of new equipment. Soybean proved economic feasible in inefficient farms but requires the development of better policies to be sustainable.

Keywords: rural development, economies of scale, logit, agricultural technology.

Resumen: Nuestro objetivo fue analizar la eficiencia de los pequeños agricultores en Mato Grosso que cultivan soja. Se empleó el método de la Análisis de la Envoltura de Datos (AED) y verificamos los factores que afectan la eficiencia con un modelo logit. Los resultados demostraron que solo pocos agricultores son eficientes en el cultivo de soja porque esta producción se basa en economías de escala debido a los altos costos involucrados en el paquete tecnológico. Se identificaron dos prácticas principales para reducir la dependencia de los pequeños agricultores de las economías de escala: con contratos entre agricultores y tradings para financiar los costosy la adquisición de maquinaria usada o contratos de servicios en sustitución de nuevos equipos. La soja demostró ser económicamente viable también en agricultores ineficientes, pero requiere el desarrollo de mejores políticas para ser sostenible.

Palabras clave: desarrollo rural, economías de escala, logit, tecnología agrícola.

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Introduction

Brazil is one of the leaders in world grain production. In 2017, the country's soybean exports (FOB) totaled US$ 5.30 billion. Mato Grosso state is the main national producer of soybean, harvesting 30 million tons in crop year 2016/2017, representing 26.75% of the national output (Conab, 2017), and exporting 36.61% of the national production (MDIC, 2018). But to reach this great agricultural production, the recent process of agricultural occupation in Mato Grosso and dominance of agricultural commodities was determinant and deeply impacted the agrarian structure.

Unexplored for centuries, the Brazilian Midwest and consequently Southern Amazon have become the great agricultural frontiers of Brazil from the 1960s, driven by the spontaneous expansion of livestock and colonization projects (Jepson, 2006). However, the expansion of soybean cropping in this region has been a recent phenomenon, mainly since the 1990s, both through extensive agricultureby conversion of native forests into agricultural areas,and intensive agriculture by increased productivity through greater application of labor and capital (Galford, Melillo, Mustard, Cerri, & Cerri, 2010; Lathuillière, Johnson, Galford, & Couto, 2014).

The success of agribusiness in Mato Grosso is mainly due to the large trading companies that increased the production of grains in the region through technological packages (pre-defined amount of input use to achieve highest productivity and product quality), which in turn increased the productivity of farms (Wesz Jr, 2016). However, this production model involves high capital expenditures, and especially large investments in modern machinery, greatly increasing the minimum area necessary for economic viability, and leading soybean cropping to economies of scale. Thus, soy cultivation is feasible only when practiced over large areas (Vander Vennet, Schneider, & Dessein, 2016).

At the margin of this paradigm are small family farmers with not enough land to achieve the economies of scale, which restricts their entry to the soybean market. Surprisingly, in recent years, we observe the growth of small family farmers in northern Mato Grosso who crop soybean and are integrated into the competitive commodities market. Confronting the entrance of small farms inmonoculture are diversification strategies (Mahy, Dupeux, Van Huylenbroeck, & Buysse, 2015), including the multifunctionality of rural areas – agriculture, forestry, landscape and tourism, non-agricultural activities– (Zasada et al., 2017). However, Ploeg, Jingzhong & Schneider (2012) show that rural development can be achieved from different perspectives: "broadening" in diversification, "re-grounding" in new forms of farm management and dependency of external resources, or joining agro-food supply chains ("deepening"). This last perspective raises questions if the production of soybean is viable for small-scale farmers, increasing the range of opportunities to explore the potential of rural areas and reduce poverty through new activities.

In this paper we aimed to analyze the efficiency in small-scale soybean production in Mato Grosso and to determine the factors that increase or decrease efficiency in these farms. Our hypothesis is that small farmers are more are more likely to be efficient when the planted area increase; this is based primarily on the principles of gains in scale and restricts the effectiveness of policies for very small farms to join soybean production. Furthermore, soybean has deep environmental (Fearnside, 2001) and social impacts (Brando, Coe, DeFries& Azevedo, 2013) questioning the sustainability of this activity in the long term.

