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# EVALUATION OF FAMILY-MANAGED SMALL FARMS USING EMERGY METHODOLOGY

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**ABSTRACT**

Two small farms, Duas Cachoeiras and Santa Helena, located in the southeast of Brazil (Amparo County, State of São Paulo), were compared using emergy methodology. The first one has been managed using agroecological concepts since 1985, while the second works according with conventional chemical technology. Both are family managed and were formed by the dismemberment of a coffee plantation 30 years ago. The results of this research show that: (a) it is economically feasible to change from a conventional agriculture to agroecological production; (b) the emergy indices show a better performance of the ecological farm; (c) accounting for the partial renewabilities of each incoming flow in the emergy evaluation allowed a more accurate calculation of sustainability; (d) the use of emergy methodology could improve the administration strategies of the farms.

Keywords: Agroecology, Sustainable Development, Emergy, Environment, Ecological Economy.

## 1. INTRODUCTION

The increase of farm productivity in terms of single product yields, due to the Second Agricultural Revolution which took place in the beginning of XX century, led to the replacement of farming systems based on rotation of crops and integration with animal production, by highly specialized monoculture farming systems. This new kind of farms is characterized by massive use of industrial products and fossil energy, as oil, agrochemicals, machinery and vegetal varieties highly responsive to chemical fertilizers. This chemical farming model was reinforced in the 70's by the so called Green Revolution resulting in considerable increase of crop volume, but at the same time, outcoming in environmental and social problems, as forests destruction, biodiversity loss, reduction of water infiltration to aquifers, pollution of water resources, soil erosion, contamination of foods.

In Brazil, besides these problems, it was produced an unfair concentration of lands ownership and wealth distribution, resulting in an intense exodus from countryside to industrialized urban areas [1]. The soil fertility has been diminishing because the adopted techniques are detrimentally affecting soil physical, chemical and biological parameters. Erosion and compacting of soil affect negatively the water supply, both for agricultural and urban use. According to the Food and Agriculture Organization (FAO), the chemical agriculture produces not only food and fiber, but great damages on ecosystems and on local, national and world economies. These impacts are called "negative externalities" and are defined as the costs of the use of the environment for the production of specific product, that currently are not accounted for in the final price of the product itself, encouraging that way conventional models of production [3, 4]. Oil became the basis of industrial agriculture; approximately, 85% of the energy incorporated in foods through farming comes from it [2]. Farming moved to a pattern that can be only sustained as long as fossil fuels are available.

Emergy methodology has being used, since the 90's, as an important tool in studying agricultural systems, in order to suggest a rational exploitation of natural resources [5].

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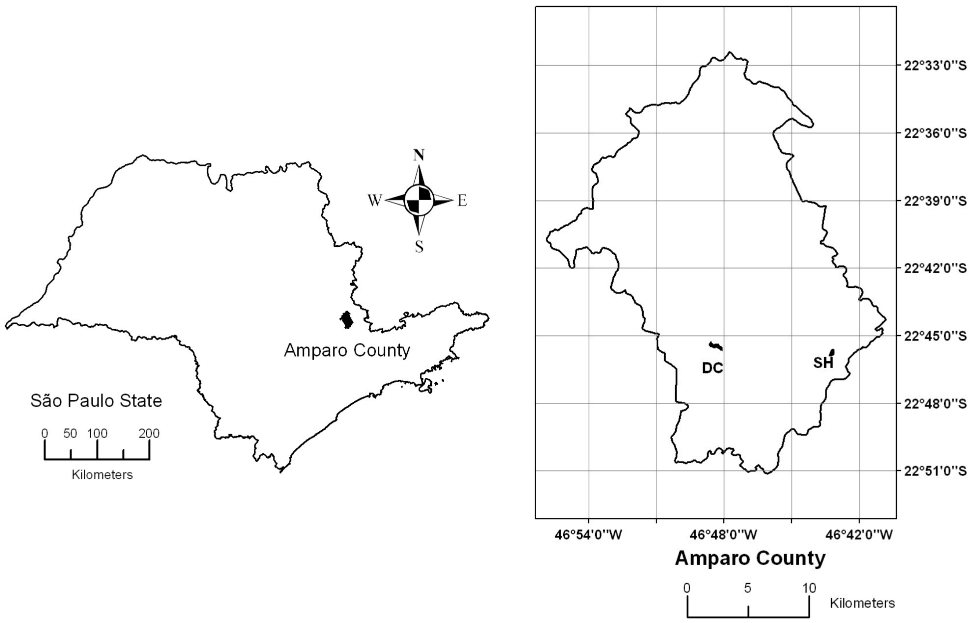
This research studies, through emergy and economic indices, two rural unit using different models of production in order to explain its performance.

