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Technical efficiency and the scale of sisal production in the state of Bahia (Brazil)

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Abstract. The purpose of this study is to measure the technical efficiency index of the sisal local productive arrangement in Bahia. Data envelopment analysis (DEA) is used to analyze data obtained in 2015 through research conducted directly with micro, small, and medium-sized enterprises. The results show that sisal companies can reduce input costs on average by 39% with the constant return model and by 21% with the variable return model, without compromising production. It was also observed that increasing returns of scale prevail.

Keywords: Efficiency; sisal; local productive arrangement; Bahia.

Acronyms and abbreviations

APAEB	Support for Sustainable and Solidarity Development of the Sisalera Region (Apoio ao Desenvolvimento Sustentável e Solidário da Região Sisalera)
APL	Local productive arrangement (arranjo produtivo local)
BCC	Banker, Charnes and Cooper DEA model
BNDES	Banco Nacional do Desenvolvimento
CCR	Charnes, Cooper and Rhodes DEA model

CIO	Cost of international operations
CRS	Constant returns to scale
DEA	Data envelopment analysis
DMU	Decision-making unit
FAO	Food and Agriculture Organization of the United Nations
FGPP	Producer Price Guarantee Financing program (Financiamento da Garantia de Preço do Produtor)
GDP	Gross domestic product
GI	Gini Index
IBGE	Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística)
INTERSIND	Inter-municipal Union of Furniture Manufacturers of Uba and Region (Unión Intermunicipal de Industrias de Muebles de Ubá y la Región).
MTE	Ministry of Labor and Employment (Ministério do Trabalho e Emprego)
PEP	Premium for Product Outflow (Prêmio para Escoamento do Produto)
PGPM	Minimum Price Guarantee Policy (Política de Garantia de Preço Mínimo, PGPM)
SECTI	Secretariat of Science, Technology and Innovation of Bahia State (Secretaria de Ciência, Tecnologia e Inovação do Estado da Bahia)
VRS	Variable returns to scale

1. Introduction

Sisal, whose scientific name is *Agave sisalana,* is a plant native to Mexico. Its fiber is used in the production of textiles such as rope, tow, matting, yarn, and screens, among others. As a natural vegetable material, it has been classified as a "future fiber" by the United Nations Food and Agriculture Organization (FAO) because it is renewable, organic, and completely biodegradable from production through to collection of the finished product, unlike the synthetic fibers with which it competes. In addition, products made with sisal fiber – just like the juice and the mucilage obtained from other parts of the plant – are recyclable and have applications across different industries, such as automobile, fuel, and fertilizer production (Organización de las Naciones Unidas para la Alimentación y la Agricultura, FAO, 2009).

Sisal is produced in countries with hot and dry climates, such as Tanzania, Kenya, and Madagascar in Africa. The crop is also cultivated in China, but it is in Brazil that production and exportation levels are the highest, and have been since 1951, with an average annual production of 300,000 tons (Companhia Nacional de Abastecimento, CONAB, 2014). However, current Brazilian output does not even amount to half of the 700,000 or so tons per year the country produced in the 1970s, which attests to the severe downturn in the sisal market over the last four decades (Silva, 2014).

According to the Secretariat of Science, Technology and Innovation of Bahia State (Secretaria de Ciência, Tecnologia e Inovação do Estado da Bahia, SECTI), the fall in world production is directly related to its poor performance in Brazil (SECTI, 2015). In percentage terms, in 2011, Brazilian *agaveicultura* accounted for around 52% of international production, followed by Tanzania (18%); Kenya (11%); and another five countries, each with less than 10%, that together make up 19% of the total (FAO, 2015).

Brazilian sisal production is concentrated in the northeast of the country, in the states of Paraíba, Rio Grande do Norte, Ceará, and above all Bahía – more specifically, in the region officially designated the "sisal territory of identity" (Instituto Brasileiro de Geografia e Estatística, IBGE, 2015). In recognition of sisal's prominence on the world market, its industrialization in the state of Bahía, and its economic and cultural importance on a local level, in 2008 a local productive arrangement (arranjo produtivo local, APL) was established for the crop, covering the municipalities of Bahia where it is produced. In addition to processing and manufacturing companies, the APL draws together the associations, labor unions, and government agencies that support local producers with the aim of promoting the industry and regional development (Secti, 2014).

This APL is currently composed of 20 municipalities, including the four with the largest planted area and the greatest number of companies engaged in the different stages of the production process: Conceição do Coité, Retirolândia, Valente, and São Domingos. Moreover, these four municipalities are the chief production and exportation centers in the APL (Apoio ao Desenvolvimento Sustentável e Solidário da Região Sisalera, APAEB, 2014).

Historically, the state of Bahia pioneered the industry, which went on to flourish in the area; it was first designated the “sisal region,” and later the “sisal territory.” The region expanded on the strength of sisal production, and attracted people from different places over the period 1938-1942 (Conselho Regional de Desenvolvimento Rural Sustentável da Região Sisalera do Estado da Bahia, CODES, 2010).

The sisal plantations represented a means of survival for the population of the Sertão, the vast semi-arid region in northeastern Brazil. In fact, sisal contributed to the revitalization of the local economy, which had been characterized by limited production options and extreme poverty (Lima Verde, 2007).