Soybean cropping in Mato Grosso: small farms and technical efficiency

The agricultural frontier expansion of Southern Amazon is a historical process that intensified mainly from the 1960s, with government policies to stimulate occupation through the migration of populations from other regions, mainly from the South Region of Brazil (Jepson, 2006). The low land value due to the soil's chemical conditions and subsidy policies favoring modern agriculture were determinants of the actual agrarian structure, leading to large rural properties becoming the symbol of economic efficiency (Filho & Vian, 2014).

The process of colonization involved the culture and tradition of Migrants from South Brazil in the production of grains, which, allied with the research conducted on soybean, allowed for the cropping of this commodity in Mato Grosso. However, the largest increase in production occurred in the 1990s following the liberalization of the economy and drastic reduction of subsidy for rural areas. On the other hand, the government encouraged large trading companies to lead the rural production (Wesz Jr, 2016). By introducing a production system based on modern technologies –technological packages– (Rodrigues & Marquezin, 2014), these companies increased their soybean production in the state to meet the demand of foreign markets, mainly China. However, the consequence of this modernization process was the use of economies of scale in farms to achieve economic feasibility, rendering small-scale farms inefficient in both economic feasibility and productivity levels.

According to microeconomic theory, a firm has two main challenges for maximizing profit: maximize revenueand reduce costs. In other words, economic agents allocate production factors optimally to obtain the best economic result. Each economic agent has a production possibility frontier (PPF), that is, the maximum reachable output using the available production factors. Operating at PPF means achieving maximum efficiency, whereas operating below this level means that some production factors are idle or used improperly. Analyzing the efficiency of agricultural production units involves the study of aspects common to all economic sectors, such as the institutional environment, production decisions, and use of input, as well as the management capacity of the productive unit. Thus, in the agricultural sector, as in any other sector, not reaching the PPF is a serious problem in terms of efficiency.

As regards small-scale family farming, some factors limit the efficiency of commodities cropping,such asthe low impact of public policies; reduced access to technology or even inadequate diffusion of knowledge; small-scale production; reduced access to basic productive inputs such as electricity, fertilizers, and seeds; and difficulty to access information and the mechanisms that reduce risks (Fan, Brzeska, Keyzer, & Halsema, 2013). In turn, inefficient small farms can compromise the family's income, increase rural poverty, and weaken rural development policies (Medina, Almeida, Novaes, Godar, & Pokorny, 2015).

To join developed productive chains,farms need speed and the intent to adopt necessary technologies for the production of commodities (Adenle, Manning, & Azadi, 2017). Moreover, the use of more capital-intensive technologies in agriculture can result in increased factor productivity. Small family farmers face difficulties because it cannot match the higher production standards set by technology in monocultures, especially soybean (Artuzo, Foguesatto, Souza, & Silva, 2018). In this way, the benefits of access to the commodity supply chain can be obtained only from overcoming its technical limitations and increasing the productivity of the factors of production to which it has access. However, the low availability of capital and access policies makes this difficult for small farms.

Some authors consider diversification of activities, and not monoculture, as a viable alternative; that is, combining high-value agricultural activities with non-agricultural activities (Di Domenico & Miller, 2012), also diversification is benefic to local biodiversity when it reduces the dependency of external input, while monoculture seeks to increase output through high input levels (pesticides, fertilizers). However, diversification as a productivity strategy is not always a viable option, because it is usually associated with the existence of sophisticated market niches, most of which are inaccessible to small producers in the Brazilian Midwest, away from the large national markets.

Reduced availability of land can be a factor leading to inefficiency in small farms commodities cultivation. For Brazil, Rada, Helfand, & Magalhães (2018) showed that large and small farms have the largest Total Factor Productivity (TFP) between 1985 and 2006, configuring a U shape, with medium farms with lower (but positive) TFP. Small farms have low use of inputs and consequently low output, while large farms have high-high relation, the authors indicated the public agricultural credit as one factor that reduced

TFP for medium farms.In terms of efficiency both groups excels in performance (Rada et al., 2018). For monocultures, as soybean production in Mato Grosso, the technological packages seems to reduce differences on TFP between farm sizes (homogenizing pressure), however efficiency within class area sizes must be also investigated.

