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Integrated Systems for Food, Ethanol and Environmental Services Production in Land Reform Settlements

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ABSTRACT

This work aimed to assess the environmental impact and the economic and social contribution of a small-scale ethanol distillery project in a group of peasants in the settlement "Gleba XV de Novembro", Rosana County, Pontal do Paranapanema region, São Paulo State, Brazil. The effects of the micro-distillery insertion into the production system were verified through the use of scenarios, emergy methodology, economic indicators and participatory tools. The results demonstrate that: (a) the micro-distillery implementation on an integrated way obtained good emergy performance (ELR = 0.66%; R = 72%), but without the integration the emergy performance decreased (ELR = 0.91 %; R = 63%); (c) the distillery project is economically viable (Payback = 3.3 years, IRR = 20%, and Simple Return = 51.2%); (d) the project could provide economic return and social inclusion (jobs). Therefore, the micro-distillery implementation in an integrated way could contribute to sustainable development of rural settlements.

INTRODUCTION

Since the stocks of oil are finishing (Campbel and Laherre, 1998) and the use and combustion of fossil fuel contribute substantially to carbon dioxide emissions, thereby contributing to global warming and climate change, the development of renewable energy sources have been encouraged (Pimentel et al, 1994). Energy from biomass is being announced as one of the main solutions (Goldemberg, 2007). One of the most important alternatives could be the use of liquid biofuels, such as ethanol, to replace gasoline and other petrochemical products.

In Brazil, most of the ethanol is produced in huge distilleries fed by sugarcane produced in large monoculture areas. This production system is showing several undesirable consequences. In the last twenty years the sugarcane crop area in São Paulo state had a great increase, almost doubling. The concern is that the expansion of sugarcane crops is competing, directly or indirectly, for land with other crops and could affect the food production (Goldemberg el al., 2008).

Pereira and Ortega (2010) using the Emergy Methodology and Life Cycle Assessment (LCA) showed that the large-scale ethanol production system has a small renewability (30.9%). It is important to highlight that the agricultural stage is the major contributor for that fact, using 80% of non-renewable inputs. In addition, a critical part of sugarcane processing is manual harvesting due to exhaustive and unhealthy work conditions and low wages (Alves and Paixão, 2008).

Instead of using huge industrial assets, the ethanol from sugarcane can be produced in small scale units, the so-called Integrated Systems for Food, Energy and Environmental Services production (ISFEES) that include micro-distilleries.

Ethanol Micro-distilleries

Ethanol micro-distillery is a small-scale ethanol production system. The production scale varies from 50 to 600 liters of ethanol per day and the area for sugarcane crop can varies from 1 to 11 hectares. The system is basically composed by a sugarcane mill, filtration and dilution tanks, fermentation tanks and distillation column (Figure 1). A boiler is also necessary to produce steam for the process. The structure is simple and the technology is not expensive. Despite that fact, there are a few companies producing the micro-distillery equipment.

There are some experiences of micro-distilleries running in Brazil in the states of Minas Gerais, São Paulo, Rio Grande do Sul, Santa Catarina, among others. One interesting example is

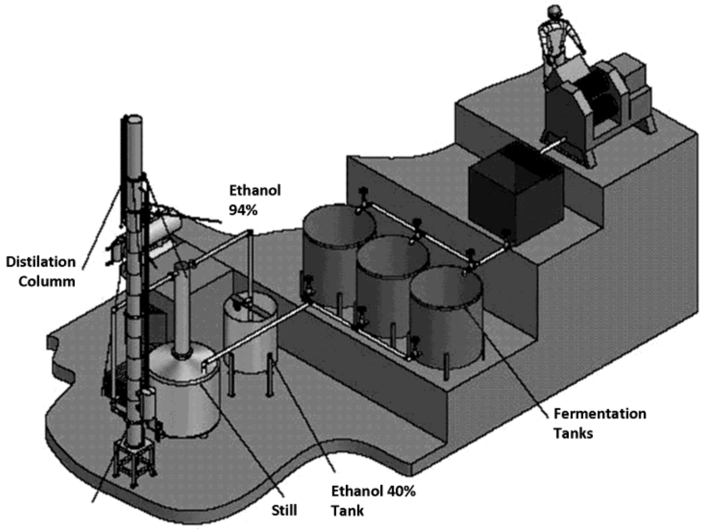

Figure 1. *Micro-distillery layout. Source: Tecnosignal (2010).*

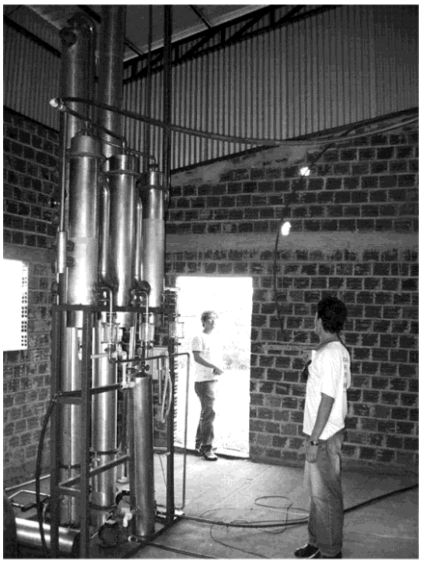

Figure 2. *Micro-distillery of COOPERBIO, Rio Grande do Sul State, Brazil*.

COOPERBIO, a cooperative of small scale farmers that is producing ethanol using micro-distillery with success (Figure 2).

Integrated Systems for Food, Energy and Environmental Services (ISFEES)

An integrated approach means that the system is designed to maximize the interaction of the system's parts through the use of products or by-products of one component by other one in order to minimize the dependence of external resources.

In this study, the requirement of sugarcane area for a micro-distillery with a production capacity of 400 liters per day is about 10 hectares. For example, considering a group of ten small farmers, each one would need to cultivate only 1 ha of sugarcane. Also, ethanol by-products such as bagasse and vinasse (distillation waste) can be used to feed animals or to fertilize the crops directly or after a composting process. In this way, productivity of the other parts of the farming system can be improved and the costs of food production reduced due to the diminishing of the purchase of inputs. Therefore, beyond the energy production, micro-distilleries allow the preservation of native forests and food production areas. In addition, this kind of integrated system leads to a democratic process due the decentralization of the production, profit, technology and, consequently, power (Vasconcelos, 2002).

Therefore, ISFEES model is able to meet social, environmental and economical goals. ISFEES is also able to overcome the technological challenge of producing ethanol at low cost and good quality without land competition with food crops (USI, 2008). The key aspect is that ISFEES considers the interactions between farm components and the environmental services. It is important to mention that in order to obtain the interactions among the different parts of the system (agriculture and livestock basically), a new kind of participatory management is mandatory. It should follow agroecological concepts and principles for system design and management of sustainable agroecosystems (Gliessman, 2000).