But despite its economic and social importance, sisal production in the region has not been upgraded since it began; the machinery currently used to extract the fiber through decortication has gone unchanged for more than 50 years. As such, it is a rudimentary, low-productivity technology that poses risks to operators, and mutilation rates are high. It also entails high costs and low profitability for producers and businesses, due to suboptimal and incomplete factory usage. Furthermore, dwindling returns on *Agave sisalana* in Brazil have been aggravated by the emergence on the market of synthetic substitutes (polypropylene), which involve lower production costs and greater financial yields, but are environmentally harmful and of inferior quality (Freixo, 2010).

In an attempt to resolve the sisal crisis, Brazil’s federal and state governments introduced several public policies to stimulate production in the state of Bahía; these included the Minimum Price Guarantee Policy (Política de Garantia de Preço Mínimo, PGPM) – part of the Producer Price Guarantee Financing program (Financiamento da Garantia de Preço do Produtor, FGPP) – established in 1980 to assure financing for the stockpiling of agricultural products such as sisal. More recently, the introduction in 2008 of the sisal APL was followed two years later by the Premium for Product Outflow (Prêmio para Escoamento do Produto, PEP), which allowed the market to pay above-minimum prices (Serviço Brasileiro de Apoio às Micro e Pequenas Empresas, SEBRAE, 2009; CODES, 2010).

However, actions of this type proved insufficient as production continued to decline; the trend was exacerbated in 2012 when the region was hit by its worst drought in 50 years, causing output to plummet to 80,000 tons that year – less than half the total for 2011. By 2014, production had climbed back up to 132,078 tons, but this was still far below the country's 20-year average (IBGE, 2015).

Given this context of tumbling sisal production within the APL of Bahía, it is important to evaluate how companies perform in terms of efficiency, and to determine whether there are discrepancies on a competitive level – that is, between the different costs incurred and between the returns accrued by production companies of varying sizes. In this study, we seek to identify the best sisal-production practices that lead to superior returns for some companies in the industry. We also seek to identify the internal factors related to inefficiency on the part of companies engaged in sisal production, such as a lack of technological, financial, or management capacity; as well as factors related to the external environment, including those linked to the economic, social, and institutional agents that comprise this environment and with which the companies interact. This assessment should serve as a guide for actions to prevent or correct industry limitations.

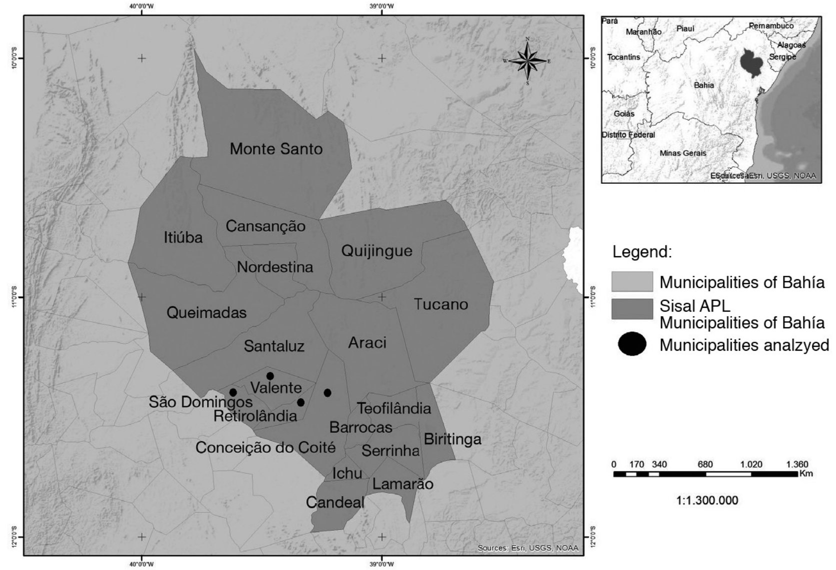
The study is divided into four sections, including this introduction. In the second section, we present information about the region's social, economic, and population spheres, among others, as well as on our data sources, sample, and analytical framework. In the third, we set out the results and the discussion. In the fourth and final section, we conclude.

2. Materials and methods

2.1 Area of study

As mentioned, the sisal APL in Bahía is made up of 20 municipalities. Our study focuses on the four municipalities with the largest number of companies engaged in sisal production: Conceição do Coité, Retirolândia, São Domingos, and Valente (see Figure 1).

Figure 1
Municipalities in the sisal APL, Bahía, 2014



Source: compiled by authors based on Companhia de Desenvolvimento Urbano do Estado da Bahia (Conder, 2014).

Situated in the semi-arid northeastern region, the sisal APL of Bahía has an area of 21,256,50 square kilometers. According to the 2010 census and demographic data from IBGE (2015), the demographics of the sisal APL municipalities are essentially rural: of a total population of 582,331 people, 333,113 – or 57% – live in rural areas. It is worth noting that Conceição do Coité is the municipality with the largest urban population, accounting for 14.6% of its 62,040 residents. The sisal APL also contains around 400,000 farmers, 2,482 settled families, two Quilombo communities, as well as indigenous lands (CONAB, 2013).

