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VIABILIDADE ENERGÉTICA DA PRODUÇÃO DO TIFTON 85 NA REGIÃO DA BAIXADA FLUMINENSE

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RESUMO: A atividade agrícola do estado do Rio de Janeiro está diretamente pautada na produção de bovinos de leite e corte. Diante do cenário de grande necessidade da produção de alimentos de qualidade para esses rebanhos, a produção do Tifton 85 tem se intensificado. A realização da análise energética do sistema de produção por meio da realização do balanço de energia permite identificar as possíveis entradas e saídas de energia no processo de produção, resultando no saldo energético final do processo produtivo. O objetivo do trabalho foi avaliar os fluxos de energia e a viabilidade energética do processo de produção do Tifton 85 na região da baixada fluminense, no estado do Rio de Janeiro durante a safra 2020. Realizou-se o estudo da eficiência energética e o balanço energético, quantificando o coeficiente energético de cada componente envolvido no processo de produção e determinando as matrizes de consumo energético nas formas de insumos, mão-de-obra, equipamentos, produção e restos culturais. Com base nos resultados é possível afirmar que a capacidade de conversão do sistema se mostrou adequada mesmo com a grande quantidade de energia direta empregada, apresentando eficiencia energética positiva e indicando o potencial da produção do Tifton 85 na região da Baixada Fluminense.

Palavras-chaves: alimentação animal, balanço de energia, energia na agricultura, forragicultura.

ENERGY VIABILITY OF TIFTON 85 PRODUCTION IN BAIXADA FLUMINENSE

ABSTRACT: The agricultural activity of the state of Rio de Janeiro is solely based on the production of dairy farming and beef cattle. Faced with a scenario of great need to produce quality food for these herds, the production of Tifton 85 has intensified. Performing the energy analysis of the production system by performing the energy balance allows identifying energy inputs and outputs in the production process, resulting in the final energy balance of the production process. The objective of the work was to evaluate the energy flows and energy viability of the Tifton 85 production process in the Baixada Fluminense region, in the state of Rio de Janeiro, during the year 2020. The study of energy efficiency and energy balance were carried out, quantifying the energy coefficient of each component involved in the production process and determining the energy consumption matrices in the forms of inputs, labor, equipment, production and cultural remains. Based on the results obtained, it is possible to state that the conversion capacity of the system proved to be adequate even with the large amount of direct energy used, presenting positive energy efficiency, and indicating the potential to produce Tifton 85 in the Baixada Fluminense region.

Keywords: animal feed, energy balance, energy in agriculture, forage.

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1 INTRODUCTION

Conventionally, the efficiency of agricultural production systems is analyzed using two distinct approaches, the productive approach, which refers to the analysis of the physical production obtained, and the economic approach, which is related to the production costs and profitability of the system (FRIGO *et al.*, 2011). On the other hand, agriculture is currently increasingly seeking the rational use of the resources used, and determining the energy efficiency of these processes is an important parameter to be considered in crop production systems in general, as it is linked to the use and consequent availability of energy and its viability (ANDREA *et al.*, 2014; GUARESCHI *et al.*, 2020).

In this way, the viability of a production system depends on the realization of the energy balance, which is based on the physical principle of energy conservation, also known as the first principle of thermodynamics; that is, the variation in energy in a process can be explained by the energy balance, that is, energy inputs and outputs (VELOSO *et al.*, 2012).

Carrying out the energy balance aims mainly to establish energy flows, identifying the total energy demand necessary to produce or process a unit of a given product. Given the need for more sustainable agricultural systems, achieving an energy balance is an important tool for helping to determine new techniques or agricultural production systems, providing energy savings and increased efficiency, and reducing costs mainly in systems with a greater amount of technology used (MULLER *et al.*, 2017).

In view of the above, the identification of energy bottlenecks in relation to the use of conventional sources allows us to intensify the search for more efficient sources and their rational use, especially with regard to reducing the use of fossil fuels, fertilizers, pesticides, and irrigation (CHEN *et al.).* , 2018).

The direct energy used in a production process includes not only the fossil fuel used but also other forms of energy derived from petroleum, such as those contained in lubricants and fertilizers (RIQUETTI; BENEZ, SILVA, 2012). However, a complete study of the energy invested must also take into account energies of biological origin, such as human work and that contained in seeds. The indirect energy used in agriculture is that used through the use of machines and implements necessary for production. In this process, all inputs used and produced are quantified and transformed into energy units according to the calorific value of each input.