Land Reform Settlements and IFEES

Land Reform public policy modifies land use in order to benefit landless workers and small scale farmers with areas for new rural settlements. However, the driving force of most of agrarian reform settlements is the pressure of landless rural workers movements (Bergamasco, 1996; Heredia et al., 2005).

Success on the implementation of agrarian reform settlements in Brazil depends on two main factors: soil fertility and governmental support. Most of land reform settlements in São Paulo State are located in low fertility soils. The governmental support is deficient, inadequate and applied incorrectly when it exists. Consequently, the infrastructure of most settlements is very poor (Heredia et al., 2005; Bueno et al., 2007). Therefore, one step toward in order to succeed is recovering the soil's natural fertility. ISFEES could be a good way of enhancing the settlements' production by inserting micro-distilleries in the system to make interactions with the other system parts (ecological agriculture and agroforestry systems).

The purpose of this work is to use participatory tools in the project design, emergy methodology and economic analysis to study a pioneering project with high public policy relevance in Brazil: the integrated system to produce energy, food, and environmental services (ISFEES) applied in a group of small farmers of a land reform settlement.

MATERIALS AND METHODS

Study Area

This study was carried out in the land reform settlement "Gleba VX de Novembro", located in Rosana County (Figure 3) in the western region of São Paulo State. This settlement is composed of 572 plots with an average size of 23 ha and it has about 1500 families living there. The landscape is composed by degraded and poor pasture areas (Figure 4). The main economic activity is grazing cattle for milk production to sell to regional dairy industries.

This case study was prepared to respond to a group of rural settlers interested in ethanol production using micro-distilleries as an alternative for developing the settlement. So, this study has considered the group of interested peasants and the area of their plots and not the whole settlement for the calculations.

Methods

In order to analyze the effect of the micro-distillery insertion in a land reform settlement to form an IFEES, three scenarios were studied: (a) the current situation, i.e., the settlement without the micro-distillery; (b) the scenario of an incomplete IFEES (or proto-IFEES, created to measure the relevance of integration); and (c) the scenario of a complete IFEES.

The effect of the micro-distillery insertion was evaluated in terms of ecosystemic and economic methods. The emergy accounting methodology (Odum, 1996) was used considering the partial renewability of the inputs from economy as proposed by Ortega et al. (2005) in order to assess the environmental performance. The economic methods used were: payback, break-even-point, internal rate of return (IRR), net present value (NPV) and simple profit, in order to evaluate the expected economic return.

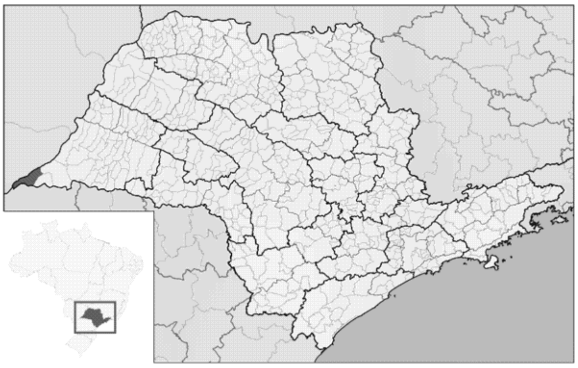

Figure 3. *Rosana County, location on the State of São Paulo and Brazil*.

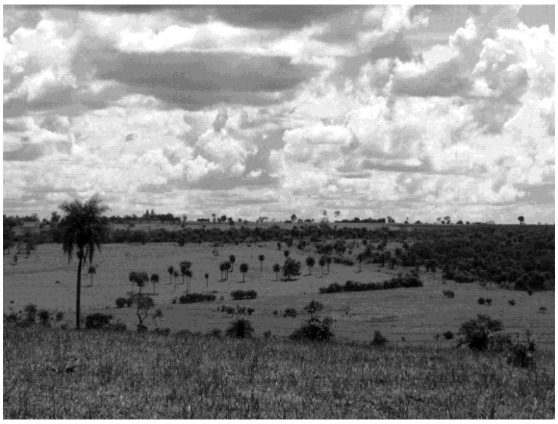

Figure 4. *View of "Gleba XV de Novembro" settlement*.

In addition, during the research, "Participant Observation" (Geilfus, 1997) was used in order to understand the reality of the peasants. It means taking part of various daily activities with the small farmers in order to consider their potentials and limits in the economic and ecological design.

Defining the Scenarios

A group of seven families was considered in which each family is living in an area of 23 hectares (average plot size). So, the total area of the system is 161 hectares. The use and occupation of the soil was based in official data of state institutions, as well as the collected data on the inputs and the output.

Current Scenario

This scenario consists in the current characteristics of the settlers group, which are:

- The 161 ha of the system area are divided in: 27.18 ha (17%) of forest, 29.74 ha (18%) of crops and 104.09 ha (65%) of pasture;
- The 27.18 ha (17%) of forested area are below the minimum required (20%) by the Brazilian legislation.
- The crop area is diversified: cassava, beans, maize, soybean, banana, and coffee, among others.

Future Scenario as Proto-ISFEES

This scenario considers the insertion of the micro-distillery without integration with the others system's components. The characteristics of this scenario are:

- The ethanol production is 192 liters/day (38,400 liters/year). To reach this amount an area of 7.0 ha of sugarcane (1.0 ha in each family) is necessary;
- It was considered that 3.5 hectares (0.5 ha each family) of sugarcane would be needed to produce 280 ton/year of “rapadura” (brown sugar) and 1.0 ha for eucalyptus, to produce wood to be used in the steamer.
- The 161 ha in this scenario are divided in: 27.18 ha (17%) of forest, 29.74 ha (18%) of crops, 92.48 ha (57.5%) of pasture, 10.5 ha (6.5%) of sugarcane, 1.0 ha (0.9%) of eucalyptus and 0.1 ha (0.1%) for the micro-distillery.
- The crop area diversity remains the same as the current scenario;
- The forest area remains the same (not according to the Brazilian legislation).

Future Scenario as a Complete ISFEES

This scenario considers the insertion of the micro-distillery in an integrated way and its characteristics are:

- The ethanol and “rapadura” production and the respective areas of sugarcane are the same as the proto-IFEES scenarios;
- An increase in the forest area was considered to reach the minimum of 20% of forest reserve necessary to obey the Brazilian legislation;
- The system management is integrating-oriented; the by-products of the micro-distillery are used in the crops and the livestock sub-systems. It was considered a area for composting, in order to produce organic compost;
- The 161 ha in this scenario is divided in: 32.2 ha of forest, 29.74 ha of crops, 87.36 ha of pasture, 10.5 ha of sugarcane, 1.0 ha of eucalyptus, 0.1 ha for the micro-distillery and 0.1 ha for the composting.
- A higher cattle density was considered because the use of bagasse and vinasse as extra feed allows more animals per area;
- The use of agroecological concepts was considered in the management of the farming systems. It means no use of chemical fertilizers, agrochemicals, and lower erosion.