As far as land distribution in Bahía's sisal territory is concerned, and looking again at the APL municipalities, the Gini index (GI)[1] points to a medium-strong land concentration (GI between 0.501 and 0.700) in 1996. In contrast, by 2006 the concentration was classed as weak to medium (GI between 0.251 and 0.500). Indeed, over the ten-year period analyzed, Bahía's

1 The GI is expressed using a scale of 0 to 1, or in percentage terms. A GI equal to 0 denotes a situation of completely equal, or perfect, land distribution; while a GI equal to 1 indicates a situation of extremely unequal land distribution, with maximum land concentration (Santos, Gomes, Braga & Pires, 2014).

sisal territory was the only part of the state in which the land concentration decreased (Santos, Gomes, Braga & Pires, 2014).

As to the relative distances in the territory, the municipality of Conceição do Coité is 207 km from Salvador, the capital of the state of Bahía; while Retirolândia is 206 km from the capital; São Domingos, 245 km; and Valente, 237 km. All of the abovementioned municipalities are connected by the BA/409 highway. Meanwhile, Conceição do Coité is a local center of influence for Valente, which in turn is a center of influence for São Domingos. Retirolândia's only local center of influence, Feira de Santana, is located outside the APL. In general terms, the city of Salvador is the common center of influence for the four municipalities (Silva, 2012).

As to employment and income, according to 2010 data from the Ministry of Labor and Employment (MTE), Conceição do Coité is the municipality with the second-highest number of formal jobs in the region, behind only Serrinha. Across all sisal APL municipalities, most formal employment is in public administration (56.9%), followed by commerce (14.2%), and the processing industry (13.8%). This latter industry accounts for more than 10% of all formal employment in each of the municipalities of Conceição do Coité, São Domingos, Retirolândia, and Valente. On the other hand, neither agriculture nor public administration account for a large proportion of employment (Brasil. Ministério do Trabalho e Emprego, MTE, 2010).

Moving on to the economy, the GDP of the entire sisal APL in 2010 was 2,658.77 million reales; this comprised just 1.72% of the statewide total, in 13th place out of the 26 so-called territories of identity. The human development index in the territory is 0.60. Serrinha has the highest GDP of the APL municipalities (at 8,332 million reales), followed by Conceição do Coité (5,684 million reales) and Valente (2,840 million reales) (IBGE, 2013).

The GDP distribution by economic activity in these municipalities is as follows. Conceição do Coité: 8% agriculture, 16.8% manufacturing, 43.7% services, and 31.5% public administration; Retirolândia: 16.2% agriculture; 12.3% manufacturing; 35.2% services; and 36.3% public administration; São Domingos: 27.1% agriculture; 9% manufacturing; 27.7% services; and 36.2% public administration; finally, Valente: 16.4% agriculture; 15.2% manufacturing; 36.1% services; and 32.2% public administration (Bahía. Secretaria da Educação, 2015). Overall, public administration accounts for the largest share of GDP in the sisal ADP municipalities. Moreover, economic activity in these municipalities revolves around agriculture, industry, and mining. Agriculture is largely oriented towards the production of sisal and subsistence crops, as well as goat, sheep, and cattle farming (Ferreira Cunha, De Oliveira Neto, Bezerra Sá, Giongo & Lopes da Silva, 2014).

Given its location in the semi-arid northeast, during wet years, around 70% of the region's rainfall tends to occur in the three months of winter. Outside these rainy periods, rainfall averages just 200 to 400 mm per year, making virtually all rainfed agriculture impossible; some dry periods have been known to last between two and five years. The sources of surface water available to the municipalities in the north of the sisal territory are the basins of the Grande Bueno, Pau a Pique, Riacho da Jurema, and Riacho rivers, in addition to several small dams built by the government (CODES, 2010).

Vegetation in the territory is indicative of the complex biodiversity of the semiarid region. Most of the land in the main biome, the *caatinga*, is covered in trees and shrubs, while other plants have adapted morphologically and physiologically to withstand lengthy periods of drought. In most of the region, the soil pertains to the planosol, neosol, vertisol, and lithosol classifications – that is, predominantly shallow and low in basic nutrients but with large quantities of calcium and potassium, making it suitable for a wide variety of vegetation, such as cotton, silk, and especially sisal (CODES, 2010).

2.2 Sample collection and data sources

This study is based on primary data from the field of research. We collected this data from questionnaires distributed to a sample of the businesspeople who run the *batedeira* and the factories in the sisal APL of Bahia, and who agreed to take part in this research. A method of classifying the companies is required to better understand and elucidate the data obtained; we opted for the size-based criteria proposed by the Banco Nacional do Desenvolvimento (BNDES), which groups firms by gross annual revenues.

Table 1
Classification of companies by gross annual revenues (in reales)

Classification	Gross annual income
Microenterprise	Lower than or equal to 2.4 million
Small enterprise	Greater than 2.4m and less than or equal to 16 million
Medium-sized enterprise	Greater than 16m and less than or equal to 90 million
Medium to large enterprise	Greater than 90m and less than or equal to 300 million
Large enterprise	Greater than 300 million

Source: Banco Nacional do Desenvolvimento, BNDES (2015).