Although soy production is associated with high productivity levelsbased on defined technological packages, Mier and Cacho (2016) identified different pathways in labor intensity, technology adoption, market and ecological practices, and social relationship in Querência (soybean producing region in Mato Grosso). As stated by the authors, there aremany practices (e.g. diversification through agriculture, forestry and livestock integration, compliance and noncompliance with environmental laws) that occur in large and small farms. This situation indicates heterogeneity in the soybean productive model even with homogenizing pressures, breaking the traditional monoculture for large scale farming versus diversification for small holders. Consequently, the technical efficiency of properties tends to diverge when analyzed in a single (financial or area size) aspect, and new variables and mechanisms present in the institutional arrangements should be observed to explain farmers decisions.

Among the policies aiming for market integration of small farms, we cite the Brazilian National Program for Production and Use of Biodiesel (PNPB), which grants tax exemptions and benefits in auctions to plants that purchase raw materials from family farmers (Rico & Sauer, 2015; Watanabe, Bijman, & Slingerland, 2012). In Brazil, soybean is the main raw material for biodiesel production, and the need for small-scale family farmers as suppliers leads to the development of mechanisms to integrate these economically efficient farmers into the supply chain (Dal Belo Leite, Justino, Silva, Florin, & van Ittersum, 2015; Leite, Bijman, Giller, & Slingerland, 2013). Institutional changes may allow more rural farmers, even the smallest ones, to access more efficient technologies and raise their productivity levels.

Although soybean can be an alternative for small-scale production, it has problems regarding sustainability. Like livestock, soybean cropping is one of the activities that mostly lead to deforestation in the Brazilian Midwest (Fearnside, 2001; Hargrave & Kis-Katos, 2013). Other environmental (soil, water, and air contamination) and social (human health) impacts arise fromthe intensive use of inputs such as fertilizers and pesticides (Brando et al., 2013). This raises the question as to whether soybean cropping by small farmers can be a sustainable production path for rural development.

Material and methods

Data.

This work focuses on the small-scale production of commodities in Northern Mato Grosso. Soybean cultivation on large farms expanded rapidly in this region over the last decade (2000's), this later expansion –when compared with other municipalities in Mato Grosso– make it possible to small farmers join in this market, while they almost disappeared in the "main core" of soybean production. The closer existence of monoculture and the pressure for income changed the reality of small-scale family farmers, including the settlements, and small farmers joined soybean through new institutions (PNPB, funding sources) and propitious infrastructure (highways, trading companies). Also, the different biome is relevant because the studied region is legally no more Cerrado (savannah), but part of Amazon, and the intense environmental law enforcement is slowing down the expansion of soybean in large areas since 2008 (federal law established fines for deforestation and increased Amazon monitoring).

To explore the mechanisms of insertion of small farmers in the soybean market, we gathered our data through a structured questionnaire containing 29 questions distributed in three blocks: (i) farmer characteristics (gender, age, marital status, and schooling); (ii) property characteristics (land tenure and

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size, economic use and activities developed, and environmental compliance); and (iii) soybean production characteristics (employees, production, productivity, price, technological and financial resources, and production costs). The information obtained relates to crop years 2013/2014 and 2014/2015.

The questionnaire was applied to a sample of 68 family farmers inthe following six municipalities: Ipiranga do Norte, Itanhangá, Nova Ubiratã, Sinop, Tabaporã, and Vera. For the criteria to classifythem as family farmers, we used the Brazilian Law 11326/2006[1](Módulo Fiscal value for Ipiranga do Norte, Itanhangá, Tabaporã = 100 hectares; Nova Ubiratã, Sinop, and Vera = 90 hectares).To compare the monetary data, we used the Brazilian General Index Price (ÍndiceGeral de Preços – IGP-DI)as deflator with December 2015 prices, and for conversion of the values to US dollars, we adopted the exchange rate used by IMEA (2015),where US$1 is equal to R$2.38 and R$2.63 for 2013/2014 and 2014/2015, respectively.

Efficiency analysis.

In order to analyze the efficiency of the different family units, we used Data Envelopment Analysis (DEA) with variable returns of scale and output orientation (output-oriented Banker, Charnes e Cooper model – BCC–), as shown in Equation 1 (Cooper, Seiford, & Tone, 2000). We choose output orientation because soy production is strongly oriented toward pre-determined inputs in technological packages provided by the main soybean trading companies. In this case, the scale of production, even in small family units, leads to positive scale impacts on the results.

$$\min z = vx_0 - v_0$$

$$\begin{aligned} &\textit{subject to } \mu y_0 = 1 \\ &vX - \mu Y - v_0 \geq 0 \\ &v \geq 0, \mu \geq 0, v_0 \textit{ free in signal} \end{aligned} \tag{1}$$

where are the coefficients associated with the inputs and outputs respectively, e are the input and output vectors of the Decision-Making Unit (DMU) under analysis respectively, and are the input and output matrices of the DMUs respectively, and is the scale factor.