RESULTS AND DISCUSSION

Figures 5, 6 and 7 show the system diagrams for the current and futures systems with the insertion of “the non-integrated micro-distillery” (proto-ISFEES) and “the integrated micro-distillery” (ISFEES).

The comparison of systemic diagrams allows to identify that the incorporation of a micro-distillery into the farm system can generate a more complex system if all the interactions are made possible. If the integration does not occur the micro-distillery is just one more element in the system, so the complexity is quite the same as the current situation.

The emergy calculations are shown in table 1 for the current system, in Table 2 for the proto-ISFEES scenario and in Table 3 for the ISFEES scenario. The comparison of the emergy performance indicators of all scenarios is shown in Table 4.

In general, the emergy performance indicators for the ISFEES scenario pointed out better performance than for the current situation and the proto-ISFEES scenario. Figure 8 shows the aggregated flows and the energy output of the three scenarios. The ISFEES scenario uses more renewable emergy and less emergy from materials (M) than the other scenarios. In addition, the energy output of the ISFEES scenario was larger than the others.

Considering the incorporation of a small scale equipment (i.e. increase of external materials use) non-integrated with the other parts of the system, made the renewability decrease compared to the current scenario. On the other hand, it is interesting to observe that the micro-distillery integration with the other parts of the system resulted in a renewability value close to the current situation. Therefore, the integration is an important process towards a better environmental performance, once it allows stopping the use of chemical fertilizers and pesticides in the system.

It is important to mention that in order to integrate the micro-distillery with the system a management based on agroecological concepts was assumed. So, the use of agroecology framework is crucial to allow the mobilization of soil nutrients for crop and pasture production.