To obtain information from a representative sample of all agents along the sisal production chain, we interviewed owners – both artisans and entrepreneurs – of enterprises along the sisal production chain operating in the APL.

SEBRAE (2009) data shows that there were 58 sisal producers in the state that year, though more recent information from the APAEB (2014) indicates that the number has since fallen to 30, of which 11 are processors and 19 are factories. These companies are clustered in municipalities that are geographically close to one another, and especially in the capital, Salvador. According to the APAEB data there are five companies in Valente, 12 in Conceição do Coité, six in São Domingos, two in Retirolândia, three in Santaluz, and two in Barrocas. Given the large size of the territory, we chose to limit the geographical scope of the study to ensure greater accuracy and effectiveness. Thus, our sample includes the municipalities of Conceição do Coité, Retirolândia, São Domingos, and Valente. In 2014, these four municipalities accounted for 83% of all active companies and 46% of production in the sisal APL, with a total output of 35.88 million tons.

That is, these municipalities comprise the largest number of companies, as well as the largest area. Moreover, they are at the forefront of Brazilian sisal exports and thus constitute the main production centers in the APL (IBGE, 2015; APAEB, 2014).

We interviewed a total of 25 companies from these four municipalities. Eight of these companies were classified as microenterprises, ten as small, and seven as medium-sized.

2.3 References and technical efficiency analysis

In this study, we used the non-parametric data envelopment analysis (DEA) method to measure the technical efficiency and the efficiency of scale of sisal companies in the Bahía APL.

The DEA method is based on the proposal by Farrell (1957), subsequently disseminated by Charnes, Cooper & Rhodes (1978), which includes multiple inputs and outputs. This technique involves the construction of a frontier of efficiency to analyze units of production (decision-making units, DMUs), with multiple inputs and outputs.

There are three main stages in the implementation of DEA models (Golany & Roll, 1989):

- Stage 1. The definition and selection of the DMUs to include in the analysis. In this study, the decision-making units are the selected sisal companies in Bahía. According to Charnes, Cooper, Lewin & Seiford (1994), for a DMU to be efficient, no output can be subject to an increase in production without increasing the use of materials (or decreasing production) of another output; and no input can be reduced without having to decrease production of another output.

- Stage 2. Selection of relevant and appropriate variables (inputs and outputs) to establish the relative effectiveness of the selected DMUs. In this study, we employ three input variables related to the annual cost of labor, annual cost of sisal, and other costs involved in sisal production; and an output variable related to the value of sisal production in 2015.
- Stage 3. Application of DEA models. In this stage, the model needs to be input or output oriented.

The original version of the DEA model was developed by Charnes *et al.* (1978) and is known to the literature as the CCR model after the initials of its three creators. It assumes constant returns to scale (CRS), and is thus also known as the CRS model.

According to Coelli, Rao, O'Donnell & Battese (2005), the DEA model with constant returns to scale can be represented by:

$$Min_{\theta,\lambda}\ \ \theta,\ \ sujeto\ \ a\text{:}\ \ -y_i + Y\lambda \geq 0,\ \ \ \theta x_i - X\lambda \geq 0\ \ \ e\ \ \ \lambda \geq 0 \quad (1)$$

where θ is the efficiency score of a given DMU; y is the DMU output; x is the input; X is the input matrix ($n\ x\ k$); Y is the output matrix ($n\ x\ m$); and λ is the vector of constants that multiplies the matrix of inputs and outputs.

An efficiency score equal to the unit means that the DMU is considered efficient. In the case of the input, a score of less than 1 indicates that production can be maintained with the use of a smaller number of inputs y for the output; while a score of more than 1 indicates that production can be increased with the same level of consumption. In 1984, the BCC model was created, again named after the initials of its proponents: Banker, Charnes and Cooper (1984). This model considers variable returns that can recognize increasing or decreasing returns to scale in the frontier of efficiency; it is also known as the variable returns to scale (VRS) model. Along these lines, Gomes & Baptista (2004) state that coefficients of technical efficiency should be compared in the model with non-increasing returns and in the variable return model in order to measure the scale of a given DMU. If these values are different, the DMU has increasing returns to scale; and if they are equal, it has decreasing returns to scale.

In this case, according to Coelli *et al.* (2005), the DEA with variable returns can be expressed by:

$$Min_{\theta,\lambda}\ \ \theta,\ \ subject\ \ to\text{:}\ \ -y_i + Y\lambda \geq 0,\ \ \ \theta x_i - X\lambda \geq 0,\ \ \ N_1{}'\lambda = 1\ \ \ e\ \ \ \lambda \geq 0 \quad (2)$$

where N_1 is a vector (*N x 1)* of the unit digits.

For a DMU to be efficient in the model with constant returns, it must necessarily be efficient in the model with variable returns, but the reverse is not the case (Coelli *et al.*, 2005). If the technical efficiency score is different in the two models, it means that the DMU considered contains inefficiency of scale.

In this study, we present the indices of efficiency of these two models using the input guide, which aims to reduce the inputs without changing the output level.