In the crop year 2013/2014, we considered 63 DMUs (five farmers did not plant that year). For the crop year 2014/2015, all the 68 sampled households were taken as DMUs. As input, we adopted threevariables (this included costs expenditures, land, and labor): i) total cost of production of each crop year (TCP) —we chose this variable because production costs represent the production inputs (fertilizers, pesticides, seeds, etc.); ii) the total planted area (TPA) of soybeansin hectares (ha), representing land as a factor of production; and iii) the total number of workers (TW) involved in production, including family and non-family members.

As output, we chose two variables: i) profit from soybean (PS) production in harvest, representing the financial results of production; and ii) total soybean production (TSP) (in 60 kilogramsacs). Efficient DMUs take the technical coefficient value of 1, while all the other DMUs are inefficient.

Logit model.

A logit model tries to analyze the probability of an event's occurrence (dependent variable), where the event is a binary variable. The regressors can be either continuous or binary variables. If is the probability of occurrence of an event, the following logit model (Equation 2) represents the probability.

$$p_i = \frac{1}{1+e^{-z}} \tag{2}$$

where , and —as the vector of independent variables—and are their respective linear coefficients. The probability ratio between an event's occurrence and non-occurrence can be given as Equation 3.

$$\frac{1}{1-p_i} = e^{z} \tag{3}$$

By transforming Equation 3 with a logarithm, we obtain a linear model, represented as Equation 4, which can be estimated with the maximum likelihood method.

$$\ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + \varepsilon \tag{4}$$

Where is the random errorvector.

Our estimation model considers the efficient DMUs (with DEA equal to 1) as the dependent variable, and assume that the DEA all the inefficient DMUs are equal to zero. Since efficiency is the dependent variable in this model, we try to understand the variables that affect the probability of a family farmer being efficient.

As independent variables, we selected the following: total Rural Product Certificate[2] (RPC) (Brazilian currency in thousands)—this contract is the soybean cost's main funding source; revenue from soybean production (RTs), excluding biodiesel price bonus (Brazilian currency in thousands), obtained by multiplying the quantity produced by the average selling price; revenue from PNPB (RTbio) (Brazilian currency in thousands); the family head's experience (EXP) in soybean cropping (in years); and two binary variables, the first representing the family units possessing land in settlements (STM), and the second representing family farmers negotiating part (or total) of their anticipated production through specifics contracts(VAt), that may include future promise of commercialization with companies or financial contracts in future markets. Descriptive statistics for all variables are presented in Table 1.

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TABLE 1
Descriptive statistics for DEA and Logit variables

Variable	CropYear	
	2013/2014	2014/2015
TCP	231423,49 ± 266517,14	253477,29 ± 306114,82
TPA	108,35 ± 112,34	113,82 ± 117,94
TW	2,98 ± 1,05	2,93 ± 1,06
OS	48243,67 ± 55123,21	62051,77 ± 59415,87
TSP	277246,22 ± 307337,37	6113,98 ± 6546,47
RPC	103765,44 ± 132698,19	121742,84 ± 166293,92
RTs	5674,02 ± 6008,03	312883,53 ± 351721,66

Author's data

We submitted the model to the Pearson Chi-Square Goodness-of-Fit test, and used the Wald test (p-value) to verify the statistical significance of the estimated parameters (Hair, Black, Babin, & Anderson, 2014).

Results and discussion

In the DEA analysis, 12 DMU's proved to be efficient in 2013/2014 and 11 in 2014/2015. Efficient DMUs obtained an average profit of R$635.60 (US$ 267.06) and R$814.53 (US$309.71) per hectare in 2013/2014 and 2014/2015, respectively. The average profit –considering all DMU's–was R$48,243.67 (US$20,270.45) and R$62,051.77 (US$23,593.83) in 2013/2014 and 2014/2015, respectively (Table 2).