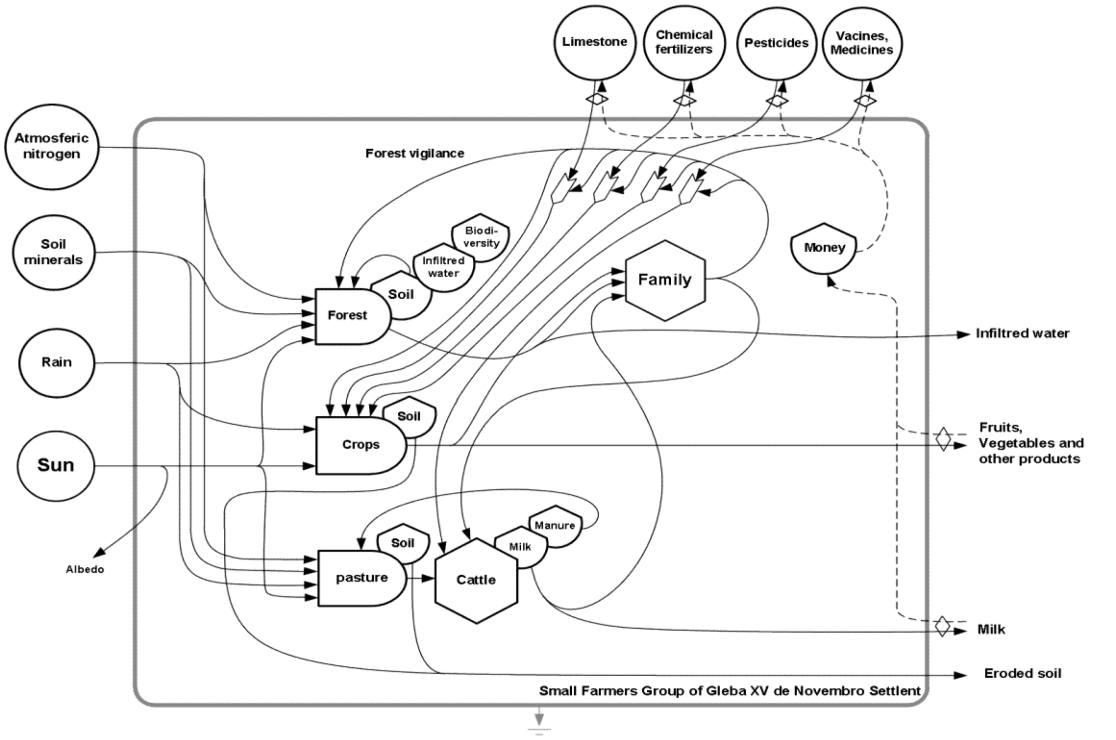

Figure 5. *System diagram of current scenario.*

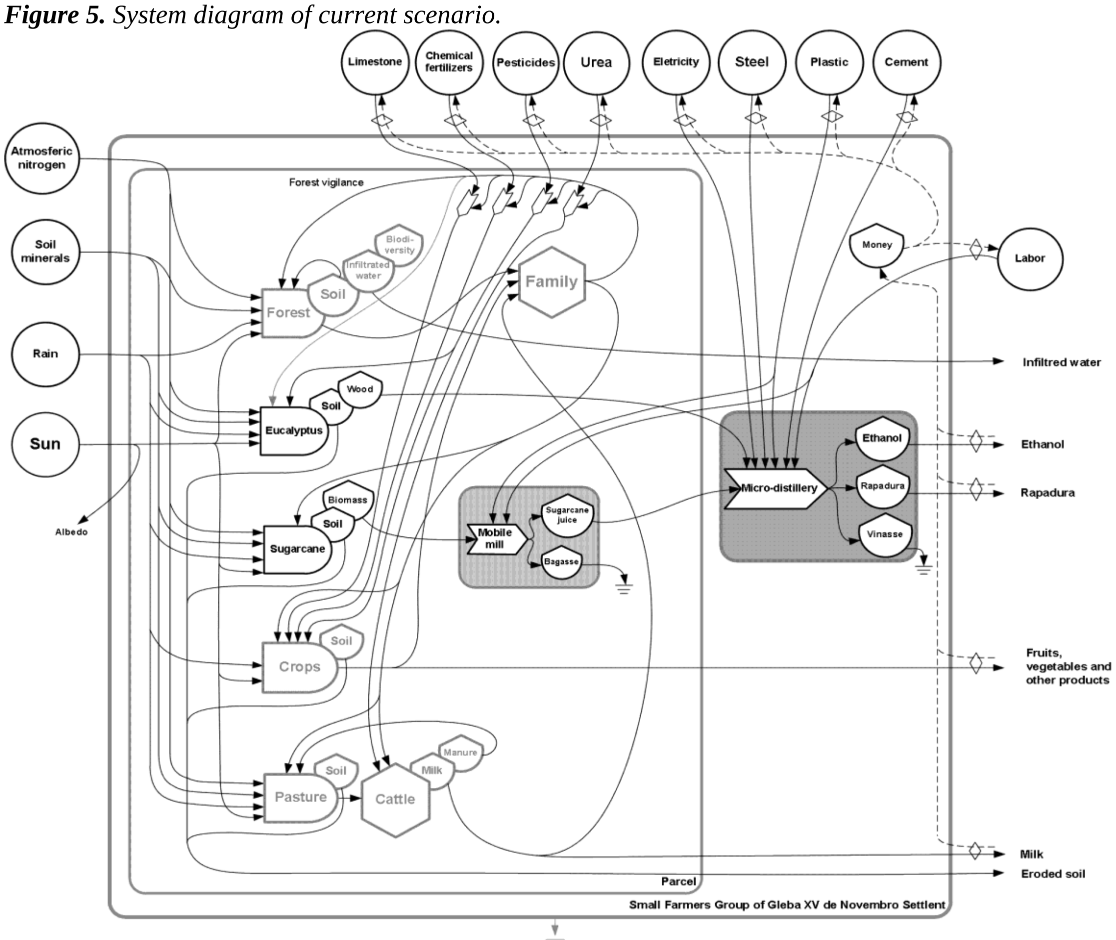

Figure 6. *System diagram of proto-ISFEES scenario.*

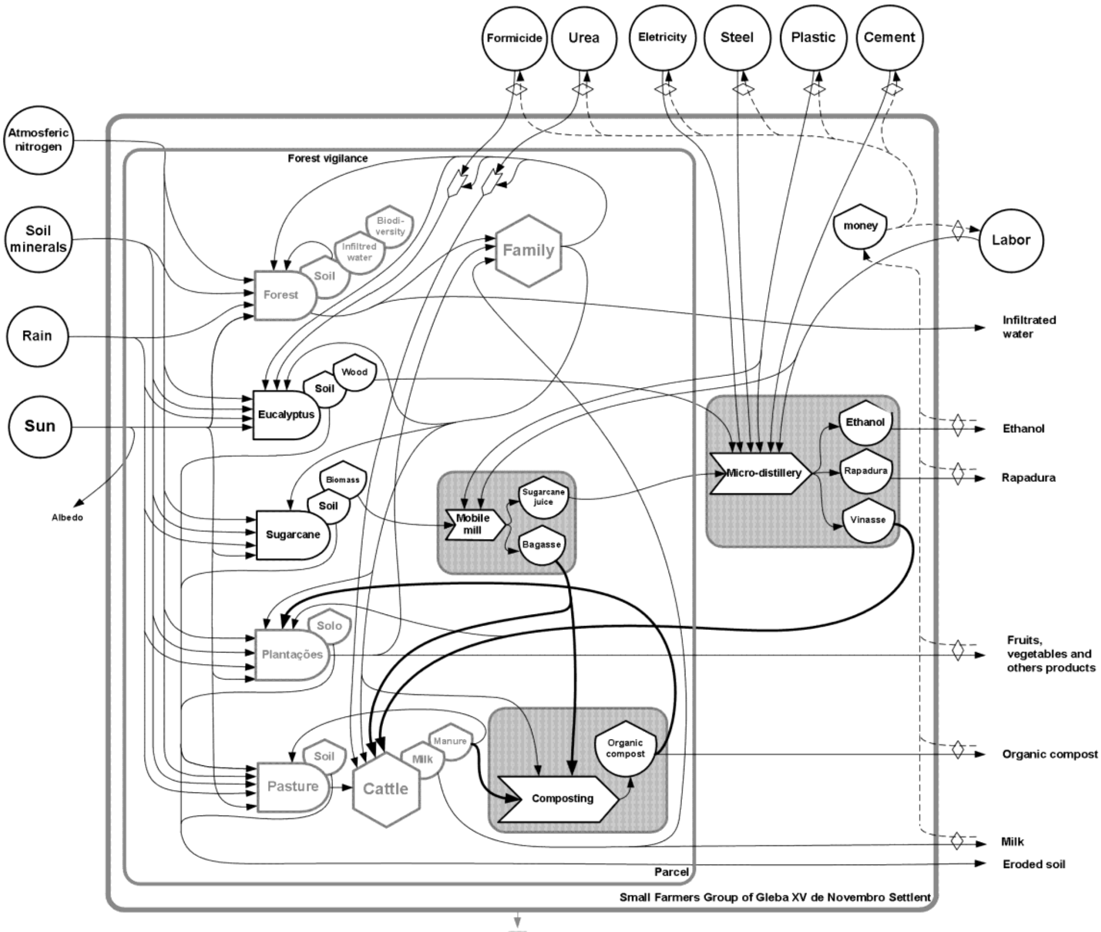

Figure 7. *System diagram of ISFEES scenario.*

Table 1. Emergy evaluation table for the current situation.

Note	Contributions	Renew. fraction	Flux [unit/ha/year]	Unit	Unit Emergy Value seJ/unit	Ref	Renewable Emergy seJ/ha/year	Non-renewable Emergy seJ/ha/year	Total Emergy seJ/ha/year	%
	Renewable						**3.20E+15**	**0.00E+00**	**3.20E+15**	**68.0**
1	Sun	1	5.57E+13	J	1.00E+00	[a]	5.57E+13	0.00E+00	5.57E+13	1.2
2	Rain	1	6.00E+10	J	3.10E+04	[b]	1.86E+15	0.00E+00	1.86E+15	39.6
3	Atm. nitrogen	1	103	kg	7.73E+12	[a]	7.94E+14	0.00E+00	7.94E+14	16.9
4	Soil minerals	1	103	kg	4.74E+12	[a]	4.87E+14	0.00E+00	4.87E+14	10.4
	Non-renewable						**0.00E+00**	**1.05E+15**	**1.05E+15**	**22.3**
5	Eroded soil	0	18.513	kg	2.83E+12	[b]	0.00E+00	1.05E+15	1.05E+15	22.3
	Materials						**4.42E+12**	**4.38E+14**	**4.42E+14**	**9.4**
6	Limestone	0.01	172	kg	1.00E+12	[c]	1.72E+12	1.70E+14	1.72E+14	3.7
7	Nitrogen	0.01	14.0	kg	7.73E+12	[a]	1.09E+12	1.07E+14	1.09E+14	2.3
8	Phosphorous	0.01	14.6	kg	6.55E+12	[a]	9.57E+11	9.48E+13	9.57E+13	2.0
9	Potash	0.01	18.4	kg	2.92E+12	[a]	5.37E+11	5.31E+13	5.37E+13	1.1
10	Pesticides	0.01	0.55	kg	1.48E+13	[b]	8.19E+10	8.11E+12	8.19E+12	0.2
11	Vaccines, medicine	0.01	1.22	US$	3.12E+12	[d]	3.80E+10	3.76E+12	3.80E+12	0.1
	Services						**1.02E+13**	**4.71E+12**	**1.49E+13**	**0.3**
12	Local labor	0.68	1.92E+07	J	7.73E+05	[e]	1.02E+13	4.71E+12	1.49E+13	0.3
	Total Emergy						**3.21E+15**	**1.49E+15**	**4.70E+15**	**100**

