

## **Emergy Evaluation of Tillage Systems in Maize Production in the Agreste of Sergipe State**



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## **Energy Evaluation of Tillage Systems in Maize Production in the Agreste of Sergipe State**

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# Avaliação Emergética de Sistemas de Preparo do Solo na Produção de Milho no Agreste Sergipano

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## Resumo

A produção de milho no Agreste do Estado de Sergipe tem passado por uma transformação em direção a sistemas de cultivo com o uso de agroquímicos, híbridos geneticamente modificados e preparo intensivo do solo. Isto devido a uma combinação de fatores tais como genótipos selecionados, proximidade de mercados consumidores, uma infraestrutura relativamente boa para o escoamento da produção e um período chuvoso que coincide com a entressafra das principais regiões produtoras. Todavia, o uso intensivo de grade pesada pode acelerar o processo de degradação do solo na região. O objetivo do presente trabalho foi avaliar o desempenho ambiental de diferentes sistemas de preparo do solo na produção de milho no Agreste de Sergipe por meio da contabilidade de energia. Indicadores ambientais mostraram que o plantio direto melhorou o desempenho ambiental quando comparado com o cultivo convencional e o cultivo mínimo.

**Palavras-chave:** semeadura direta, preparo convencional, cultivo mínimo, preservação ambiental, indicadores ambientais.

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# Emergy Evaluation of Tillage Systems in Maize Production in the Agreste of Sergipe State

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## Abstract

*Maize production in the Agreste part of Sergipe State in Brazil is undergoing a shift towards farming system with use of chemical inputs, high yielding GMO hybrids and intensive tillage for seedbed preparation. This can be attributed to a combination of factors like improved genotypes, closeness to consuming market, relative good infrastructure to production outlet and a rainy period that falls during the off-season of main producing areas. However, the intensive tillage being extensively used may accelerate the soil degradation process in the region. The goal of this study was to assess the environmental performance of different tillage systems in maize production in the Agreste of Sergipe through emergy accounting. Environmental indicators showed that no-till improves environmental performance when compared to reduced and conventional tillage.*

**Key words:** no-till, conventional tillage, reduced tillage, environment conservation or environmental indicators.

## Introduction

Even though subsistence agriculture is the main kind of farming system in Brazilian Semiarid Tropics (SAT), maize production in the so called Agreste part of the region is undergoing a shift towards systems with use of chemical inputs, machinery and high yielding GMO hybrids. This changing in the technological profile is being driven by a combinations of factors like adapted genotypes; closeness to consuming market (poultry farming); relative good infrastructure for production outlet, and rainy period during the off-season of traditional producing areas (BARROS et al., 2013). Such changes, specially the intensive tillage, may speed-up soil degradation and threaten the sustainable agricultural development of the region, since long-term studies have shown that continuous intensive plowing is undesirable as it leads to unsustainability, particularly in the SAT (JAT et al., 2012).

Possibly, the most suitable option to overcome soil degradation and promote sustainable farming in Semiarid Tropics is conservation tillage, which is the collective umbrella term given to no-tillage, direct-drilling, minimum tillage and/or ridge-tillage, to denote that the specific practice has a conservation goal of some nature (BAKER et al., 2002; JAT et al., 2012). It is been presented as a solution for many agricultural issues in the tropics (HEBBLETHWAITE et al., 1996; STEINER et al., 1998; FOWLER; ROCKSTRÖM, 2001; HOBBS, 2007; HOBBS et al., 2008; FOLEY et al., 2011) and aims to address questions concerning agricultural sustainability through soil management with minimum disturbance, therefore protecting it against the processes that lead to degradation - erosion, compaction, aggregate breakdown, loss in organic matter, leaching of nutrients among others (JAT et al., 2012; SERRAJ SIDDIQUE, 2012).

Despite all advantages, the adoption of conservation tillage in SAT is still low. According to Silva et al. (2011), there are difficulties for farmers to adopt no-till because the low production of crop residue that, combined with high temperatures, accelerates its decomposition,

decreasing soil cover quickly after harvest (SILVA NETO, 2003; NUNES, 2006; BOT; BENITES, 2005). Also, early studies have concluded that no-till would be not a suitable management for SAT, because severe yield depressions on several crops have been documented (NYE; GREENLAND, 1964; CHARREAU; NICOU, 1971; BUANEC, 1972, BUANEC, 1974; NICOU, 1974; LAL, 1995).

Nevertheless, recent research findings have shown that even in semi-arid areas no-till can be an appropriate management to improve soil fertility and crop yields (MRABET, 2000; MRABET et al., 2001a, b; BESSAM; MRABET, 2003; SILVA et al., 2011; SILVA, 2002; NUNES, 2006; HOOGMOED, 1999). It would appear that there is a need to identify situations where availability of even moderate amount of residues can be combined with conservation tillage to enhance soil quality and efficient use of rainwater in rainfed agriculture (GUTO et al., 2011).

## **Emergy accounting for agricultural performance evaluation**

As agriculture operates exactly at the interface between nature and the human economy, it depends on a combination of economic as well as natural inputs. Consequently, both economic and environmental contributions need to be accounted in equivalent terms when comparing resource uses in agricultural systems (CAMPBELL, 1998). However, conventional performance evaluation of agricultural production systems relies mostly on economic information, or on multi-criteria analysis that lacks an equitable basis for the different assets involved, economic, environmental, or social.

Since assessments of systems' performance based solely on economic analysis clearly underrate environmental contributions to the system (MARTIN et al., 2006), optimal use of natural resources cannot be achieved as it results from an inappropriate accounts and an undervaluation of environmental relative to economic inputs (ULGIATI et al., 1994). Therefore, methods that quantify "non-marketed"



resource value by avoiding reliance on human preferences may provide an informative standard against which derived monetary valuation can be compared.

Emergy synthesis is a form of energy analysis in which the large-scale environmental support to the human economy is quantified by computing the values of natural and economic resources on a common basis (ODUM, 1988). It is a 'donor-side' evaluation approach, because it accounts for all environmental work and natural capital previously involved in generating a resource, product or service and, in so doing, the emergy method sets out to provide a scientific basis for wealth (LEFROY; RYDBERG, 2003). Therefore, emergy synthesis is a promising tool to evaluate resource uses, production, and performance of agricultural systems.