## 2. MATERIAL AND METHODS

Two family managed farms were compared using emergy indices: (a) Duas Cachoeiras (DC) and (b) Santa Helena (SH). The first one by means of agroecology since 1985, while the second works conventionally. They are located in the in São Paulo, Brazil (Figure 1). The first step in performing the emergy evaluation is the identification of the boundaries of the study area. After that, the main components of the system were identified as well as its exchanges with the external environment. A generic systems diagram was drawn using symbolic energy language (Figure 2) and emergy indices (Table 1) were then calculated.




(a) (b)

Figure 1. (a) Localization of Amparo county in São Paulo State, Brazil; (b) Localization of Duas Cachoeiras farm (DC) and Santa Helena farm (SH) within Amparo county

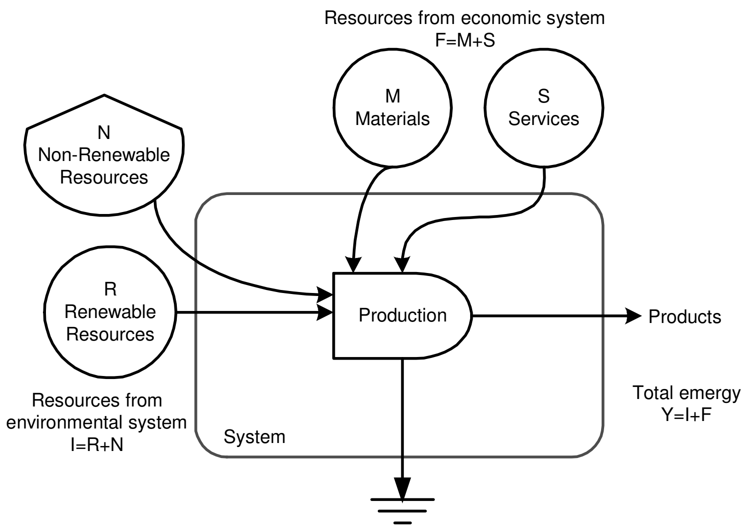



Figure 2. Emergy systems diagram of a generic production system

Table 1. Emergy indices used in environmental accounting

| Indices | Expression | Signification |
|---|---|---|
| Solar transformity (Tr) | Y/Ep | The ratio of the emergy of the output divided by the energy of the products |
| Emergy yield ratio (EYR) | Y/F | The ratio of the emergy of the output divided by the emergy of those inputs that are fed back from outside the system |
| Emergy investment ratio (EIR) | F/I | The ratio of emergy of purchased inputs divided by the emergy of free inputs |
| Renewability (%R) | 100(R/Y) | The ratio of the renewable inputs divided by the total emergy of system |
| Emergy exchange ratio (EER) | Y/[($)x(emdollar)] | The ratio of the delivered emergy by the system to economy divided by the emergy received by the sells of products |

R=renewable resources; N=non-renewable resources; I=R+N= inputs from environment; M= materials; S=services; F=M+S= feedback from economic system; Y=F+I=total emergy; Ep= energy of products; $=money input; emdollar in Brazil.

Table 2. Classification of Emergy flows considering the partial renewability

| Inputs and services | Description |
|---|---|
| **I: Nature contribution** | **R + N** |
| R: Renewable resources from nature | Rain, materials and services from preserved areas, inputs from air and soil. |
| N: Nonrenewable resources from nature | Soil, biodiversity, people exclusion. |
| **F: Feedback from economy** | **F = M + S** |
| **M: Materials** | $\mathbf{M = M_R + M_N}$ |
| $M_R$: Renewable materials and energy | Renewable materials from natural origin. |
| $M_N$: Nonrenewable materials and energy | Minerals, chemicals, steel, fuel, etc. |
| **S: Services** | $\mathbf{S = S_R + S_N}$ |
| $S_R$: Renewable services | Manpower of renewable sources. |
| $S_N$: Nonrenewable services | Other services, taxes, insurance, etc. |
| **Y: Total emergy** | **Y = I + F** |

The following equations were used to calculate the economic indices:

$$yield = \frac{(input\ money) - (output\ money)}{(output\ money)}$$

$$real\ yield = \frac{(input\ money) - (output\ money + negatives\ externalities)}{(output\ money + negatives\ externalities)}$$

Where:

Input money = money received for the products sales;
Output money = money expenses with purchasing of materials and payment of services;
Negatives externalities = money that would have to be paid for the environmental and social damages (in this paper, the negative externalities were considered 360 US$/ha/year - extracted by [3, 4] - for the farm that uses a conventional model of agricultural production).