It is worth noting that according to Gomes & Baptista (2004), the presence of a single observation with outliers in the sample will influence all efficiency scores and compromise the results. Therefore, before determining the measures of efficiency, we applied the extreme value identification test proposed by Sousa, Cribari-Neto & Stosic (2005), which is based on the "jackstrap" method – a combination of the jackknife test and the bootstrap resampling method. *A priori*, we used a randomly selected L[2] DMU known as "bubbles." From the literature, we determined that bubbles accounted for 20% of the sample of companies surveyed, corresponding to five DMUs, and the bootstrap technique employed a resample of 2,000.

Then, we constructed a measure of leverage to measure the influence of the DMUs on one another; those with a large influence were excluded from the analysis so as not to compromise the DEA estimations. According to Sousa *et al.* (2005), the suggested cut-off point should be based on the Heaviside function, which factors in the data obtained from leverages and the number of DMU K[3] using the following specifications:

$$P(\tilde{l}_k) = 1, se\,\tilde{l}_k \le \tilde{l}\log K \text{ and } P(\tilde{l}_k) = 0, se\,\tilde{l}_k > \tilde{l}\log K \quad (3)$$

where $P(\tilde{l}_k)$ is the probability that the k-th DMU with an average leverage is not an outlier, and that the cut-off point corresponds to the output of the overall average leverage and the logarithm of *K*.

At present, the DEA method is widely used and has a variety of practical applications. However, only a few studies have employed this method to measure the efficiency of the forestry sector (Macpherson, Lentini, Carter & Baitz, 2009; Santos, 2011; Pimentel, 2014).

Macpherson *et al.* (2009) used the DEA to characterize the technical efficiency of sawmills located on different timber frontiers in the Brazilian Amazon. Using data from 291 sawmills, they analyzed variations in technical efficiency by comparing levels thereof on four timber frontiers. The results show that the levels of efficiency vary greatly from one company to another, and those with larger-scale production tend to exhibit greater efficiency.

2 Randomly selected subset of the number of observations.
3 Total number of observations.

In addition, they found that the companies located on the old and new frontiers are statistically more efficient than those located in the estuary or in the intermediate frontiers. The results also show that industrial earnings on the old timber frontiers can be transferred to new frontiers when the companies migrate to new areas, largely in search of raw materials, especially high-value timber.

In his study, Santos (2011) proposed a search for targets in stages, with intermediate targets in "isoefficiency layers," so that the forest-based product manufacturing sector in each state can gradually attain a superior level of technical efficiency. To this end, he used data from the Annual Industrial Survey (Pesquisa Industrial Anual, PIA) published by the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística, IBGE). In his application of the DEA, he used the net revenue of the industry as an output; and the total cost of industrial operations (CIO) and wages in the sector as inputs. Of the 14 states analyzed, Espíritu Santo was found to be most efficient, and Río de Janeiro the most inefficient. Another 12 states were technically inefficient, and it was recommended that three, in the short term, pursue layer 1; three, layer 2; two, layer 3; and three, layer 4. The CIO was found to be the main cause of technical inefficiency in Brazil.

Ervilha, Gomes & Alves (2013) attempted to assess companies with relative production efficiencies in the APL of Ubá, Minas Gerais, and to identify their respective benchmarks with a view to the elimination of any deficiencies found. To measure efficiency, they used the DEA with variable returns and input orientation. The results were filtered using the discriminant analysis method, and the data were collected through questionnaires completed by 51 member companies of the Inter-Municipal Union of Furniture Manufacturers of Uba and the Region (Unión Intermunicipal de Industrias de Muebles de Ubá y la Región, INTERSIND). Among other things, the results highlight the role of investment in training, education, and new technologies as part of improvements in efficiency and competitiveness in the furniture APL.

For its part, the objective of the study by Pimentel (2014) was to explain the factors responsible for countries' actions in relation to greenhouse gas emissions. The study employed a quantitative efficiency analysis method, supported by the DEA. It featured an output-oriented BCC model, and variables of scale across countries (technology and energy sources) as inputs. The results show that the pattern of consumption has effects on return; that changes in the energy matrix (greater consumption of less polluting sources) influence return relative to other countries; and that changes in land use are important factors in a country's performance, both in its own terms and in comparison with other countries, over time.

3. Results and discussion

3.1 Characterization of sisal companies in Bahía

Before estimating the efficiency indices, we applied the jackstrap method to identify whether there are outliers among the sisal companies visited, given that the survey included companies of different sizes (micro, small, and medium-sized). Based on the cut-off point of 0.07 and by way of the Heaviside function, we detected six outliers – that, is six sisal companies that exceeded the cut-off point. We removed them from the study so as not to compromise the analysis since, as we noted above, the DEA method is very sensitive to the presence of outliers. Therefore, our estimation of indices of efficiency included 19 sisal companies.

Table 2 shows the composition of the original sample of sisal companies, discarding outliers. As can be seen with respect to company type,[4] of the six outliers, three are classified as processors, one as a *batedeira*, and two as factories. As to size, the influential companies with values above the cut-off point of 0.07 include one micro-enterprise, three small enterprises, and two medium-sized enterprises. As to municipalities, the two Retirolândia-based companies had leverage below the cut-off point and so remained in the analysis; while one of the Valente-based companies, four from Conceição do Coité; and one from São Domingos had leverage above the cut-off point and so were excluded from the analysis.