[a] Odum, 1996; [b] Brown and Ulgiati, 2004; [c] Brandt-Williams, 2002; [d] Coelho et al., 2003; [e] this work

(i) The baseline used is 15,83E+24 seJ/year, (ii) The item "Sun" was not accounted to avoid double accounting

Table 2. Emergy evaluation table for the proto-ISFEES scenario.

Note	Contributions	Renew. fraction	Flux unit/ ha/year	Unit	Unit emergy Value seJ/unit	Ref	Renewable Emergy seJ/ha/year	Non-renewable Emergy seJ/ha/year	Total Emergy seJ/ha/year	%
	Renewable						**2.61E+15**	**0.00E+00**	**2.61E+15**	**52.7**
1	Sun	1	5.57E+13	J	1.00E+00	[a]	5.57E+13	0.00E+00	5.57E+13	1.1
2	Rain	1	6.00E+10	J	3.10E+04	[b]	1.86E+15	0.00E+00	1.86E+15	37.5
3	Atm. nitrogen	1	56	kg	7.73E+12	[a]	4.33E+14	0.00E+00	4.33E+14	8.7
4	Soil minerals	1	56	kg	4.74E+12	[a]	2.65E+14	0.00E+00	2.65E+14	5.3
	Non-renewable						**0.00E+00**	**9.87E+14**	**9.87E+14**	**19.9**
5	Eroded soil	0	17.459	kg	2.83E+12	[b]	0.00E+00	9.87E+14	9.87E+14	19.9
	Materials						**1.66E+13**	**4.49E+14**	**4.65E+14**	**9.4**
6	Defensives	0	0.54	kg	1.48E+13	[b]	0.00E+00	8.04E+12	8.04E+12	0.2
7	Limestone	0	157	kg	1.00E+12	[c]	0.00E+00	1.57E+14	1.57E+14	3.2
8	Nitrogen	0	14	kg	7.73E+12	[a]	0.00E+00	1.06E+14	1.06E+14	2.1
9	Phosphorous	0	14	kg	6.55E+12	[a]	0.00E+00	8.92E+13	8.92E+13	1.8
10	Potash	0	18	kg	2.92E+12	[a]	0.00E+00	5.16E+13	5.16E+13	1.0
11	Electricity	0.5	56	kWh	5.94E+11	[a]	1.66E+13	1.66E+13	3.31E+13	0.7
12	Steel	0	1.46	kg	1.13E+13	[b]	0.00E+00	1.65E+13	1.65E+13	0.3
13	Plastic	0	0.02	kg	5.85E+12	[g]	0.00E+00	1.45E+11	1.45E+11	0.0
14	Cement	0	0.24	kg	2.07E+12	[g]	0.00E+00	4.87E+11	4.87E+11	0.0
16	Vaccine, medic	0	1.06	US$	3.30E+12	[d]	0.00E+00	3.49E+12	3.49E+12	0.1
	Services						4.95E+14	4.03E+14	8.98E+14	**18.1**
16	Local labor	0.63	2.35E+07	J	0.00E+00	[e]	2.92E+05	0.00E+00	2.92E+05	0.0
17	External labor	0.63	238	US$	3.30E+12	[d]	4.95E+14	2.91E+14	7.86E+14	15.8
18	Debt services	0	34	US$	3.30E+12	[d]	0.00E+00	1.12E+14	1.12E+14	2.3
	Total Emergy						**3.13E+15**	**1.84E+15**	**4.96E+15**	**100**

[a] Odum, 1996; [b] Brown and Ulgiati, 2004; [c] Brandt-Williams, 2002; [d] Coelho et al., 2003; [e] this work; [f] Cuadra e Rydberg, 2006; [g] Buranakarn, 1998 apud Buranakarn and Brown, 2002.
(i) The baseline used is 15.83E+24 seJ/year
(ii) The item "Sun" was not accounted to avoid double accounting

Table 3. Emergy evaluation table for the ISFEES scenario

Note	Contributions	Renew. fraction	Flux unit/ ha/year	Unit	Unit emergy value seJ/unit	Ref	Renewable Emergy seJ/ha/year	Non-renewable Emergy seJ/ha/year	Total Emergy seJ/ha/year	%
	Renewable						**3.49E+15**	**0.00E+00**	**3.49E+15**	**60.8**
1	Sun	1	5.57E+13	J	1.00E+00	[a]	5.57E+13	0.00E+00	5.57E+13	**1.0**
2	Rain	1	6.00E+10	J	3.10E+04	[b]	1.86E+15	0.00E+00	1.86E+15	**32.4**
3	Atm. nitrogen	1	126	kg	7.73E+12	[a]	9.74E+14	0.00E+00	9.74E+14	**17.0**
4	Soil minerals	1	126	kg	4.74E+12	[a]	5.97E+14	0.00E+00	5.97E+14	**10.4**
	Non-renewable						**0.00E+00**	**4.73E+14**	**4.73E+14**	**8.3**
5	Eroded soil	0	8.373	kg	2.83E+12	[b]	0.00E+00	4.73E+14	4.73E+14	**8.3**
	Materials						**1.66E+13**	**6.48E+14**	**6.65E+14**	**11.6**
6	Formicide	0	3.86E-05	kg	1.48E+13	[b]	0.00E+00	5.71E+08	5.71E+08	**0.0**
7	Electricity	0.5	56	kWh	5.94E+11	[a]	1.66E+13	1.66E+13	3.31E+13	**0.6**
8	Urea	0	92	kg	6.62E+12	[e]	0.00E+00	6.08E+14	6.08E+14	**10.6**
9	Steel	0	1	kg	1.13E+13	[b]	0.00E+00	1.65E+13	1.65E+13	**0.3**
10	Plastic	0	0.02	kg	5.85E+12	[f]	0.00E+00	1.45E+11	1.45E+11	**0.0**
11	Cement	0	0.24	kg	2.07E+12	[f]	0.00E+00	4.87E+11	4.87E+11	**0.0**
12	Vaccines, medic.	0	2	US$	3.30E+12	[c]	0.00E+00	6.59E+12	6.59E+12	**0.1**
	Services						6.61E+14	4.49E+14	1.11E+15	**19.3**
13	Local labor	0.73	2.56E+07	J	1.17E+05	[d]	2.18E+12	8.22E+11	3.00E+12	**0.1**
14	External labor	0.63	317	US$	3.30E+12	[c]	6.58E+14	3.87E+14	1.05E+15	**18.2**
15	Debt services	0	19	US$	3.30E+12	[c]	0.00E+00	6.11E+13	6.11E+13	**1.1**
	Total Emergy						**4.16E+15**	**1.57E+15**	**5.73E+15**	**100**