TABLE 2
Comparative of DEA results

Indicator	DMU's	2013/2014	2014/2015
Profit per hectare	Efficient	R$635,60 (US$267,06)	R$814,53 (US$309,71)
	Inefficient	R$388,03 (US$163,04)	R$485,98 (US$184,78)
Productivity	Efficient	55,89	59,28
	Inefficient	51,31	52,49
	Mato Grosso	51,9	51,9

Mato Grosso productivity from IMEA (2016)

The increase in profit between crops was from the more favorable climatic conditions, which raised the average productivity per hectare from 55.89 sacs/ha in 2013/2014 to 59.28 sacs/ha in 2014/2015 (for efficient DMUs). For inefficient DMUs, the average productivity was 51.31 sacs/ha in 2013/2014 and 52.49 sacs/ha in 2014/2015. The average productivity per hectare for efficient farmers was higher than inefficient farmers by 8.9% in 2013/2014 and 12.9% in 2014/2015. The Mato Grosso average was 51.9 sac/ha for both years (IMEA, 2016).

Small-scale family farmers can respond to market demand; their productivity level is similar tothe Mato Grosso average. However, even if it is economically viable (including for inefficient farmers), soybean production cannot be guaranteed as a safe activity. Family's income is subject to risks in commodity markets (demand for the commodity), climate changes–leading to lower productivity–, and market prices that are subject to variations, and all these risks impact farm profit.

In economic terms, innovations –institutional, contractual, technological– are needed to reduce the disparities between farmers by raising the production and income of inefficient DMUs.A total of 79.41% of the surveyed small farmers reported financial dependence on trading companies through the RPC. The total volume of resources funded by RPC accounted for 42.98% and 44.71% of the production costs forthe 2013/2014 and 2014/2015 crop years, respectively.

The RPC contract is based on the commercialization of anticipated production, involving the acceptance of prices and interest rates, reducing the profitability of farmers through higher costs.In practice, this contract implies that soybean farmers use standardized agricultural techniques, since trading providesnot financial resources, but inputs (fertilizers, seeds, and pesticides).Thus, alternative mechanisms are required to reduce the dependence on RPC, such as the Pronaf, which accounted for only 1.91% and 1.86% of the total production costs for 2013/2014 and 2014/2015, respectively.

Another factor compromising the efficiency of family farmers in soy production is related to labor productivity. The capital requirement for investment in machinery is high, but the most expensive machinery, harvesters, remain idle for most part of the year. The average cost of a new harvester was R $553,750.00 (US$210,551.33); this high price explains why only 11.77% of farmers bought new harvesters. The first and most-adopted option for small farmers (52.94% of cases) is to acquire used harvesters, which have an average price of R$110,101.38 (US$41,863.64).

As many as 35.29% of farmers do not have their own harvester, but engage harvesting services to harvest their produce. Payment for this service is usually a fixed percentage of the total soybean harvested (usually 6%, but it may reach 10%), in addition to monetary compensation for fuel costs. Although it reduces family income –increasing costs–, contracting soybean harvesting services is essential to small family farmers engaging in soybean production because it reduces the long-term needs of investment. Watanabe et al. (2012), in their study on Minas Gerais, Brazil, verified that soybean production by small farmers is feasible only when they share machinery.

In Mato Grosso, harvesting in small farmsis carried out by engaging harvesting servicesor by acquiring lower-priced used machines that can be used for harvesting. Harvesting services and the emerging market of used harvesters are quite functional and improve the systemic competitiveness of the soybean production chain in Mato Grosso as a whole. These market mechanisms reduce both idle machinery and investment costs. However, this is not the only reason for the efficiency of small farms. To analyze other variables, we performed a logit model analysis. The dependent variable is the efficient DMU in the DEA model. The results are shown in Table 3.

TABLE 3
Coefficients for the Logit model. Efficient DMU's as dependent variable

Variable	2013/2014	2014/2015
	Coefficient (std. error)	**Coefficient (std. error)**
Intercept	-2.21247 †	-4.18891 *
	(1.232243)	(1.534234)
RPC	-0.01643 **	-0.01182 **
	(0.008035)	(0.005852)
RTs	0.008251 **	0.005701 **
	(0.003763)	(0.002723)
EXP	-0.00217	0.035
	(0.031636)	(0.030412)
RTbio	-0.21591	-0.20629
	(0.187862)	(0.201636)
STM	0.998824	1.353329
	(1.012118)	(1.076972)
Vat	-0.50707	0.708871
	(0.827789)	(0.96268)

Author's data
* significant at 1%; ** significant at 5%; † significant at 10%.