4 To aid understanding we define these companies as follows:
- Concessionaires: engage in the resale of products made by local cooperatives and associations, generally handicrafts such as handbags, rugs, kitchenware, and lamps, from sisal fiber.
- *Batedeiras*: informal businesses whose activity corresponds to the second stage of the sisal production chain. Their owners receive the fibers directly from the producers, feed them into a brushing machine and then a baler, before packaging and binding them for resale to processors or factories.
- Processors: located in the middle of the production chain; they process the extracted fiber and resell their products to local and international factories that make ropes, carpeting, and textiles, among other goods, and to other industries, such as the automobile sector.
- Factories: located at the end of the sisal production chain; they produce textiles using processed fibers, both as intermediate goods for other industries and for direct consumption on the domestic and foreign markets in the form of rope, carpeting, yarn, etc.

Table 2
Composition of the sample of sisal companies, Bahía, 2015

Description		Number of companies in the original sample	Number of companies in the current sample, excluding outliers
Company type	Concessionaire	2	2
	Processor	9	6
	Batedeira	6	5
	Factory	8	6
Total		25	19
Size	Micro	8	7
	Small	10	7
	Medium-sized	7	5
Total		25	19
Municipality	Retirolândia	2	2
	Valente	5	4
	Conceição do Coité	12	8
	São Domingos	6	5
Total		25	19

Source: compiled by authors based on data from the survey.[5]

The primary descriptive statistics of the variables used in the estimation of the sisal production frontier are presented in Table 3. As can be observed, the surveyed sisal companies reported a high level of variability across all the variables considered, and more significant heterogeneity in the costs incurred in producing sisal and other products in which sisal is a raw material. The differences between the company sizes remain even after disregarding the most divergent companies, which can give rise to very different costs; for example, in the category of "other costs," the lowest annual cost recorded was 420 reales, incurred by a micro-sized concessionaire, or cooperative, while the highest was 4,390,000 reales, by a medium-sized factory.

5 Applies to all subsequent tables.

Table 3
Descriptive statistic of the variables used to determine the indices of technical efficiency of sisal companies under the DEA model, Bahía, 2015 (In reales)

Statistic	Production value	Labor costs	Raw material costs (sisal)	Other costs(1)
Minimum	14,000.00	10,800.00	0.00	420.00
Average	15,991,326.32	689,511.37	7,665,510.53	372,030.95
Maximum	84,000,000.00	3,315,000.00	74,400,000.00	4,390,000.00
Standard deviation	23,931,954.54	1,018,491.69	18,420,322.40	1,049,354.58
Coefficient of variation (%)	149.66	147.71	240.30	282.06

Note
(1) Refers to the annual cost of association membership, machinery and equipment maintenance, and electricity.

Here, the other costs incurred in sisal production are those of association, cooperative, or union membership, as well as electricity, maintenance, and other inputs. Those concessionaires (cooperatives) wholly engaged in manual production without any machinery or equipment do not incur any maintenance costs; in these cases, the electricity costs refer to consumption in the small huts where members meet.

Conversely, medium-sized companies work with large machines and equipment that imply high maintenance and electricity costs. In addition, cooperatives have no costs associated with other production inputs, while medium-sized companies use inputs such as solvents, emulsion, pigments, diesel, and additives, both for fiber and textile production.

Raw material costs also vary; raw, extracted, or processed fiber can be used, each with a different price, depending on the type of activity engaged in. In this category, the average expenditure on raw materials for sisal production is 7,665,510.53 reales, but one micro-enterprise, a sisal concessionaire, did not incur any raw material costs whatsoever. This is a function of the cooperative structure in which artisans are responsible for their own raw materials, generally from personal sisal plantations. In this case, the company's role is to train the sisal artisans and resell their products; in return, they obtain a significant portion of the proceeds from sales, which are used to cover site maintenance and to pay the three employees: two running the business and one in charge of sales.

Of the three cost components evaluated, labor has the lowest heterogeneity, captured by the coefficient of variation, although it is still quite high. This distinction is even more marked when comparing the magnitudes of the minimum and maximum values, respectively, of a micro-sized concessionaire and a medium-sized factory. On average, sisal companies in Bahía spend 689,511.37 reales on the labor factor. Once again, these results reflect the considerable variation in the activities in which the different companies engage. While micro-sized concessionaires have a labor cost equivalent to the earnings of just three employees, the labor cost of medium-sized companies corresponds to the payment of 300 employees.

As to the value of sisal production, the minimum annual amount of 14,000 reales is related to the type and level of production of those companies in the first stage of the sisal production chain, such as *batedeiras*, while the highest figure of 84,000,000 reales corresponds to the sale of finished sisal products and manufactured goods. On average, the sisal companies have a production value of 15,991,326.32 reales.

3.2 Analysis of technical efficiency and the scale of sisal production in Bahía

Reflecting the high heterogeneity of the variables used in the DEA model presented in Table 3, the coefficient of variation in Table 4 shows that the technical efficiency and efficiency of scale indices are quite dissimilar, while the CRS model had the highest dispersion value. On average, it can be inferred from the technical efficiency score of the CRS model that sisal companies could reduce their input usage by 39% without compromising production. In the VRS model, usage of these factors should be reduced by 21% if inefficient sisal companies are to be part of the variable returns frontier. As to efficiency of scale, it can be seen that sisal companies can increase their production scales by 23%, on average.