Emergy is defined as the energy of one kind required directly or indirectly to create a product or service (ODUM, 1996; ODUM et al., 2000). Since each input (whether economic or environmental) to a process is itself a product of energy transformations, emergy is often referred to as energy memory, with units referenced to a standard energy source, typically solar energy (seJ) (COHEN et al., 2006). The ratio of emergy in a product to the remaining available energy (exergy) is called transformity (ODUM, 1988; COHEN et al., 2006) or energy transformation ratio (ODUM, 1984).

Transformity is a measure of energy quality, because the available energy after each transformation has properties that distinguish it from heat and the fundamental assumption of emergy analysis is that the contribution of a resource is proportional to the available energy of one kind required to produce the resource (BROWN; HERENDEEN, 1996). The theoretical background on emergy approach can be found in Odum (1996), Odum (1998b), Brown; Ulgiati (1999), Odum et al. (2000), Brown; Ulgiati (2001); Brown; Ulgiati (2004b) and Odum; Odum (2008).

The capacity to value economic inputs, renewable and non-renewable resources and environmental services on a common basis represents a potential advantage of emergy evaluation over conventional economic and energy analysis (LEFROY; RYDBERG, 2003).

Environmental accounting based on emergy synthesis has been increasingly used to evaluate the sustainability of agricultural systems worldwide, offering a solid base for environmental decision making related to agricultural policy and management (ULGIATI et al., 1994; BASTIANONI et al., 2001; RYDBERG; JANSEN, 2002; RODRIGUES et al., 2002; HONG-FANG et al., 2003; LEFROY; RYDBERG, 2003; MARTIN et al., 2006; AGOSTINHO et al., 2008; BARROS et al., 2009; ZHANG et al., 2012; FERRARO et al., 2015). These studies however, have usually aimed to compare very contrasting agricultural systems (conventional intensive farming against low-input traditional indigenous systems, etc.), often with different crops in each analyzed system, and where large differences are expected. However, emergy accounting can also be instrumental to evaluate how changes in specific management practices within a cropping system affect the environmental performance of the system as a whole.

The goal of the present study is to compare three different tillage systems for maize production in the “Agreste” part of the State of Sergipe with regard to: resource use, productivity, environmental impact and overall sustainability based upon the emergy approach.

## Methodology

### Study site and tillage systems

An experiment was carried out during the period of 2011 to 2013 aiming at evaluating the performance of different tillage systems for maize production in the “Agreste” part of the State of Sergipe. Popularly, the Agreste is a kind of climate region, the transition between humid region (Atlantic coast) and semi-arid region. The experiment was set up in the research station of Embrapa Coastal

Tablelands in the municipality of Frei Paulo, State of Sergipe (10° 55' S; 37° 53' W and 272 m.a.s.l). According to Emdagro (2008), the mean annual temperature is 24.5°C and the average precipitation is 580 mm per year, with more than 71% of rainfall concentrated during the period of March to August (mean 2006-2014, direct measurements in the research station). Following Köpenn-Geiger climate classification system (KÖPEN, 1936; PEEL et al., 2007) the region falls in semiarid or steppe climate class (BSh).

Three tillage systems were been tested as follow: 1) Conventional tillage – Disk plowing (20 cm depth) followed by disk harrowing; 2) Reduced tillage – Chisel plowing (20 cm depth) followed by disk harrowing and 3) No-till.

Seeding was carried out on May, 18<sup>th</sup>; June, 28<sup>th</sup> and June, 12<sup>th</sup> respectively for 2011, 2012 and 2013 and GM maize hybrid with both glyphosate resistance and Bt events have been used. During seeding, 20 kg of N and 43.7 kg of P per ha (in the form of Monoammonium Phosphate - MAP) have been band applied as starter. No K supply was needed. When plants reached 4 – 5 leaves, a further 180 kg.ha<sup>-1</sup> of N were sidedress applied.

Weed dissection was performed with Glyphosate (1.5 kg a.i. per ha) three weeks prior to seeding in no-till and Atrazine (1.92 kg a.i. per ha) was used for weed control in conventional and reduced tillage just after seeding.

Experimental design was Complete Blocks with 3 replications. Each plot had 77 m<sup>2</sup> (3.5 x 22 m) but only the 48 m<sup>2</sup> (2.4 x 20 m) in the center of the plot have been considered for statistical analysis.

Harvests occurred on October, 28<sup>th</sup>; November, 26<sup>th</sup> and November, 11<sup>th</sup> for 2011, 2012 and 2013 respectively and the measured grain yields have been standardized for 13% commercial benchmark humidity level

For further details concerning experimental set-up and yield performances, please refer to Barros et al. (2015a, b).

## **Emergy accounting**

After defining the objective of the study and the product to be analyzed, an emergy accounting requires the following steps according to Rotolo et al (2015):

- a) A diagram, drawn in energy systems language, showing components, interactions, driving forces, economic and product flows.
- b) A detailed inventory of the flows contributing to the process. These are usually grouped as Local renewable resources (R), Local non-renewable resources (N), Imported or purchased products, labor and services (F) and inputs expressed in their raw units.
- c) Construction of a table, to summarize inventory flows, transformities, and emergy values. The table includes all kinds of input and output flows from the inventory.
- d) Calculation of Total Emergy ( $U = R + N + F$ ), and emergy-based performance and sustainability indicators. These include:
  - i) Transformity: The ratio between the total emergy used (Y in seJ) and emergy content (in J) of the exported products.
  - ii) Mass emergy: The ratio between the total emergy used (Y in seJ) and the mass (in g) of the exported products (ODUM, 1998b);
  - iii) Fraction renewable (FR): The percentage represented by the renewable resources (R) in the total emergy used (Y). Fraction renewable =  $100.R.Y^{-1}$ .
  - iv) Environmental loading ratio (ELR): reports on the ratio of non-renewable resources (N + P) to renewable flows (R) and is an

estimation of the environmental impact of the system. As ELR increases, stress on environmental services is expected due to convergence of sources that intensify existing flow patterns (COHEN et al., 2006).  $ELR = (N + P).R^{n1}$ .

v) Emergy investment ratio (EIR): describes the ratio of purchased inputs (P) to total endogenous flows (N + R), and quantifies outside investment to match flows of locally available emergy, therefore evaluating if a process is a good user of the invested emergy while compared to other alternatives for the use of the same resources (BROWN; ULGIATI, 2004a).  $EIR = P.(N + R)^{-1}$ .

vi) Emergy yield ratio (EYR): computes the return-on-investment of environmental work. It is a measure of the ability of a process to exploit and make local resources available by investing in outside resources, which can be read as a potential additional contribution to the main economy, gained through the investment on inputs.  $EYR = Y.P^{-1}$ .

vii) Emergy exchange ratio (EER): measures the advantage of one partner over the other in the trading of a product or service by money, providing a measure of who “wins” or who “loses” environmental work in economic trade (BROWN; ULGIATI, 2001).  $EER = Y.(sales \bullet EMR)^{-1}$ , being EMR (emergy-money ratio) the ratio of gross domestic product (GDP) to total emergy use.