When evaluating the agricultural sector in the state of Rio de Janeiro, a large part of the production is based on beef and dairy farming, accounting for up to 39% of the gross revenue of agricultural production in the state (EMATER, 2020). The genus Cynodon is frequently used in pasture production systems due to its production characteristics and adaptation to tropical and subtropical conditions, and Tifton 85, a grass that stands out especially for presenting several favorable characteristics, such as high dry matter production, leaf ratio/stem and nutritional value (SILVA *et al*., 2017).

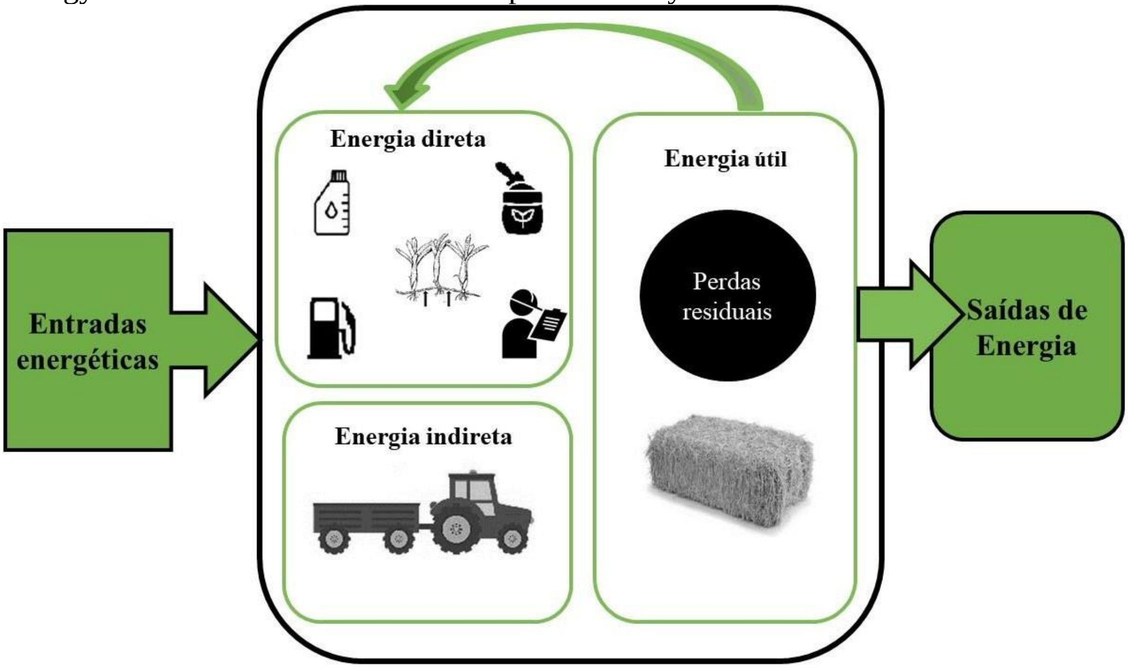
Several authors have verified the potential of Tifton for animal feed, but information about the energy viability of the crop is still scarce and based on literature that may not represent current production systems. Therefore, the present study aimed to evaluate the energy viability of Tifton 85 in the Baixada Fluminense region by determining the energy flows of the production process.

2 MATERIALS AND METHODS

The experiment was carried out at the Feno Rio Farm, located on the Seropédica campus of the Federal Rural University of Rio de Janeiro, during the 2020 harvest in an area of three hectares cultivated with Tifton 85 and geographical coordinates 22°47'27.68" S and 43°40'49.24"W. The region has a climate Aw, according to the Köppen classification, an average temperature of 23.9°C and an average rainfall of 12 13 mm annually. The soil in the area is classified as a typical dystrophic red–yellow argisol according to a survey carried out by Ramos, Castro and Camargo (1973).

To determine the energy balance of the studied system, it was necessary to report the energy components involved in the Tifton 85 production system (*Cynodon* spp.), as shown in the energy flow in Figure 1. As direct energy, expenses related to fuels, lubricants and grease, labor, seeds, fertilizers and pesticides were taken into account, while for indirect energy, expenses related to agricultural machinery and implements were considered (VELOSO *et al*., 2012).