The Pearson Chi-Square Goodness-of-Fit test (p-value = 0.3243) rejects the hypothesis that the model is not well-adjusted. Two variables impact the efficiency of small farmers in both crop years. The RPC as previously discussed was negative in the model for both crops. We converted the logit coefficients in the odds of the DMU be efficient if the independent variables changes. We can infer that for each additional R $1,000 in RPC contracted, the probability of efficiency reduces by 1.629% (coefficient -0.01643) and 1.175% (coefficient -0.01182), respectively, for the 2013/2014 and 2014/2015 crop years.

Contracts with RPC reduce the farmer's profit, making the farmer inefficient in terms of DEA analysis, but small farmers need to integrate into the soybean supply chain. The small farmers' lack of capital and low Pronaf credit volume give themno alternative to RPC as source to meet the high costs in soybean production. However, institutional changes such as more public policies and social organization (as cooperative model) can reduce the reliance on trading resources and increase the efficiency of family farmers.

Another significant variable (logit model) on the efficiency of DMUs is the total revenue from soybean production (RTs). This variable was positive and significant for the two years. By transforming the coefficient into a probability, each additional thousand units in revenue (also in Brazilian currency) from the sale of soybean increases the probability of the DMU becoming efficient at 0.828% (coefficient 0.008251) and 0.571% (coefficient 0.005701), respectively, for the 2013/2014 and 2014/2015 crop years.

To increase revenue, farmers options are limited and found some barriers: (a) increase productivity, but adopting the technological packages they are constrained by the technological limits; (b) increase prices, but this is impossible for small farmers, because prices are given by the market; and (c) increase the total cultivated area, which implies that the economies of scale in soybean production impacts also small farmers. Further, both productivity and prices are variables of risk, because they are exposed to changes in climate and market. On one hand, increasing the planted area will raise the efficiency and family income of farmers, but, on other hand,it will increase the dependency on trading companies, because large areas will require more capital and consequently more resources from RCP.

From Table 4, the total number of soybean farmers in Mato Grosso increase as the total area rises. Only 0.32% of the propertieswith less than 50 hectares cultivate soybeans. This is 18.96% for the properties with more than 1,000 hectares. Even family farms require economies of scale, and larger households show higher technical efficiency. Efficient DMUs planted on average 131.50 and 126.73 hectares, and inefficient DMUs planted on average 102.90 and 111.33 hectares, respectively, for the 2013/2014 and 2014/2015 crop years.

TABLE 4
Properties that cultivated soybean in Mato Grosso, 2006

Class of Area (hectares)	Total of properties that cultivated soybean in 2006	% of soybean farms in total farms in 2006
< 50	192	0.36%
≥ 50 and < 200	560	1.56%
≥ 200 and < 1000	1351	9.35%
≥ 1000	1658	18.96%

Brazilian Statistical Office, IBGE (2006)
Note The preliminary data from Brazilian Agricultural Census 2017 has not yet been released to determine the proportion of farms that cultivated soybean in classes of area, being 2006 the most recent year

Soybean production in Mato Grosso is based on the economies of scale. Large production areas reduce the average cost of production, because this activity has historically been restricted to large rural areas. For smaller farms, the difficulties in recovering the high investments and production costs restrict their entry to the soybean market in Mato Grosso, andhave historically driven their mode of production to diversification to integrate other food chains. However, new institutional mechanisms are slightly changing this paradigm. The smallest family farmers excel in soybean production when they adopt practices that do not require high initial investment in machinery. On the other hand, the needs of capital financing are met through contracts (RPC), reducing their efficiency.

When analyzing the institutional environment surrounding family soybean production in Mato Grosso, we need to consider the official institutional mechanisms that promote the development of family agriculture but do not yet determine efficiency. Policies as the PNPB promotes the participation of family agriculture in this sector by offering price bonuses. Pronaf credit can be used for machinery acquisition and capital needs. However, none of these variables are significant in the model.Policies showed insufficient in contributing to the development of family farmers in Mato Grosso.