In the DEA model, as noted by Souza, Braga & Ferreira (2011), any value that does not record maximum efficiency can be interpreted as inefficient since the method is deterministic. Thus, it can give rise to erroneous classifications. For these authors, one way of resolving a restriction of this type is to adopt the bootstrap technique. This statistical procedure involved a resampling process of 1,000 interactions, and the confidence interval results for the efficiency averages are presented in Table 4.

Table 4
Descriptive statistics and confidence intervals of the technical efficiency scores under CRS, VRS, and indices of efficiency of scale for sisal companies, Bahía, 2015

Descriptive statistic	Technical efficiency		Efficiency of scale
	CRS	VRS	
Minimum	0.04	0.23	0.04
Maximum	1.00	1.00	1.00
Standard deviation	0.37	0.30	0.32
Coefficient of variation (%)	60.49	37.75	41.17
Observed average	0.61	0.79	0.77
Average confidence interval (95%)			
Minimum	0.44	0.65	0.62
Maximum	0.77	0.91	0.89

Table 5 presents the sample distribution of sisal companies in the categories of technical efficiency and efficiency of scale, under the input-orientation. As can be seen, under the CRS assumption, seven of the 19 sisal companies analyzed – 36.84% of the total – had an efficiency score of 0.4, while four exhibited a level of efficiency below 0.2. In contrast, six proved to be totally efficient, serving as a benchmark for other companies.

Table 5
Absolute and relative distributions of sisal companies under the measurement categories of technical efficiency and efficiency of scale, Bahía, 2015

Efficiency measurements	Technical efficiency				Efficiency of scale	
	CRS		VRS			
	No. of* companies	%	No. of companies	%	No. of companies	%
< 0.2	4	21.05	0	0.0	1	5.26
0.2 – 0.4	3	15.79	3	15.79	3	15.79
0.4 – 0.6	2	10.53	3	15.79	1	5.26
0.6 – 0.8	1	5.26	1	5.26	0	0.00
0.8 – 1.0	3	15.79	2	10.53	8	42.11
1.0	6	31.58	10	52.63	6	31.58
Total	19	100.00	19	100.00	19	100.00

*In this and all subsequent tables in which it appears, "No." means "number of companies."

By incorporating a restriction of convexity, it can be seen that six companies (31.58%) had indices of technical efficiency below 0.6. In turn, ten sisal companies obtained maximum efficiency – that is, four more companies than under the CRS model are on the variable returns frontier, but not on the constant returns frontier. In other words, it can be inferred that the companies have no problems with the excessive assignment of factors of production, but do have problems related to an inadequate scale of production.

The findings also show that just 31.58% of sisal companies achieved the maximum score for efficiency of scale without presenting any problems related to scale of production. This means that almost 71% of sisal companies were subject to inefficiency of scale, which makes it important to identify exactly what this inefficiency entails.

The absolute and relative distributions of Bahía sisal companies by types of returns to scale are shown in Table 6. There is a higher proportion of increasing returns to scale, which indicates that the rise in sisal production can be attributed to falling average costs – that is, production increased in greater proportion than the inputs.

Table 6
Absolute and relative distributions of sisal companies as types of returns to scale, Bahía, 2015

Type of returns to scale	No.	%
Increasing	9	47.37
Constant	6	31.58
Decreasing	4	21.05
Total	19	100.00

Tables 7, 8, and 9 show the efficiency distribution of sisal companies in Bahía by company type, size, and location, respectively, under the two forms of measurement: the model with constant returns to scale, and that with variable returns to scale.

Table 7 shows that under the CRS model, one of the two sisal concessionaires has the lowest efficiency score, while the other has the maximum. For the other company types, no particular behavior is concentrated in a given classification of efficiency. This lack of commonality in terms of efficiency is also true under the VRS model, except for concessionaires, as both companies of this type in the sample proved to be completely efficient.

Table 7
Relative distribution of sisal companies by company type and form of technical efficiency measurement, Bahía, 2015

Efficiency measurements	Concessionaire		Processor		*Batedeira*		Factory	
	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS
< 0.2	50.00	0.00	16.67	0.00	20.00	0.00	16.67	0.00
0.2 – 0.4	0.00	0.00	0.00	16.67	20.00	20.00	33.33	16.67
0.4 – 0.6	0.00	0.00	33.33	33.33	0.00	20.00	0.00	0.00
0.6 – 0.8	0.00	0.00	0.00	0.00	0.00	0.00	16.67	16.67
0.8 – 1.0	0.00	0.00	16.67	16.67	40.00	20.00	0.00	0.00
1.0	50.00	100.00	33.33	33.33	20.00	40.00	33.33	66.67
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

From the data shown in Table 8, it cannot be inferred that the highest level of efficiency is associated with the largest companies, since the micro-enterprises surveyed were found to assign their factors more efficiently. Under the CRS and VRS models, 57.14% and 71.43% of companies obtained the maximum score for efficiency, respectively. In contrast, 80% of medium-sized companies had an efficiency score below 0.4 under CRS, versus 40% in the VRS model.