Figure 1. Energy flow in the evaluated Tifton 85 production system



Source: Authors (2023)

Useful energy or energy output was considered to be the production obtained in the evaluated areas where after passing the baler, the number of Tifton bales produced in each cut was counted. In the case of losses caused by failure to collect the baler or transport the hay, in the present study, these losses were considered useful energy for the next cuts, equivalent to 3% of the total produced in each cut.

The energy balance was calculated by transforming the system components into caloric units based on the energy coefficients established by different authors, according to Table 1. The energy costs with the labor used were obtained depending on the number of hours and people required for the operation, multiplied by the energy coefficient referring to this factor.

Table 1. Energia Magazine. Energy components referring to the Tifton 85 production system and their respective energy coefficients.

Source of Consumption	Energy coefficient	Unit	Reference
Labor	2.9	MJ man h $^{-1}$	Campos *et al.* (2009)
Tifton Stolon	17.1	MJ kg $^{-1}$	Authors
Fertilization (Urea)	78.0	MJ kg $^{-1}$	Romanelli and Milan (2005)
Fertilization (P 2° 5)	12.6	MJ kg $^{-1}$	Romanelli, Nardi and Saad (2012)
Fertilization (K_2O)	6.7	MJ kg $^{-1}$	Romanelli, Nardi and Saad (2012)
Limestone	0.2	MJ kg $^{-1}$	Macedonian and Picchioni (1985)
Glyphosate	418.2	MJ L $^{-1}$	Pimentel (1980)
Pyrethroid	184.6	MJ L $^{-1}$	Campos *et al* . (2009)
Diesel oil	43.7	MJ L $^{-1}$	Duarte *et al.* (2018)
Lubricant	39.4	MJ L $^{-1}$	Campos *et al* . (2004)
Grease	43.4	MJ kg $^{-1}$	Campos *et al* . (2004)
Tractor	69.8	MJ kg $^{-1}$	Martins *et al* . (2015)
Implements	57.2	MJ kg $^{-1}$	Martins *et al.* (2015)
Hay	18.9	MJ kg $^{-1}$	Authors

Source: Authors (2023)

The higher calorific value (PCS) of stolon and hay samples from Tifton 85 were determined using an adiabatic calorimetric bomb (C200, IKA WORKS, China), in accordance with the ABNT NBR 8633 (1984) standard. According to the results obtained, the stolon yield (PCS) was 17.09 MJ kg $^{-1,}$ while the hay yield (PCS) was 18.9 MJ kg $^{-1}$.

The energy consumed by machines and equipment consisted of applying the method based on energy depreciation described by Riquetti, Benez and Silva (2012). This methodology consists of depreciating machines and implements during their useful life based on their masses. Therefore, to perform the calculations, Equation 1 was used.

$$DE = \frac{(M.Ce).Tu}{Vu} \quad (1)$$

On what
DEE = specific energy demand, in MJ;
M - weight of machines or equipment, in kg;
Ce - energy coefficient of machines or equipment, in MJ kg-1;
Vu - useful life, in h; It is
Tu - time of use, in h.

In this way, the number of times each mechanized operation was carried out during the evaluated harvest and the time spent (in machine hours) were quantified. To obtain the weights of the machines and implements used, technical data from the manufacturers' catalogs were used. The fuel consumption of the mechanized operations carried out was obtained through field logbooks and later checked using the ASAE D497.7 standard (ASABE, 2011) and was then multiplied by its respective energy coefficient, which, together with the spent on grease and lubricants, allowed us to obtain all the fossil energy consumed.

A Ferguson MF4275 agricultural tractor was used, with a diesel cycle engine, nominal power according to ISO 1585 of 55.1 kW (75 hp), an auxiliary front-wheel drive, wheelsets equipped with front diagonal tires (12.4-24) and a rear (16.9-30). To carry out the conventional management of the evaluated system, a Tatu Marchesan plow, model AF, was used, with three fixed 26” discs, a usable width of 920 mm and a mass of 408 kgf; the Tatu Marchesan heavy harrow, model GAM, was equipped with 14 discs, a useful width of 1500 mm and a mass of 1124 kgf.

To improve and correct the soil, liming was carried out using a trough-type limestone distributor from the MEPEL brand equipped with 18 holes, previously adjusted to a dosage of 1500 kg ha $^{-1}$, with a width of 2500 mm and a mass of 280 kgf. To incorporate fertilizers, a KLR levelling harrow, model GN195, equipped with 24 20” discs, a usable width of 2145 mm and a mass of 914 kgf was used.