[a] Odum, 1996; [b] Brown and Ulgiati, 2004; [c] Coelho et al., 2003; [d] this work; [e] Cuadra and Rydberg, 2006; [f] Buranakarn, 1998 and Buranakarn and Brown. 2002.
(i) The baseline used is 15,83E+24 seJ/year, (ii) The item "Sun" was not accounted to avoid double accounting

Table 4. Emergy performance indicators for the three scenarios.

Indicator	Formula	Current scenario	Proto-ISFEES scenario	ISFEES scenario	Unit
Transformity	Tr = Y/Ep	769,351	291,353	117,815	seJ/J
Specific Emergy	Y/Total mass	4.58E+10	4.83E+10	1.19E+10	seJ/kg
Emergy Yield Ratio	EYR = Y/F	10.25	3.61	3.16	adimen.
Emergy Investment Ratio	EIR = F/I	0.11	0.38	0.46	adimen.
Environmental Loading Ratio	ELR = $(N+M_N+S_N)/(R+M_R+S_R)$	0.47	0.91	0.66	adimen.
Renewability	%R = $100(R+M_R+S_R/Y)$	68.2	62.8	71.9	%
Emergy Exchange Ratio	EER = Y/[($)*(seJ/$)]	3.74	1.22	1.15	adimen.

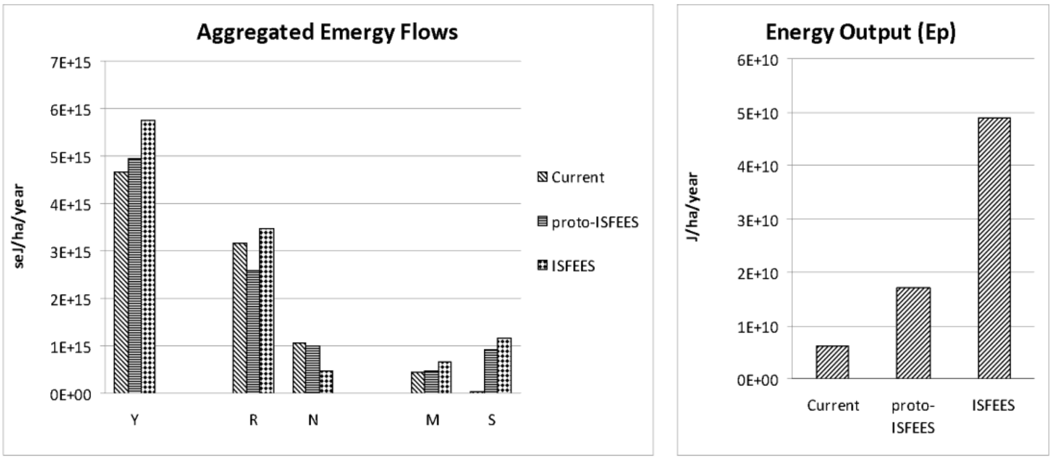

Figure 8. *Graphic of aggregated emergy flows and energy output for all scenarios.*

Table 5 shows the comparison of the emergy performance indicators obtained for proto-IFEES and IFEES scenarios with ethanol production and a large scale production of ethanol. The large-scale ethanol chosen is located in São Paulo State and was studied by Pereira and Ortega (2010). The environmental performance of the IFEES system is better than the large scale system. The renewability was twice as higher and the pressure in the environment (ELR) was three times lower.

In order to produce the same amount of ethanol that is produced today (concentrated in few states) through micro-distilleries, a much larger area would be needed. Therefore, other Brazilian regions should produce their own ethanol instead of buying this fuel from others states such as São Paulo (main producer). In this way, differently from large scale, ethanol production in micro-distillery could promote a decentralization of the ethanol production.

Table 5. Emergy performance indicators the scenarios with ethanol production and a large scale ethanol production.

Indicator	Formula	Proto-ISFEES scenario	ISFEES scenario	Large Scale[a]	Unit
Transformity	Tr = Y/Ep	291,353	117,815	48,700	seJ/J
Specific Emergy	Y/Total mass	4.83E+10	1.19E+10	-	seJ/kg
Emergy Yield Ratio	EYR = Y/F	3.61	3.16	1.57	adimen.
Emergy Investment Ratio	EIR = F/I	0.38	0.46	-	adimen.
Environmental Loading Ratio	ELR = $(N+M_N+S_N)/(R+M_R+S_R)$	0.91	0.66	2.23	adimen.
Renewability	%R = $100(R+M_R+S_R/Y)$	62.8	71.9	30.90	%
Emergy Exchange Ratio	EER = Y/[($)*(seJ/$)]	1.22	1.15	0.68	adimen.

[a] Pereira and Ortega (2010)

Table 6. Economic indicators for the micro-distillery project

Indicator	Unit	Value
Payback	Years	3.32
Break-even-point	%	24.35
Internal Rate of Return	%	20%
Net Present Value	US$	65,604.71
Simple Return	%	51.2

In Table 6 it is possible to visualize the results for conventional economic indicators applied to the micro-distillery project. The payback calculated in this study informs that the investment can be recovered in about 3 years; the brake-even-point calculated was 24%. An operation of 8 h/day uses 33% of the installed capacity, i.e. above the brake-even-point and obtaining profit; the net present value was positive; the Internal Rate of Return was 20%, three times higher than the considered minimum acceptable rate of return (6.8% related to investment in a savings account); and the simple return was 51.2%. Therefore, the investment in the micro-distillery is profitable, and can provide economic return.

As result of the participant observation is fair to say that beyond the profit, the insertion of the micro-distillery also means new jobs in the settlement "Gleba XV de Novembro". This job offer can be good to the young people in the settlement. During the research in the field, some women said that they wanted their kids to be working in the community, avoiding leaving the land due to the lack of job opportunities. Therefore, the micro-distillery can help changing this situation for the settled families. In addition, the self-esteem can be improved and this experience can be used as an example to other groups in the "Gleba XV de Novembro" and other settlements in the surrounding area.