Table 8
Relative distribution of sisal companies by company size and form of technical efficiency measurement, Bahía, 2015

Efficiency measurements	Microenterprise		Small enterprise		Average enterprise	
	CRS	VRS	CRS	VRS	CRS	VRS
< 0.2	28.57	0.00	0.00	0.00	40.00	0.00
0.2 – 0.4	0.00	0.00	14.29	14.29	40.00	40.00
0.4 – 0.6	0.00	14.29	28.57	28.57	0.00	0.00
0.6 – 0.8	0.00	0.00	14.29	14.29	0.00	0.00
0.8 – 1.0	14.29	14.29	28.57	14.29	0.00	20.00
1.0	57.14	71.43	14.29	28.57	20.00	40.00
Total	100.00	100.00	100.00	100.00	100.00	100.00

As regards company location, Table 9 shows that the sisal companies based in São Domingos obtained the lowest scores for technical efficiency – 80% were below 0.6. In the municipality of Valente, a majority of the sisal companies surveyed had technical efficiency scores of at least 0.8 under the CRS model, and all were within the range under the VRS model. In Retirolândia, none of the sisal companies surveyed had a technical efficiency score below 0.6, while those from Conceição de Coité were distributed across different technical efficiency classifications.

Table 9
Relative distribution of sisal companies by location and form of technical efficiency measurement, Bahía, 2015

Efficiency measurements	Retirolândia		Valente		Conceiçãodo Coité		São Domingos	
	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS
< 0.2	0.00	0.00	25.00	0.00	25.00	0.00	20.00	0.00
0.2 – 0.4	0.00	0.00	0.00	0.00	25.00	12.50	20.00	40.00
0.4 – 0.6	0.00	0.00	0.00	0.00	0.00	12.50	40.00	40.00
0.6 – 0.8	50.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00
0.8 – 1.0	0.00	0.00	50.00	50.00	0.00	0.00	20.00	0.00
1.0	50.00	50.00	25.00	50.00	50.00	75.00	0.00	20.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 10 shows the sisal companies with an efficiency score equal to 1 under the CRS model – that is, those that use the appropriate materials and/or inputs and scale of production; these companies serve as a benchmark for other sisal companies. Overall, one Conceição do Coité-based micro-enterprise in the processor category stands out as a benchmark for less efficient companies, while two other micro-enterprises – a concessionaire in Valente and a processor in Conceição do Coité – achieve maximum efficiency but nonetheless do not serve as benchmarks for inefficient companies.

Table 10
Times that each efficient sisal company serves as a benchmark for inefficient sisal companies, Bahía, 2015

Efficient sisal companies	Number of times as benchmark
Medium-sized factory, Retirolândia	2
Small factory, Conceição do Coité	7
Micro processor, Conceição do Coité	10
Micro concessionaire, Valente	0
Micro processor, Conceição do Coité	0
Micro *batedeira*, Conceição do Coité	4

Table 11 shows that seven of the 19 companies surveyed experienced problems with the use of sisal as a raw material. This may be directly related to low productivity associated with the machinery and equipment used, which have not been upgraded in the industry's 50-year existence.

Table 11
Absolute and relative distributions of sisal companies with surplus production factors, Bahía, 2015

Factors of production	No.	%
Labor costs	6	31.58
Gross sisal costs	7	36.84
Other costs	3	15.79

The use of labor was also inefficient for six of the companies. That is, close to 32% and 37%, respectively, of the companies were not using the factors cited in Table 11 correctly. There are a number of possible reasons for this; first, many of the company employees have not completed primary education, and practical and cultural knowledge of the activity in the region is instead held as the most relevant qualification. Second, company owners and managers lack the skills for effective management of business resources since many of them, like their employees, are only educated to the primary or secondary level; moreover, because profit levels tend to be low, companies often lack the financial means of hiring qualified personnel. This is also a function of the lack of technological innovation.

4. Conclusions

The results obtained through the DEA method show that sisal companies based in the Bahía sisal APL can reduce their usage of inputs by 39% or 21%, respectively, without compromising production, under the CRS and VRS models.

We sought to explore the factors behind the scale of production inefficiencies faced by some of the companies, and found that almost half of those surveyed have increasing returns to scale. We also found that there is no common standard of efficiency across the different company types, and that the highest level of efficiency is not correlated with the largest company size. Of the four municipalities analyzed in the sisal APL, we found that those based in São Domingos had the lowest scores for technical efficiency. This is related to the fact that São Domingos hosts many *batedeiras,* whose operations are more rudimentary than those of the processors or factories.

In addition, the results show that six of the 19 companies achieved maximum efficiency in the model with constant returns, and four served as benchmarks for inefficient companies. This result reflects the fact that the factories purchase sisal fiber, whether in brushed or processed form, at very low prices due to their proximity to local producers and processors operating in the APL; thus, they make profits on the sale of finished products, usually abroad, that far outstrip their costs and expenses. It might be worthwhile for micro- and small enterprises, especially *batedeiras* and processors, to increase their production capacity or graduate to a more advanced stage in the production chain, and thereby improve their financial performance in the short to medium term by selling the finished product.

Finally, failure by sisal companies to employ the factors of production correctly is related to a lack of appropriate technology in the production process and to a lack of knowledge, resources, and management capacity on the part of the owners.

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