In the process of installing the Tifton 85 culture, the distribution of stolons was carried out manually by a team made up of 12 workers, requiring a total service time of 32 hours for the evaluated area, assisted by a tractor/agricultural trailer set. Triton, model TR791 with a single axle, a mass of 365 kg and a load capacity of 3000 kg, which allowed the distribution of 2.5 T ha $^{-1}$ of stolons in the area. After the stolons were distributed, a light harrowing operation with a KLR harrow, model GN 195, with a mass equal to 914 kgf, was implemented, allowing the distributed material to be chopped and incorporated into the soil. To complete the implantation process, a Canastra compactor roller, with a width of 1.5 m and mass of 375 kgf, was used to compact the soil, increasing contact with the seedling, more specifically, the buds from which the roots originate, with the soil.

In the precultivation of tifton, with the aid of a hydraulic boom sprayer from the Incomagri brand, model ATTACK 600, with a useful width of 10 meters and a mass of 220 kgf, the herbicide glyphosate was applied at a dosage of 3 l ha $^{-1}$. The same equipment was used to apply insecticides to control caterpillars, using pyrethroids at a dosage of 0.4 l ha $^{-1}$. In the present study, controls subjected to rapid growth during Tifton culture were not included.

In terms of fertilization, cover fertilization was carried out, where a Cremasco brand launch fertilizer distributor, model DAC 1300, with a strip width of 2.1 m and a mass of 228 kgf, was attached to the tractor, which was used according to recommendations from previously carried out soil analyses of 80 kg ha^{-1} phosphorus, 60 kg ha^{-1} potassium and 150 kg ha^{-1} nitrogen in the form of 45% urea.

The tifton harvesting operation was carried out in three stages: cutting, raking and baling. To cut the forage, a STABRA mower, model S1.70, was used, with a 1.70 m cutting range and a mass of 320 kgf. During the grass raking process, a Khunn rake (model Hay BOB 300) with a raking width of 300 cm and a mass of 300 kgf was used. To carry out the baling, a Nogueira brand baler, model 5040 Express, with a collection width of 1.7 m and a mass of 1460 kgf was used, which allowed baling the tifton into 13 kg bales. Concomitant with the baling process, the baled material was transported using a tractor pulling a Triton agricultural trailer, model TR791, with a single axle, a mass of 365 kgf and a load capacity of 3000 kg.

The energy efficiency (η) of the evaluated Tifton 85 production system was obtained through the ratio between all energy converted and consumed, based on the estimated quantities of energy input and output, obtained during the monitoring of the production cycle, as per equation 2 (CUNHA *et al.*, 2015).

$$\eta = \frac{\sum saídas\ energéticas}{\sum entradas\ energéticas} \qquad (2)$$

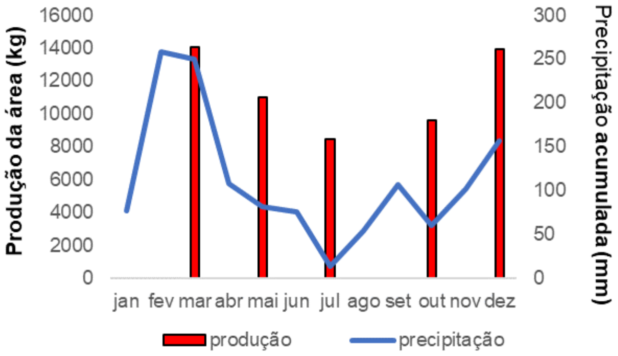
The specific energy (Es) has been widely used to express the amount of energy invested to produce a unit quantity of product, while the energy productivity (Pe) measures the amount of product produced per unit of energy input and is the inverse of the energy specific (DUARTE *et al*., 2018).

3 RESULTS AND DISCUSSION

Figure 2 shows that the annual production of Tifton 85 and the accumulated precipitation during the 2020 harvest were highest in the months of March and December. On the other hand, the values decreased in the months of May and July, reaching the lowest values in October. This behavior is similar to that obtained by Silva *et al*. (2021), grazing

Tifton 85, aiming to feed lactating cows, found that production tends to decrease in autumn and winter, thus reaching the lowest values and returning to growth in spring.