CONCLUSIONS

The insertion of a micro-distillery can improve the environmental conditions, provide economic return and promote social inclusion for the small farmers group of "Gleba XV de Novembro" settlement;

The integration between micro-distillery, crops and cattle is necessary to avoid the use of chemical fertilizers and pesticides. Those should be replaced by natural material flows and biological self regulation. In order to develop a good environmental performance, agroecological concepts should be introduced in the IFEES system implementation;

Ethanol production in a micro-distillery has higher renewability (72%) than the large scale production (31%). It indicates that biofuel production can be more sustainable if produced in small-scale units to supply to satisfy regional demand;

Therefore, a new public policy for the implementation of micro-distilleries in land reform settlements is advised, considering the economic and environment indicators and social inclusion.

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APPENDICES

Appendix A. Calculations and references to Table 1.

Note	Description				
1	**Sun**				
		Insolation =	1,821.35	kW/m^2 year	[a]
		Albedo =	15.00	%	[a]
		Energy =	(isolation)×(100-albedo)		
		Conversion =	(kW/m^2 year)×(3.6E+6 J/1 kW)×(1E+4m^2/ha)×((100−15)/100)		
		Energy =	5.57E+13	J/ha year	
2	**Rain**				
		Rainfall =	1,200	mm/year or L/m^2	[b]
		Water energy =	5,000	J/kg	
		Water density =	1	kg/l	
		Conversion =	(l/m^2 year)×(kg/l)×(J/kg)×(1E+4m^2/ha)		
		Energy =	6.00E+10	J/ha year	
3	**Atmospheric nitrogen**				
		N required =	20	g of N/Kg of d.m.	[d]
		Dry matter production (d.m.)		kg/ha year	[e]
		Conversion =	((g of N/kg of d.m.)x(kg/ha year))/(1E+3 g/kg)		
		Mass flow =	103	kg/ha year	
4	**Soil minerals**				
		soil minerals (s.m.) required	20	g of s.m./ g of d.m.	[d]
		Dry matter production (d.m.)		kg/ha year	[e]
		Conversion =	((g of s.m./kg of d.m.)x(kg/ha year))/(1E+3		
		Mass flow =	103	kg/ha year	
5	**Soil loss**				
		Eroded soil =	18,512.76	kg/ha year	[f]
		Average organic matter	2	%	[g]
		Conversion =	(kg/ha year)x(% o.m./100)x(5400 kcal/kg)x(4186 J/kcal)		
		Energy =	8.37E+09	J/ha year	
6	**Limestone**				
		Mass flow =	172.11	kg/ha year	[h]
7	**Nitrogen (fertilizer)**				
		Mass flow =	14.04	kg/ha year	[h]
8	**Phosphorous (fertilizer)**				
		Mass flow =	14.61	kg/ha year	[h]
9	**Potash (fertilizer)**				
		Mass flow =	18.36	kg/ha year	[h]
10	**Pesticides**				
		Mass flow =	0.55	kg/ha year	[h]
11	**Vaccines, medicines and antibiotic**				
		Monetary flow =	1.22	US$/ha year	[i]
12	**Local labor**				
		Time spent =	9	h/day	[j]

Spent energy =	225 kcal/h	
Conversion =	((h/day)x(225 kcal/h)x(365 day/year)x(4186J/kcal))/(161 ha)	
Energy =	1.92E+07 J/ha year	

[a] Obtained from the website
[b] Obtained from the website do INMET
[c] Obtained from the website http://www.cpa.unicamp.br/outras-informacoes
[d] Ashton and Montagnini, 1999
[e] Estimated by the land use, Aber and Melilo (2001) and Santos et al (1997)
[f] Estimated by the land use, Marques and Pazzianotto (2009) and Santos et al
[g] ITESP, 1999
[h] Estimated by the land use, ITESP (1998) e IAC (1998)
[i] Estimated by the density of the cattle (1,41 animals/ha)
[j] Consideration of this work

Appendix B. Calculations and references to Table 2.

Note	Description		
1	**Sun**		
	Insolation =	1,821.35 kWh/m^2 year	[a]
	Albedo =	15.00 %	[a]
	Energy =	(isolation)×(100-albedo)	
	Conversion =	(kW/m^2 year)×(3.6E+6 J/1 kW)×(1E+4m^2/ha)×((100−15)/100)	
	Energy =	5.57E+13 J/ha year	
2	**Rain**		
	Rainfall =	1,200 mm/ano ou L/m^2	[b]
	Water energy =	5,000 m^2/ha	
	Water density =	1 kg/l	
	Conversion =	(l/m^2 year)×(kg/l)×(J/kg)×(1E+4m^2/ha)	
	Energy =	6.00E+10 J/ha year	
3	**Atmospheric nitrogen**		
	N required =	20 g of N/Kg of d.m.	[d]
	Dry matter production =	2,800.00 Kg/ha year	[e]
	Conversion =	((g of N/kg of d.m.)x(kg/ha year))/(1E+3 g/kg)	
	Mass flow =	56 Kg/ha year	
4	**Soil minerals**		
	soil minerals (s.m.) required	20 g of s.m./ g of d.m.	[d]
	Dry matter production (d.m.)	2,800.00 kg/ha year	[e]
	Conversion =	((g of s.m./kg of d.m.)x(kg/ha year))/(1E+3 g/kg)	
	Mass flow =	56 Kg/ha year	
5	**Soil loss**		
	Eroded soil =	1,7458.74 kg/ha year	[f]
	Average organic matter	2 %	[g]
	Conversion =	(kg/ha year)x(% o.m./100)x(5400 kcal/kg)x(4186 J/kcal)	
	Energy =	7.89E+09 J/ha year	
6	**Electricity**		
	Consumption =	55.79 kWh/year	[h]
	Conversion =	(kWh/year)x(3600000 J/kWh)	
	Energy =	1.25E+06 J/ha year	
7	**Pesticides**		
	Mass flow =	0.54 kg/ha year	[i]
	8	**Limestone**	
	Mass flow =	157.11 kg/ha year	[j]
9	**Nitrogen (fertilizer)**		