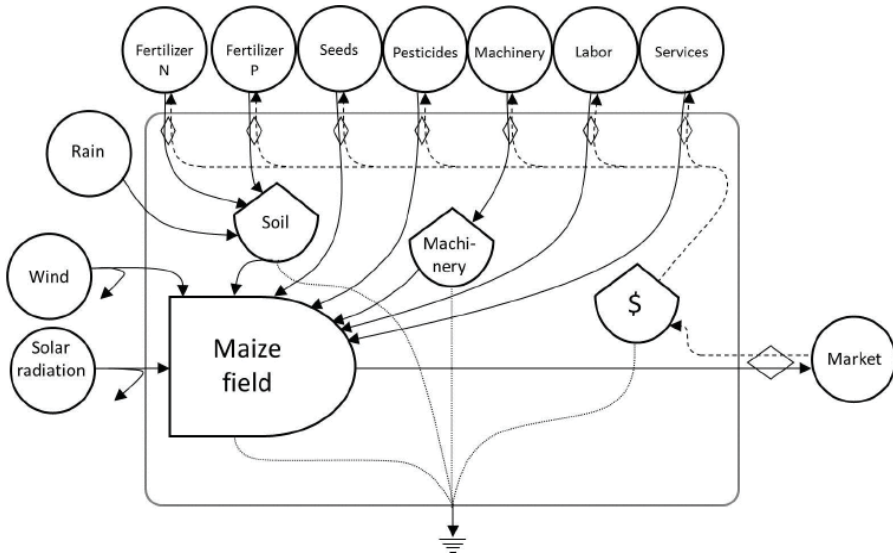
viii) Emergy sustainability index (ESI): is the ratio of the EYR to ELR. Sustainability (as ESI) increases with returns on investment and decreases with environmental load. This measure assumes that the objective function for sustainability is to obtain the highest yield ratio while minimizing environmental pressure (BROWN; ULGIATI, 1999).

For a deeper understanding on emergy approach for environmental performance assessment, readers are invited to consult Odum (1996), Ulgiati and Brown (1998) and Brown and Ulgiati (2004a, b).

## Results and Discussion

### Emergy accounting diagram, analysis and performance indices

A diagram representing the flows of free environmental inputs, energy, materials and services used as basis for the assessment of emergy accounting of the tillage systems studied is showed in Figure 1. Quantitative flows of all main natural resources and economic inputs as well as the emergy analysis weighing the flows by their respective transformity factors are detailed in Table 1, while the emergy performance indices are presented in Table 2. The calculations of raw data in Table 1 are presented in Appendix 1.



**Figure 1.** Generic maize production system diagram, showing the flows of renewable, non-renewable and economic resources (solid lines) as well as the flow of money (dashed lines) driving the production process.

**Source:** Odum (1998b) and Brow (2004).

**Table 1.** Emery table of maize production following three different tillage systems in the Agreste of Sergipe.

N <sup>o</sup>	Item	Raw unit	Raw amounts (units.ha <sup>-1</sup> .year <sup>-1</sup> )	NT <sup>a</sup>	Emery/unit (sej/unit)	Ref <sup>b</sup>	Emery (E+13 sej.ha <sup>-1</sup> .year <sup>-1</sup> )	CT	RT	NT
Local renewable resource (R)										
1	Solar radiation	J	5.23E+13	5.23E+13	1	[1]	5.23	5.23	5.23	5.23
2	Wind Kinetic Energy	J	1.76E+11	1.76E+11	2.51E+03	[2]	44.23	44.23	44.23	44.23
3	Rain geopotential	J	3.28E+08	3.28E+08	4.70E+04	[3]	1.54	1.54	1.54	1.54
4	Rain chemical	J	2.72E+10	2.72E+10	3.05E+04	[2]	82.87	82.87	82.87	82.87
Local non-renewable source (N)										
5	Top soil loss	J	1.32E+08	8.25E+07	1.24E+05	[4]	0.98	0.98	0.61	0.51
Feedback from market (F)										
6	Fuel & Lubricants	J	4.77E+09	3.61E+09	1.81E+05	[5]	86.39	65.28	65.28	44.82
7	Seeds	g	2.65E+04	2.65E+04	1.98E+09	[6]	5.26	5.26	5.26	5.26
8	Nitrogen Fertilizer (N)	g	2.00E+05	2.00E+05	2.41E+10	[7]	154.60	154.60	154.60	154.60
9	Phosphate Fertilizer (P <sub>2</sub> O <sub>6</sub> )	g	1.00E+05	1.00E+05	5.67E+09	[7]	56.70	56.70	56.70	56.70
10	Herbicide: Atrazine	g	2.00E+03	2.00E+03	1.92E+10	[8]	3.84	3.84	3.84	.....
11	Herbicide: Glyphosate	g	.....	1.44E+03	4.32E+10	[8]	.....	.....	.....	6.22
12	Agricultural machinery	g	9.59E+03	4.32E+03	3.78E+09	[9]	3.63	1.63	1.63	1.28
13	Transport bags	US\$	8.03E+01	8.03E+01	3.70E+12	[10]	29.71	29.71	29.71	29.71
14	Labor	J	5.01E+07	4.62E+07	1.10E+07	[2]	55.14	50.82	50.82	46.51
15	Services	US\$	2.19E+01	1.71E+01	3.70E+12	[10]	8.09	6.34	6.34	4.63

Continua...

Tabela 1. Continuação.

N <sup>o</sup>	Item	Raw unit	Raw amounts (units.ha <sup>-1</sup> .year <sup>-1</sup> )			Energy/ unit (seJ/unit)	Ref <sup>b</sup>	Energy (E+13 seJ.ha <sup>-1</sup> .year <sup>-1</sup> )		
			CT <sup>a</sup>	RT <sup>a</sup>	NT <sup>a</sup>			CT	RT	NT
Total energy							487.21	457.66	433.11	
Output (Y)										
16a	Grain Mass	g	8.24E+06	8.04E+06	8.26E+06					
16b	Grain Energy	J	1.44E+11	1.40E+11	1.44E+11					
	Grain Economic Value	US\$	2.34E+03	2.28E+03	2.35E+03					

<sup>a/</sup> CT: Conventional tillage; RT: Reduced tillage; NT: No-till.