Figure 2. Tifton 85 production behavior and precipitation during the 2020 harvest



Source: Authors (2023)

This production behavior is expected for grasses of the genus Cynodon since they are considered tropical forage species. Linked to good soil management and plant nutrition, climate is a predominant factor in increasing production, being directly related to adequate availability of water and temperature, whether in rainfed production or using supplementation via irrigation (SILVA *et al.* 2017).

The input and output energies for each management system are presented in Table 2. According to the results presented, it is possible to verify that the energy contained in the stolons was only recorded in the first cut. in March, as subsequent cuts occur as a result of continued pasture growth. According to Busato *et al.* (2017), accounting for input energy allows an understanding of the entire production process, allowing the identification of parameters and a precise estimate of energy demands since the amount of energy will be directly linked to the individual characteristics of each production unit.

Table 2. The energy inputs and outputs (MJ) in each Tifton 85 cutting season were evaluated.

Energy description (MJ ha $^{-1}$)	**Cutting season**					
Inputs	**Sea**	**May**	**Jul**	**Oct**	**Ten**	**Total**
Diesel	6447.9	3351	3351	4276	3351	20776.9
Grease and lubricant	24.5	13.1	13.1	18.1	13.1	81.9
Stolons	42725.0	-	-	-	-	42725.0
Waste (straw)	-	7976.4	6240.5	4801.2	5307.2	24325.3
Fertilizers	12810.1	11100.5	11100.5	11470.5	11100.5	57582.1
Labor	416.7	93.8	93.8	106.5	93.8	804.6
Defensive	1328.4	1254.6	147.7	1254.6	1254.6	5239.9
Tractor	271.6	141.2	141.2	258.1	141.2	953.3
Implements	185.8	105.2	105.2	198.2	105.2	699.6
Output						
Waste (Straw)	7976.4	6240.5	4801.2	5307.2	7899.5	32224.8
Hay	178378.1	139557.6	107370.9	116412.7	176658.2	718377.5

Source: Authors (2023)

Nevertheless, according to the results obtained, the energy spent on diesel, fertilizers and pesticides was quite significant in the different cuts of Tifton 85 evaluated. It is worth highlighting the low energy value of pesticides in July, which is the reason for the reduced need for pyrethroid application and caterpillar control. According to Dubis *et al.* (2019), food or biomass production systems require a large amount of inputs derived from fossil sources and fertilizers.

It is also possible to observe the large amount of waste generated in the harvesting process for subsequent cutting. Jankowski *et al.* (2020) mentioned that energy demand will vary depending on the geographic region, the size of the property and, mainly, the production technologies adopted.

Specifically, regarding energy expenditure on diesel, it is worth highlighting the increasing search for replacement with alternative sources. Given the high-cost scenario and energy crisis, this factor, according to Martins *et al.* (2015), is one of the most limiting and difficult to replace since solutions aimed at reducing energy consumption involve reducing the use of machines and implements, which directly impact production capacity.

The use of energy from labor, even though it is a small portion of the energy consumed, allows us to evaluate whether the first cut evaluated presented the highest value compared to the others. According to Dal Ferro *et al.* (2017), the amount of energy spent on this factor is directly related to the frequency and number of operations carried out due to the degree of intensity of mechanization.

Regarding the energy balance of the Tifton production system, Table 3 shows that the largest energy inputs occurred in the first cut (carried out in March) due to the large amount of energy used in the installation of the culture. This behavior directly reflects the energy efficiency of the system since the period presented the lowest value among the cuts evaluated (2.9).

Table 3. Energy balance, energy efficiency (η), specific energy (Es) and energy productivity (Pe) in each cutting season evaluated for Tífton 85

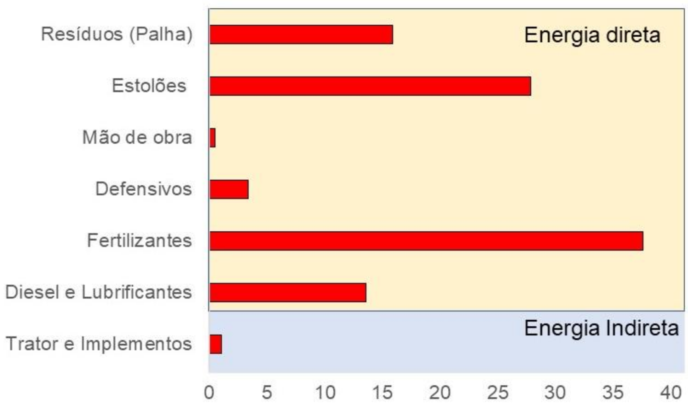
	Appetizer (MJ ha $^{-1}$)	**Outputs (MJ ha $^{-1}$)**	**Net energy (MJ ha $^{-1}$)**	***n***	***is***	***ps***
Sea	64210.0	186354.5	122144.5	2.9	6.8	0.15
May	24035.8	145798.0	121762.3	6.1	3.3	0.31
Jul	21193.0	112172.1	90979.2	5.3	3.7	0.27
Oct	22383.2	121719.9	99336.7	5.4	3.6	0.28
Ten	21366.6	184557.7	163191.0	8.6	2.3	0.44
Average	153188.6	750602.3	597413.7	4.9	4.03	0.24