Pronaf credit to meet production costs is less than 2% (for studied farms), which is almost immaterial. The limited resources of Pronaf is ineffective to face the cost structure required by soybean production (or other agricultural commodities, as maize or cotton). The institutional arrangements converge to market-oriented solutions in funding, machinery acquisition, and technology adoption, while government subsidies are mainly directed to small scale productions to solve social problems (extreme poverty, food security and regional development policies).

The sale of soybean to the biodiesel program (PNPB) is restricted, in this study occurring just to some properties located in rural settlements. The benefit of this sale[3] is still insufficient to create positive effects in terms of efficiency, although the policy is an incentive to small farmers to produce soybean. Cases of success in PNPB are more frequent in regions where the predominant cultures are the castor beans and the palm oil (César, Batalha, & Zopelari, 2013), while soybean remains the most important raw material in Biodiesel Program but do not contribute significantly to small farmers efficiency (Conejero, César, & Batista, 2017). Experience (EXP) and location of properties in settlements (STM) showed no significant effect on efficiency, confirming that soybean cropping is driven by technological determinants.

To surpass some barriers, small-scale family farmers assimilated some innovations to integrate them into the existing paradigm but did not change it. Environmental pressure questions the sustainability of this activity. Farmers in this study owned the total amount of 8911.5 hectares, whereas only 1212.5 hectares remained as native forest (more than 86% are agricultural areas). Moreover, to increase income, farmers must increase their planted area, but this could lead to new deforestation and more pesticide, fertilizer, and oil (in machines) use, and impacts over human health.

To reduce deforestation, enforcement (command and control) of government through law, regulation and supervision receives support from private initiative in soybean supply chain, the Soy Moratorium (Gibbs et al., 2015). Soybean farmers must adequate themselves to Brazilian environmental policies to be integrated in supply chain, including the small farmers. But with law compliance reduce economic efficiency, because Brazilian Forestry Code limits to 20% the conversion of forests to planted area in the Amazon. To increase economic efficiency the environment must be harmed.

Increase the potential of arable lands to achieve higher productivity levels are also relevant to reduce deforestation. With legal limitations to expand cropped arable by conversing native forests, the adequate use of production factors and inputs (Hampf et al., 2018), as well as technical and institutional solutions are necessary to reduce gaps in land use, including small farms. But the few market opportunities, technical assistance, and financial alternatives (Schneider, Coudel, Cammelli, & Sablayrolles, 2015) can lead to paths of unsustainable small scale agricultural production.

Conclusion

This paper tried to verify the efficiency of small farmers cropping soybean in Mato Grosso and the determinants of their efficiency. We found that 19% and 16% of family farmers were efficient in crop years 2013/2014 and 2014/2015, respectively. From a comparison of the results, efficient family farms have higher profitability (R$ per hectare) and productivity (sacs per hectare), but both groups can generate satisfactory family income from soybean production.

Some factors affect the odds of efficiency of small farms: (i) financing mechanisms, represented by the RPC binding the funding costs with future payment in soybean, but entailing loss in prices and payment of interest; and (ii) the dependence of economies of scale, by which larger areas are more efficient from the increase in total output and efficient use of machinery. Another strategy of small farmers is to buy used machinery (52.94%) or pay for harvesting services (35.29%) reducing their need of long-term needs of investment. We alsoshow that public policies, such as the biodiesel program and Pronaf, are inadequate or irrelevant to increase the efficiency of small-scale soybean production in Mato Grosso.

Although economically feasible, having potential to reduce poverty and giving better use of land, we cannot as of now confirm that the production of soybeans in family farms is sustainable. Questions remain to be answered on the ecological impact of the expansion of activity in the Amazon as well as the risks to human health due to the intensive use of inputs. The focus on economies of scale in small farms can lead to increased deforestation in the Amazon (adding the already existing impact of large scale farms) and determining soybean (monoculture) as development path to small farmers is risk in the long term, because climate and market changes impact in family's income.

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Notes

[1] To be legally classified as family farmers in Brazil, farmers must simultaneously have the following four criteria: (i) up to four módulos fiscais, that is, an extent of land in hectares, varying for each municipality and determined by the Brazilian National Institute of Colonization and Agrarian Reform (INCRA); (ii) rural activity as main income source, (iii) greater family labor compared to non-family labor, and (iv) family management of rural activities.

[2] Rural Product Certificateallows families to fund their costs against future payment in farm produce (soy).

[3] When selling to PNPB, farmers receive a bonus price.

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