<sup>b/</sup> Transformity references: [1] by definition; [2] Odum (1996); [3] Odum et al. (2000); [4] Brown and Bardi (2001); [5] Brown et al. (2011); [6] ROTOLO et al. (2015a); [7] Brandt-Williams (2002); [8] after Hiesel (1992), multiplied by crude oil transformity from Brown et al (2011 - [5]); [9] Bargigli and Ulgiati (2003); [10] Demetrio (2011).



**Table 2.** Environmental performance indicators based on emergy indices for tillage systems in maize production in the Agreste of Sergipe.

	Performance index	Formulae	CTa	RTa	NTa
R	Renewable resources	R	8.29E+14	8.29E+14	8.29E+14
N	Non-renewable resources	N	9.80E+12	6.10E+12	5.10E+12
F	Feedback from market	F	4.03E+15	3.74E+15	3.50E+15
Y	Yield	Y	4.87E+15	4.58E+15	4.33E+15
Tr	Transformity	sej.j <sup>-1</sup>	3.39E+04	3.27E+04	3.01E+04
ME	Mass-emergy ratio	sej.g <sup>-1</sup>	5.91E+08	5.69E+08	5.24E+08
FR	Fraction renewable	R.Y <sup>-1</sup>	17.01%	18.11%	19.13%
ELR	Environmetal Loading Ratio	(N + F).R <sup>-1</sup>	4.88	4.52	4.23
EIR	Emergy Investment Ratio	F.(N + R) <sup>-1</sup>	4.81	4.48	4.19
EYR	Emergy Yield Ratio	Y.F <sup>-1</sup>	1.21	1.22	1.24
	Empower Density	sej.ha <sup>-1</sup> .yr <sup>-1</sup>	4.87E+15	4.58E+15	4.33E+15
EER	Emergy Exchange Ratio	Y.(PEV <sup>b</sup> .EMR <sup>c</sup> ) <sup>-1</sup>	0.671	0.645	0.595
ESI	Emergy Sustainability Index	EYR.ELR <sup>-1</sup>	0.25	0.27	0.29

<sup>a/</sup> CT: Conventional tillage; RT: Reduced tillage; NT: No-till.

<sup>b/</sup> Production Economic Value.

<sup>c/</sup> Emergy-to-money ratio.

## Renewable flows

Renewable flows (sunlight, wind, rainfall geopotential and chemical energy) were expressed for the emergy accounting of maize production mainly as evapotranspiration, which is the largest flow and integrates all the sunlight derived flows. This is recommended in emergy analysis of agricultural systems in order to avoid double counting, because all the climatic derived energy flows are by-products of the same coupled process of sunlight energy dissipation (ODUM, 1996; LEFROY; RYDBERG, 2003; MARTIN et al., 2006).

In semiarid environments, potential evapotranspiration is larger than rainfall and pronounced water deficits are observed in most part of the year. Using Thornthwaite; Mather approach (THORNTWHAITE; MATHER, 1955) for estimating water balance, an average water deficit of  $881 \text{ mm}\cdot\text{year}^{-1}$  and a reference evapotranspiration of  $551.5 \text{ mm}$  was estimated using locally collected data. Therefore, the contribution of renewable environmental resource to maize production in this semiarid region was in the amount of  $82.87\text{E} + 13 \text{ seJ}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ .

## Non-renewable flows

Non-renewable resources used by the systems included important flows referred to as soil erosion, which varied from  $0.51$  up to  $0.98\text{E} + 13 \text{ sej}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ . No tillage systems reduced the flows of non-renewable sources by 48 and 16% in relation to conventional and reduced till respectively (Tables 1 and 2). Conservation tillage practices like no-till and reduced tillage are specifically designed to hinder soil degradation primarily by reducing soil erosion.

Conservation tillage has been highly effective in reducing the use of non-renewable resources in the form soil loss. While an average loss of soil of  $31.5 \text{ g}\cdot\text{m}^{-2}\cdot\text{year}^{-1}$  was measured in Conventional Tillage, in No-till the soil loss was  $16.4 \text{ g}\cdot\text{m}^{-2}\cdot\text{year}^{-1}$ . Despite this result, the values may be considered low when compared to some others emergy accountings of maize production. Martin et al. (2006) published emergy flows by soil erosion as high as  $21.60\text{E} + 13 \text{ seJ}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  in Kansas (USA);

Ulgiati (2001) found  $40.10E + 13 \text{ seJ}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  in Italy; FRAZESSE et al (2013) estimated  $50.50E + 13 \text{ seJ}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  in the South of Brazil and Rótolo et al. (2015) calculated  $3.90E + 13 \text{ seJ}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  in the Argentinean Pampas.

## Purchased resource flows

The main differences among tillage systems were in the flows of imported resources from the market that varied from  $35.00E + 14 \text{ seJ}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  in no-till system to  $40.30E + 14 \text{ seJ}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  in conventional tillage, reflecting the effects of reduced intensity in soil management. No-till reduced emergy imports in the form of fuel, machinery, labor and services while increased imports of emergy sources in the form of herbicides. Overall, emergy imports from the market were 12.5 and 5.7% higher in conventional and reduced till than in no-till, respectively (Table 2).

In spite of the differences, high yielding maize production in the Agreste of Sergipe may be considered highly dependent upon purchased resources. These represent about 82% of total emergy use. Of all imported resources, between 53 and 61% were invested in fertilizer, 1/4 as phosphate and 3/4 as nitrogen. The main impact that tillage systems have had on imported resources was observed in the use of fuels, that was reduced by half, from  $86.39E + 14$  to  $44.82E + 13 \text{ seJ}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  or, from 22 to 13% of all imported emergy sources.

## Maize yields

In average of the three years, the emergy allocated to maize production in Brazilian SAT varied from  $433.11E + 13$  in no-till up to  $487.21E + 13 \text{ seJ}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$  when conventional tillage was used for seedbed preparation, resulting in transformities for maize production between  $3.01$  and  $3.39E + 04 \text{ seJ}\cdot\text{J}^{-1}$  (Table 2).