Source: Authors (2023)

It is also worth noting that for the other periods evaluated, energy efficiency showed growth in relation to the March period, confirming that energy efficiency is directly related to the amount of energy used. According to Duarte *et al*. (2018); consequently, as greater energy efficiencies are obtained, there is less specific energy spent and greater energy productivity, a behavior that is corroborated by the values obtained in the present study. Therefore, in general, the system presented a positive energy balance throughout the Tifton 85 production process during the evaluated harvest.

According to Figure 3, it is possible to observe the items and the amount of energy used during the year evaluated in the production of tifton. The data obtained allow us to say that direct energy consumption was much greater than indirect energy consumption, corroborating the results obtained by Ferreira *et al*. (2018) in the production of irrigated corn for silage purposes.

Figure 3. Participation of energy items in indirect and direct energy for the production of Tifton 85



Source: Authors (2023)

Regarding biological inputs, 37.9% of the tifton production system presented energy inputs with stolons used for the installation of the culture. The behavior of this forage crop is quite specific since the crop remains installed throughout the harvest, showing continuous growth with each cut and directly impacting energy inputs in subsequent cuts, making these residues responsible for 15.9% of all input energy.

The contribution of the energy expenditure of fertilizers, herbicides and fuels was decisive for the high energy consumption of the studied cultivation systems, corroborating the results obtained by Kheiry and Dahab (2016) for sorghum cultivation. Notably, the energy costs related to fertilizers were responsible for 37.6% of all the energy spent on Tifton production during the harvest evaluated. Horváth, Nyéki and Neményi (2018) mention that agriculture is currently based on the use of nitrogen-based fertilizers, which directly impact the energy spent in the production process.

Lin *et al.* (2016) mentioned that agriculture is currently very dependent on the input of fossil fuel, which is based on the consumption of fuels and lubricants, and depending on the system adopted, the consumption of this energy source becomes even greater due to the intensity of mechanization, thus increasing production costs. In view of the above, in the present work, energy expenditure on diesel and lubricant was responsible for 13.6%, a value well below that obtained by other authors evaluating other crops for forage purposes.

The present work presented a low representation of indirect energy spent (1.1%), which indicates that the tifton production system uses low intensity in mechanized operations. Martins *et al.* (2015) mention that indirect energy consumption occurs because the tractor is the primary driving force for carrying out all cultural activities, thus making the energy spent dependent on the operational capacity and the mass of the equipment.

According to Woods *et al.* (2010), the relationship between energy inputs and the energy yield of a crop is not linear; therefore, in several crops, a smaller amount of energy inputs can lead to lower yields and greater energy demands per ton of harvested product. . Specifically, the energy efficiency of the crop during the period evaluated for the Tifton 85 crop was an average of 4.9, which is lower than that of other crops used for animal feed.

Despite the above, it is possible to state based on the results that the Tifton 85 culture presented a positive energy balance and consequently proved to be energy efficient. Therefore, it is possible to affirm the great potential for exploitation of the culture by producers in the metropolitan region of the state of Rio de Janeiro, given that, in different regions of Brazil, the culture has demonstrated good results.

4 CONCLUSIONS

The harvest evaluated in this study showed positive energy balance results, even with high energy demands. Direct energy inputs were predominant due to the significant share of diesel oil and chemical fertilizers.

Despite the large amount of energy used, especially for the implementation of the crop, the system's conversion capacity proved to be adequate, presenting positive energy efficiency and with values close to those of other studies with forage crops.

Energy analysis is an important tool for evaluating and measuring the sustainability of different agricultural systems, and the results obtained in the present study verify the potential of the Baixada Fluminense region for the production of Tifton 85.

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