		Mass flow =	13.66	kg/ha year	[j]
10	**Phosphorous (fertilizer)**				
		Mass flow =	13.62	kg/ha year	[j]
11	**Potash (fertilizer)**				
		Mass flow =	17.65	kg/ha year	[j]
12	**Steel**				
		Micro-distillery =	900.00	kg	[h]
		Mill =	800.00	kg	[h]
		hangar =	3,000.00	kg	[h]
		Life	20.00	year	[k]
		Mass flow =	1.46	kg/ha year	
13	**Plastic**				
		Mass =	80.00	kg	[h]
		Life	20.00	year	[k]
		Mass flow =	0.02	kg/ha year	
14	**Cement**				
		Mass =	758.00	kg	[h]
		Life	20.00	year	[k]
		Mass flow =	0.24	kg/ha year	
15	**Vaccines, medicines**				
		Nº o animals =	130	animal	[j]
		Consumption	1.0	drop/animal year	[k]
		Cost =	1.30	US$/drop	
		Conversion =	((nº animals)x(drop/animal year)x(US$/drop))/(161 ha)		
		Monetary flow =	1	US$/ha year	
16	**Local labor**				
		Time spent =	11	h/day	[k]
		Spent energy =	225	kcal/h	
		Conversion =	((h/day)x(225 kcal/h)x(365 day/year)x(4186 J/kcal))/(161 ha)		
		Energy	2.35E+07	J/ha year	
17	**External labor**				
		Nº usual workers =	3.00		[k]
		Annual cost =		US$/year	
		Nº specialized worker =			
		Annual cost =		US$/year	
		Monetary flow =		US$/ha year	
18	**Debt services**				
		Expenses =	109.732	US$	[h]
		Life =	20	year	
		Monetary flow =	34,08	US$/ha year	

[a] Obtained from the website http://eosweb.larc.nasa.gov/sse/

[b] Obtained from the website do INMET http://www.inmet.gov.br

[c] Obtained from the website http://www.cpa.unicamp.br/outras-informacoes

[d] Ashton and Montagnini, 1999

[e] Estimated by the land use, Aber e Melilo (2001) and Santos et al (1997)

[f] Estimated by the land use, Marques e Pazzianotto (2009), Santos et al (2007), Nogueira et al

[g] (ITESP, 1999)

[h] Estimated from USI (2008)

[i] Estimated by the land use, ITESP (1998) e IAC (1998)

[j] Estimated by the density of the cattle (1,41 animals/ha)

[k] Consideration of this work

Appendix C. Calculations and references to Table 3.

Note	Description		
1	**Sun**		
	Insolation =	1,821.35 kWh/m^2 year	[a]
	Albedo =	15.00 (%)	[a]
	Energy =	(isolation)×(100-albedo)	
	Conversion =	(kW/m^2 year)×(3.6E+6 J/1 kW)×(1E+4m^2/ha)×((100−15)/100)	
	Energy =	5.57E+13 J/ha year	
2	**Rain**		
	Rainfall =	1,200 mm/ano ou L/m^2	[b]
	Water energy =	5,000 J/kg	
	Water density =	1 kg/l	
	Conversion =	(l/m^2 year)×(kg/l)×(J/kg)×(1E+4m^2/ha)	
	Energy =	6.00E+10 J/ha year	
3	**Atmospheric nitrogen**		
	N required =	20 g of N/Kg of d.m.	[d]
	Dry matter production =	6,300.00 Kg/ha year	[e]
	Conversion =	((g of N/kg of d.m.)x(kg/ha year))/(1E+3 g/kg)	
	Mass flow =	126 Kg/ha year	
4	**Soil minerals**		
	soil minerals (s.m.) required	20 g of s.m./ g of d.m.	[d]
	Dry matter production (d.m.)	6,300 kg/ha year	[e]
	Conversion =	((g of s.m./kg of d.m.)x(kg/ha year))/(1E+3	
	Mass flow =	126 Kg/ha year	
5	**Soil loss**		
	Eroded soil =	8,373.20 kg/ha year	[f]
	Average organic matter	2 %	[g]
	Conversion =	(kg/ha year)x(% o.m./100)x(5400 kcal/kg)x(4186	
	Energy =	3.79E+09 J/ha year	
6	**Electricity**		
	Consumption =	55.79 kWh/year	[h]
	Conversion =	(kWh/year)x(3600000 J/kWh)	
	Energy =	1.25E+06 J/ha year	
7	**Formicide**		
	Mass flow	6,21E-03 Kg/ha year	[i]
8	**Urea**		
	Nº of animals =	246 animals	[j]
	Daily consumption =	0.3 kg/animal day	[k]
	Days =	200 day/year	
	Conversion =	((nº animals)x(kg/animal day)x(day/year))/(161 ha)	
	Mass flow	91.8 kg/ha year	
9	**Steel**		
	Micro-distillery =	900.00 kg	[h]
	Mill =	800.00 kg	[h]
	hangar =	3.000.00 kg	[h]
	Life	20.00 year	[k]
	Mass flow =	1.46 kg/ha year	
10	**Plastic**		
	Mass =	80.00 kg	[h]
	Life	20.00 year	[k]
	Mass flow =	0.02 kg/ha year	
11	**Cement**		
	Mass =	758.00 kg	[h]
	Life	20.00 year	[k]
	Mass flow =	0.24 kg/ha year	
12	**Vaccines, medicines**		
	Nº o animals =	246 animal	[j]
	Consumption	1.0 drop/animal year	[k]

	Cost =	1.30	US$/drop	
	Conversion =	((nº animals)x(drop/animal year)x(US$/drop))/(161 ha)		
	Monetary flow =	2.00	US$/ha year	
13	**Local labor**			
	Time spent =	12	h/day	[k]
	Spent energy =	225	kcal/h	
	Conversion =	((h/day)x(225 kcal/h)x(365 day/year)x(4186 J/kcal))/(161 ha)		
	Energy	2.56E+07	J/ha year	
14	**External labor**			
	Nº usual workers =	3.00		[k]
	Annual cost =		US$/year	
	Nº specialized worker =	1.00		
	Annual cost =		US$/year	
	Monetary flow =	316.70	US$/ha year	
15	**Debt services**			
	Expenses =	109,732	US$	[h]
	Life =	20	year	
	Monetary flow =	18.52	US$/ha year	

[a] Obtained from the website http://eosweb.larc.nasa.gov/sse/
[b] Obtained from the website do INMET http://www.inmet.gov.br
[c] Obtained from the website http://www.cpa.unicamp.br/outras-informacoes
[d] Ashton and Montagnini, 1999
[e] Estimated by the land use, Aber e Melilo (2001) and Santos et al (1997)
[f] Estimated by the land use, Marques e Pazzianotto (2009), Santos et al (2007), Nogueira et al (2000) and Margarido et al (2005)
[g] ITESP, 1999
[h] Estimated from USI (2008)
[i] Estimated by the land use, ITESP (1998) e IAC (1998)
[j] Estimated by the density of the cattle (1,41 animals/ha)
[k] Consideration of this work