## Performance indices

No-till showed better environmental performance than reduced and conventional tillage for all evaluated indices (Table 2). Fraction renewable (FR) increased by 12.5% while environmental loading ratio (ELR) decreased by 13% only by changing from conventional to no-till, indicating that such change in seedbed preparation reduces the potential of environmental impact due to lower stress on environmental services (COHEN et al. 2006).

At the same time, no-till showed to be a better user of invested emergy than reduced and conventional tillage. Emergy investment ratio (EIR) was lower and the emergy yield ratio (EYR) was higher in this system than in the other two evaluated tillage methods (Table 2). This indicates that more free environmental resources are being incorporated into the system with less emergy being invested in purchased sources.

The results of emergy exchange ratio (EER) point out that, when selling the outputs, all three systems are getting more emergy from the market (in form of money) than giving emergy to this same market (in the form of maize grains), being therefore a “winner” in the trading process. And, among the three systems, no-till gets more emergy than reduced and conventional tillage. In average of all three years, 1.49 seJ is gotten (as money) for each seJ given (as maize grains) when conventional tillage is adopted. This proportion increases to 1.68 seJ seJ<sup>-1</sup> for no-till.

As consequence, emergy sustainability index (ESI) is higher in no-till than in conventional tillage, indicating that no tillage yields more emergy and adds more contributions to the main economy while reduces potential environmental loading.

## Conclusions

This study showed that emergy synthesis can be instrumental to highlight improvements towards sustainability promoted by changes in very specific management practices, because it accounts for the spreading effects of this change in the whole system due to the holistic nature of this approach.

In relation to seedbed preparation, no-till is a management practice environmentally more efficient than conventional or reduced tillage while keeping the yielding capacity even in the Agreste part of Sergipe State.

According to emergy accounting, the main effects of no-till in relation to conventional tillage are related to reductions in the flows of non-renewable resources of soil losses and in the flows of purchased inputs like fuel, machinery, labor and services, while increasing flows of agrochemicals (herbicides). In synthesis, no-till improves sustainability of maize production in relation to conventional tillage in the Agreste of Sergipe State.

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## Appendix

### Appendix 1. Calculation notes for maize production systems in Table 1.

Note	Description	Value	Unit	Source
<b>1</b>	<b>Solar radiation</b>			
	Energy received over land = solar radiation (kWh.m <sup>-2</sup> .day <sup>-1</sup> ) x (3.6E+06 J/kWh) x (1 – albedo) x 10 000 m <sup>2</sup> .ha <sup>-1</sup> x 365 days.year <sup>-1</sup> .			
	Insolation	4.628	kWh.m <sup>-2</sup> .day <sup>-1</sup>	<a href="http://maps.nrel.gov/swera">http://maps.nrel.gov/swera</a>
	Albedo	14	%	<a href="http://eosweb.larc.nasa.gov">http://eosweb.larc.nasa.gov</a>
	<i>Insolation energy</i>	<i>5.23E+13</i>	<i>J.ha<sup>-1</sup>.year<sup>1</sup></i>	
<b>2</b>	<b>Wind Kinetic Energy</b>			
	Energy of wind (KANGAS, 2002 Folio #5): 0.5 x density of air (1.2E-1 g.cm <sup>-3</sup> ) x wind velocity <sup>2</sup> (cm.s <sup>-1</sup> ) x Eddy diffusion coefficient (2.8E+4 cm <sup>2</sup> .s <sup>-1</sup> – ODUM AND ODUM, 1983) x 1.d <sup>1</sup> (d = height of boundary layer = 1E+4 cm) x 2.38E+11kcal.erg <sup>-1</sup> x 3.15E+07s.year <sup>-1</sup> x 1E+08cm <sup>2</sup> .ha <sup>-1</sup> x 4186 J.kcal <sup>-1</sup> .			
	Average wind velocity	5.781	m.s <sup>-1</sup>	<a href="http://maps.nrel.gov/swera">http://maps.nrel.gov/swera</a>
	<i>Wind Kinetic Energy</i>	<i>1.76E+11</i>	<i>J.ha<sup>-1</sup>.year<sup>1</sup></i>	
<b>3</b>	<b>Rain geopotential</b>			
	Geopotential energy of rain: rain (m) x runoff fraction (%) x 10 000m <sup>2</sup> .ha <sup>-1</sup> x mean elevation (m) x density of water (1000 kg.m <sup>-3</sup> ) x gravity (9.8 m.s <sup>-2</sup> )			
	Average rainfall	551.5	mm	Direct measurement
	Runoff fraction	2.24	%	BARROS et al. (2013)
	Mean elevation	272	m.a.s.l.	Direct measurement
	<i>Geopotential energy of rain</i>	<i>5.28E+08</i>	<i>J.ha<sup>-1</sup>.year<sup>1</sup></i>	
<b>4</b>	<b>Chemical energy of rain</b>			
	Chemical energy of rain: Evapotranspiration of crops (m.year <sup>-1</sup> ) x 10 000 m <sup>2</sup> .ha <sup>-1</sup> x density of water (1000 kg.m <sup>-3</sup> ) x Gibbs free energy of rainwater (4940 J.kg <sup>-1</sup> )			
	Evapotranspired water calculated using water balance by Thornthwaite and Mater (1955) with following data:			
	<u>Average temperature (°C)</u> : Jan: 26.27; Feb: 26.17; Mar: 26.03; Apr: 25.50; May: 24.79; Jun: 23.87; Jul: 23.22; Aug: 23.63; Sep: 24.77; Oct: 26.04; Nov: 26.52; Dec: 26.68 ( <a href="http://maps.nrel.gov/swera">http://maps.nrel.gov/swera</a> )			
	<u>Average rainfall (mm)</u> : Jan: 16.20; Feb: 36.00; Mar: 34.90; Apr: 51.50; May: 82.70; Jun: 59.20; Jul: 94.40; Aug: 60.90; Sep: 34.20; Oct: 62.80; Nov: 18.70; Dec: 0.00 (From direct measurements)			
	<u>Latitude (Degrees)</u> : -10.9 (From direct measurements)			
	Evapotranspired water by maize	551.5	mm	THORNTHWAITTE AND MATER (1955)
	<i>Chemical energy of rain</i>	<i>2.72E+10</i>	<i>J.ha<sup>-1</sup>.year<sup>1</sup></i>	

## Appendix 1. Continuação.

Note	Description	Value	Unit	Source
<b>5</b>	<b>Top soil loss</b>			
	Loss of top soil: erosion rate ( $\text{g}\cdot\text{m}^{-2}\cdot\text{year}^{-1}$ ) x organic content in the soil ( $\text{g}\cdot\text{g}^{-1}$ ) x energy content of soil organic matter ( $5.40 \text{ kcal}\cdot\text{g}^{-1}$ ) x $4186 \text{ J}\cdot\text{kcal}^{-1}$ x $10\,000 \text{ m}^2\cdot\text{ha}^{-1}$ .			
	Erosion rates			
	5.1. Conventional tillage (CT)	31.5	$\text{g}\cdot\text{m}^{-2}\cdot\text{year}^{-1}$	BARROS et al. (2015a, b)
	5.2. Reduced tillage (RT)	19.6	$\text{g}\cdot\text{m}^{-2}\cdot\text{year}^{-1}$	BARROS et al. (2015a, b)
	5.3. No-till (NT)	16.4	$\text{g}\cdot\text{m}^{-2}\cdot\text{year}^{-1}$	BARROS et al. (2015a, b)
	Organic content in the soil	0.0186	$\text{g}\cdot\text{g}^{-1}$	BARROS et al. (2015a, b)
	Energy in soil loss			
	5.1. Conventional tillage (CT)	$1.32\text{E}+08$	$\text{J}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$	
	5.2. Reduced tillage (RT)	$8.25\text{E}+07$	$\text{J}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$	
	5.3. No-till (NT)	$6.89\text{E}+07$	$\text{J}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$	
<b>6</b>	<b>Fuel &amp; Lubricants</b>			
	Energy in fuel and lubricants: quantity of fuel and lubricants (l) x energy content ( $4.77\text{E}+07 \text{ J}\cdot\text{l}^{-1}$ )			
	Machine-hours used up			
	6.1. Conventional tillage (CT)	8.32	$\text{m}/\text{h}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$	MATOSO AND MELO FILHO (2009)
	6.2. Reduced tillage (RT)	6.29	$\text{m}/\text{h}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$	MATOSO AND MELO FILHO (2009)
	6.3. No-till (NT)	4.32	$\text{m}/\text{h}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$	MATOSO AND MELO FILHO (2009)
	Average consumptions			
	Diesel	12	$\text{l}\cdot(\text{m}/\text{h})^{-1}$	Based on tractor power
	Lubricants	0.05	$\text{l}\cdot(\text{m}/\text{h})^{-1}$	Based on tractor power
	Fuel used: machine-hours (m/h) x consumption ( $\text{l}\cdot(\text{m}/\text{h})^{-1}$ )			
	6.1. Conventional tillage (CT)	100.01	$\text{l}\cdot\text{ha}^{-1}$	
	6.2. Reduced tillage (RT)	75.58	$\text{l}\cdot\text{ha}^{-1}$	
	6.3. No-till (NT)	51.89	$\text{l}\cdot\text{ha}^{-1}$	
	Energy in fuels and lubricants:			
	6.1. Conventional tillage (CT)	$4.77\text{E}+09$	$\text{J}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$	
	6.2. Reduced tillage (RT)	$3.61\text{E}+09$	$\text{J}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$	
	6.3. No-till (NT)	$2.49\text{E}+09$	$\text{J}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$	

**Appendix 1. Continuação.**

Note	Description	Value	Unit	Source
<b>7</b>	<b>Seeds</b>			
	Mass of seeds used: mass of seeds (g.ha <sup>-1</sup> .year <sup>-1</sup> ) x (1-humidity)			
	Seeds used	3.0E+04	g.ha <sup>-1</sup> .year <sup>-1</sup>	From field work
	Humidity of seeds	0.13	g.g <sup>-1</sup>	From seed supplier
	<i>Mass of seeds used</i>	<i>2.65E+04</i>	<i>g.ha<sup>-1</sup>.year<sup>-1</sup></i>	
<b>8</b>	<b>Nitrogen Fertilizer (N)</b>			
	Nitrogen fertilizer used: N in starter application (g.ha <sup>-1</sup> .year <sup>-1</sup> ) + N in sidedress application (g.ha <sup>-1</sup> .year <sup>-1</sup> )			
	N starter			
	MAP used (10-50-00)	2.0E+05	g.ha <sup>-1</sup> .year <sup>-1</sup>	From field work
	N content in MAP	0.10	g.g <sup>-1</sup>	Supplier information
	N starter application	2.0E+04	g.ha <sup>-1</sup> .year <sup>-1</sup>	
	N sidedress			
	Urea used	4.0E+05	g.ha <sup>-1</sup> .year <sup>-1</sup>	From field work
	N content in Urea	0.45	g.g <sup>-1</sup>	Supplier information
	N starter application	1.8E+05	g.ha <sup>-1</sup> .year <sup>-1</sup>	
	<i>Nitrogen fertilizer used</i>	<i>2.0E+05</i>	<i>g.ha<sup>-1</sup>.year<sup>-1</sup></i>	
<b>9</b>	<b>Phosphate Fertilizer (P<sub>2</sub>O<sub>5</sub>)</b>			
	Phosphate fertilizer used: P <sub>2</sub> O <sub>5</sub> in starter application (g.ha <sup>-1</sup> .year <sup>-1</sup> )			
	MAP used (10-50-00)	2.0E+05	g.ha <sup>-1</sup> .year <sup>-1</sup>	From field work
	P <sub>2</sub> O <sub>5</sub> content in MAP	0.5	g.g <sup>-1</sup>	Supplier information
	<i>Phosphate fertilizer used</i>	<i>1.0E+05</i>	<i>g.ha<sup>-1</sup>.year<sup>-1</sup></i>	
<b>10</b>	<b>Herbicide: Atrazine</b>			
	Herbicide consumption (Atrazine): Product consumption (l.ha <sup>-1</sup> .year <sup>-1</sup> ) x active ingredient content (g.l <sup>-1</sup> )			
	Product consumption			
	10.1. Conventional tillage (CT)	4.0	l.ha <sup>-1</sup> .year <sup>-1</sup>	From field work
	10.2. Reduced tillage (RT)	4.0	l.ha <sup>-1</sup> .year <sup>-1</sup>	From field work
	10.3. No-till (NT)	0.0	l.ha <sup>-1</sup> .year <sup>-1</sup>	From field work
	Active ingredient content	500	g.l <sup>-1</sup>	Supplier information

Continua...



**Appendix 1. Continuação.**

Note	Description	Value	Unit	Source
	<i>Atrazine consumption</i>			
	10.1. Conventional tillage (CT)	2.0E+03	g.ha <sup>-1</sup> .year <sup>-1</sup>	
	10.2. Reduced tillage (RT)	4.0E+03	g.ha <sup>-1</sup> .year <sup>-1</sup>	
	10.3. No-till (NT)	0.0E+03	g.ha <sup>-1</sup> .year <sup>-1</sup>	
<b>11</b>	<b>Herbicide: Glyphosate</b>			
	Herbicide consumption (Glyphosate): Product consumption (l.ha <sup>-1</sup> .year <sup>-1</sup> ) x active ingredient content (g.l <sup>-1</sup> )			
	Product consumption			
	10.1. Conventional tillage (CT)	0.0	l.ha <sup>-1</sup> .year <sup>-1</sup>	From field work
	10.2. Reduced tillage (RT)	0.0	l.ha <sup>-1</sup> .year <sup>-1</sup>	From field work
	10.3. No-till (NT)	3.0	l.ha <sup>-1</sup> .year <sup>-1</sup>	From field work
	Active ingredient content	480	g.l <sup>-1</sup>	Supplier information
	<i>Glyphosate consumption</i>			
	10.1. Conventional tillage (CT)	0.0E+03	g.ha <sup>-1</sup> .year <sup>-1</sup>	
	10.2. Reduced tillage (RT)	0.0E+03	g.ha <sup>-1</sup> .year <sup>-1</sup>	
	10.3. No-till (NT)	1.44E+03	g.ha <sup>-1</sup> .year <sup>-1</sup>	
<b>12</b>	<b>Agricultural machinery</b>			
	Machinery depreciation: Sum of (# of machines (#.ha <sup>-1</sup> ) x average weight (kg.machine <sup>-1</sup> ) x 1E+3 g.kg <sup>-1</sup> / machine lifespan (hours) x machine-hours used up (hours.year <sup>-1</sup> ))			
	Total # of machines			
	12.1. Conventional tillage (CT)			
	12.1.1. Tractor (105 hp)	01	#.ha <sup>-1</sup>	
	12.1.2. Disk plow (4 disks - reversible)	01	#.ha <sup>-1</sup>	
	12.1.3. Disk harrow (14 disks 24" off-set)	01	#.ha <sup>-1</sup>	
	12.1.4. Sprayer	01	#.ha <sup>-1</sup>	
	12.1.5. Row crop planter (5 rows)	01	#.ha <sup>-1</sup>	
	12.1.6. Fertilizer distributor (24 m spam)	01	#.ha <sup>-1</sup>	
	12.1.7. Cereal harvester (2 lines for corn)	01	#.ha <sup>-1</sup>	
	12.1.8. Trailer (2 axles)	01	#.ha <sup>-1</sup>	

Continua...

**Appendix 1. Continuação.**

Note	Description	Value	Unit	Source
12.2. Reduced tillage (RT)				
12.2.1.	Tractor (105 hp)	01	#.ha <sup>-1</sup>	
12.2.2.	Disk harrow (14 disks 24" off-set)	01	#.ha <sup>-1</sup>	
12.2.3.	Chisel plow (7 tynes)	01	#.ha <sup>-1</sup>	
12.2.4.	Sprayer	01	#.ha <sup>-1</sup>	
12.2.5.	Row crop planter (5 rows)	01	#.ha <sup>-1</sup>	
12.2.6.	Fertilizer distributor (24 m spam)	01	#.ha <sup>-1</sup>	
12.2.7.	Cereal harvester (2 lines for corn)	01	#.ha <sup>-1</sup>	
12.2.8.	Trailer (2 axles)	01	#.ha <sup>-1</sup>	
12.3. No-till (NT)				
12.3.1.	Tractor (105 hp)	01	#.ha <sup>-1</sup>	
12.3.4.	Sprayer	01	#.ha <sup>-1</sup>	
12.3.5.	Row crop planter no-till (5 rows)	01	#.ha <sup>-1</sup>	
12.3.6.	Fertilizer distributor (24 m spam)	01	#.ha <sup>-1</sup>	
12.3.7.	Cereal harvester (2 lines for corn)	01	#.ha <sup>-1</sup>	
12.3.8.	Trailer (2 axles)	01	#.ha <sup>-1</sup>	
Average weight				
	Tractor (105 hp)	5,775	kg.machine <sup>-1</sup>	Equipment's technical manual
	Disk plow (4 disks - reversible)	947	kg.machine <sup>-1</sup>	Equipment's technical manual
	Disk harrow (14 disks 24" off-set)	600	kg.machine <sup>-1</sup>	Equipment's technical manual
	Chisel plow (7 tynes)	290	kg.machine <sup>-1</sup>	Equipment's technical manual
	Sprayer (Condor M12 Jacto)	255	kg.machine <sup>-1</sup>	Equipment's technical manual
	Row crop planter (5 rows)	792	kg.machine <sup>-1</sup>	Equipment's technical manual
	Row crop planter no-till (5 rows)	1,093	kg.machine <sup>-1</sup>	Equipment's technical manual
	Fertilizer distributor (24 m spam)	280	kg.machine <sup>-1</sup>	Equipment's technical manual
	Cereal harvester (2 lines for corn)	2,100	kg.machine <sup>-1</sup>	Equipment's technical manual
	Trailer (2 axles)	1,500	kg.machine <sup>-1</sup>	Equipment's technical manual

Continua...

**Appendix 1. Continuação.**

Note	Description	Value	Unit	Source
<i>Machine lifespan</i>				
	Tractor (105 hp)	15,000	hours	KALLIVROUSSIS et al. (2002)
	Disk plow (4 disks - reversible)	2,500	hours	KALLIVROUSSIS et al. (2002)
	Disk harrow (14 disks 24" off-set)	2,500	hours	KALLIVROUSSIS et al. (2002)
	Chisel plow (7 tynes)	2,500	hours	KALLIVROUSSIS et al. (2002)
	Sprayer (Condor M12 Jacto)	1,500	hours	KALLIVROUSSIS et al. (2002)
	Row crop planter (5 rows)	2,000	hours	KALLIVROUSSIS et al. (2002)
	Row crop planter no-till (5 rows)	2,000	hours	KALLIVROUSSIS et al. (2002)
	Fertilizer distributor (24 m spam)	2,500	hours	KALLIVROUSSIS et al. (2002)
	Cereal harvester (2 lines for corn)	2,500	hours	KALLIVROUSSIS et al. (2002)
	Trailer (2 axles)	15,000	hours	KALLIVROUSSIS et al. (2002)
<i>Machinery depreciation</i>				
	12.1. Conventional tillage (CT)	9.59E + 03	$g.ha^{-1}.year^{-1}$	
	12.2. Reduced tillage (RT)	4.36E + 03	$g.ha^{-1}.year^{-1}$	
	12.3. No-till (NT)	3.39E + 03	$g.ha^{-1}.year^{-1}$	
<b>13</b>	<b>Transport bags</b>			
	Transport bags: yield ( $kg.ha^{-1}$ ) / ( $60kg.bag^{-1}$ ) x (cost of bag ( $US\$.bag^{-1}$ ))			
	<i>Average yield</i>			
	13.1. Conventional tillage (CT)	8,238	$kg.ha^{-1}.year^{-1}$	From field work
	13.2. Reduced tillage (RT)	8,051	$kg.ha^{-1}.year^{-1}$	From field work
	13.3. No-till (NT)	8,268	$kg.ha^{-1}.year^{-1}$	From field work
	Cost of bag	0.53	$US\$.bag^{-1}$	PACHECO et al. (2013)
	<i>Transport bags</i>			
	13.1. Conventional tillage (CT)	80.30	$US\$.ha^{-1}.year^{-1}$	
	13.2. Reduced tillage (RT)	80.30	$US\$.ha^{-1}.year^{-1}$	
	13.3. No-till (NT)	80.30	$US\$.ha^{-1}.year^{-1}$	

Continua...

**Appendix 1. Continuação.**

Note	Description	Value	Unit	Source
<b>14</b>	<b>Labor</b>			
	Energy of human labor: working hours (hrs.ha <sup>-1</sup> .year <sup>-1</sup> ) x 312.5 kcal.hour <sup>-1</sup> x 4.186E+06 J.kcal <sup>-1</sup>			
	Working hours			
14.1.	Conventional tillage (CT)	38.32	hrs.ha <sup>-1</sup> .year <sup>-1</sup>	MATOSO AND MELO FILHO (2009)
14.2.	Reduced tillage (RT)	35.32	hrs.ha <sup>-1</sup> .year <sup>-1</sup>	MATOSO AND MELO FILHO (2009)
13.3.	No-till (NT)	32.32	hrs.ha <sup>-1</sup> .year <sup>-1</sup>	MATOSO AND MELO FILHO (2009)
	<i>Energy of human labor</i>			
14.1.	Conventional tillage (CT)	5.01E+07	J.ha <sup>-1</sup> .year <sup>-1</sup>	
14.2.	Reduced tillage (RT)	4.62E+07	J.ha <sup>-1</sup> .year <sup>-1</sup>	
13.3.	No-till (NT)	4.23E+07	J.ha <sup>-1</sup> .year <sup>-1</sup>	
<b>15</b>	<b>Services</b>			
	Soil analysis	0.97	US\$.ha <sup>-1</sup>	1 sample for each 10 ha
	Machinery maintenance	2.02	US\$. (m/h) <sup>-1</sup>	www.portalkff.com.br
	Machinery insurance	0.30	US\$. (m/h) <sup>-1</sup>	www.portalkff.com.br
	<i>Services</i>			
14.1.	Conventional tillage (CT)	21.90	US\$.ha <sup>-1</sup> .year <sup>-1</sup>	
14.2.	Reduced tillage (RT)	17.10	US\$.ha <sup>-1</sup> .year <sup>-1</sup>	
13.3.	No-till (NT)	12.50	US\$.ha <sup>-1</sup> .year <sup>-1</sup>	
<b>16</b>	<b>Maize output</b>			
	Energy in maize grains: (mass of grains(g.ha <sup>-1</sup> .year <sup>-1</sup> ) x grain humidity (g.g <sup>-1</sup> ) x protein content (g.g <sup>-1</sup> ) x energy of protein (J.g <sup>-1</sup> )) + (mass of grains(g.ha <sup>-1</sup> .year <sup>-1</sup> ) x grain humidity (g.g <sup>-1</sup> ) x carbohydrate content (g.g <sup>-1</sup> ) x energy of carbohydrate (J.g <sup>-1</sup> )) + (mass of grains(g.ha <sup>-1</sup> .year <sup>-1</sup> ) x grain humidity (g.g <sup>-1</sup> ) x fat content (g.g <sup>-1</sup> ) x energy of fat (J.g <sup>-1</sup> ))			
	Mass of grains			
16.1.	Conventional tillage (CT)	8.238E+06	g.ha <sup>-1</sup> .year <sup>-1</sup>	Direct measurement
16.2.	Reduced tillage (RT)	8.051E+06	g.ha <sup>-1</sup> .year <sup>-1</sup>	Direct measurement
16.3.	No-till (NT)	8.268E+06	g.ha <sup>-1</sup> .year <sup>-1</sup>	Direct measurement

Continua...

**Appendix 1. Continuação.**

Note	Description	Value	Unit	Source
	Standard grain humidity	0.130	g.g <sup>-1</sup>	From field work
	Protein content	0.136	g.g <sup>-1</sup>	PAUL AND SOUTHGATE (1978)
	Carbohydrate content	0.789	g.g <sup>-1</sup>	PAUL AND SOUTHGATE (1978)
	Fat content	0.079	g.g <sup>-1</sup>	PAUL AND SOUTHGATE (1978)
	Energy content of protein	24.0E+03	J.g <sup>-1</sup>	PAUL AND SOUTHGATE (1978)
	Energy content of carbohydrate	17.0E+03	J.g <sup>-1</sup>	PAUL AND SOUTHGATE (1978)
	Energy content of fat	39.0E+03	J.g <sup>-1</sup>	PAUL AND SOUTHGATE (1978)
<hr/>				
<i>Energy in maize grains</i>				
	<i>16.1. Conventional tillage (CT)</i>	<i>1.436E+11</i>	<i>J.ha<sup>-1</sup>.year<sup>-1</sup></i>	
	<i>16.2. Reduced tillage (RT)</i>	<i>1.401E+11</i>	<i>J.ha<sup>-1</sup>.year<sup>-1</sup></i>	
	<i>16.3. No-till (NT)</i>	<i>1.439E+11</i>	<i>J.ha<sup>-1</sup>.year<sup>-1</sup></i>	

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**Embrapa**

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***Tabuleiros Costeiros***

Ministério da  
**Agricultura, Pecuária  
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