## 3. RESULTS

After visiting the farms and interviewing the owners, it was possible to be acquainted with the managing and emergy systems diagram of each farm (Figures 3 and 4) were drawn. These diagrams show the matter and energy flows and point out which are the flows that need to be considered in the emergy evaluation. Evaluation Tables were elaborated (Tables 3 and 5) as well as Aggregated Emergy Diagrams (Figures 5 and 6).

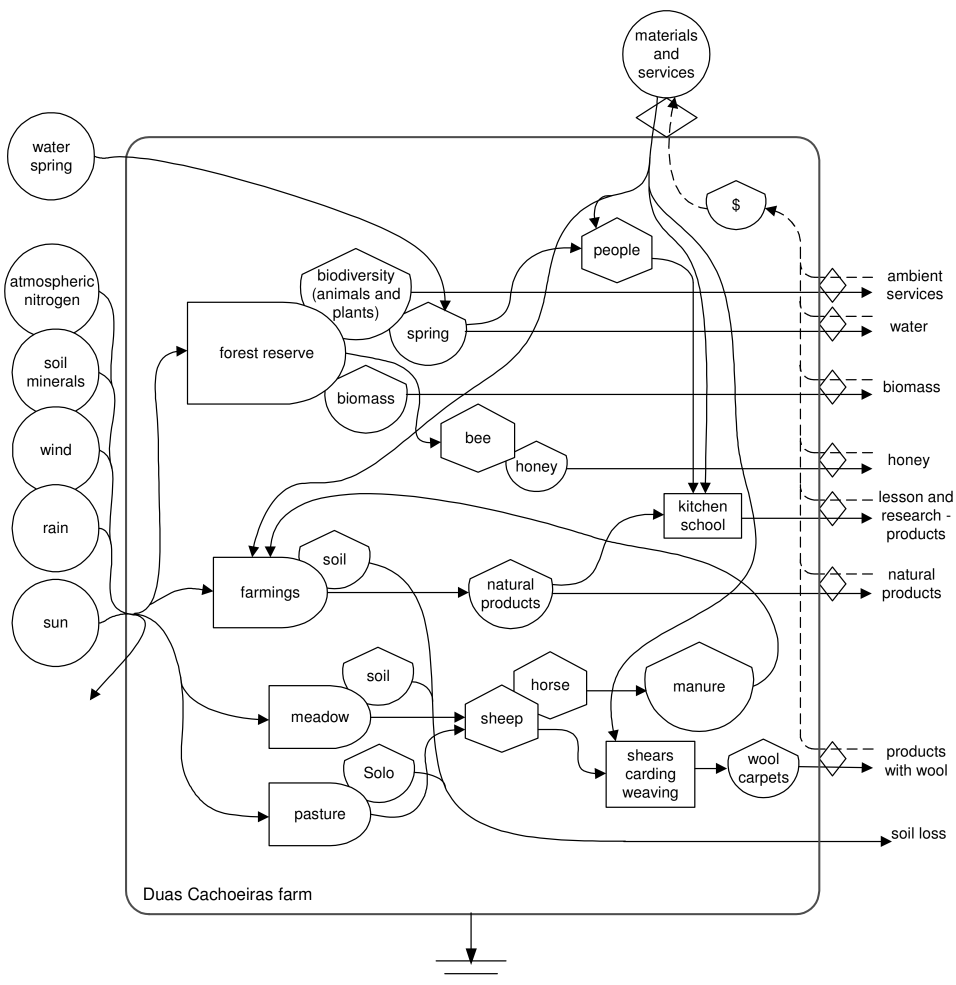


Figure 3. Emergy systems diagram of Duas Cachoeiras farm, year 2003

Soil nitrogen, phosphorous, potassium and calcium were considered as renewable natural resources, since in the DC farm the agroecological management does not require external chemical inputs.

The green manure and the organic matter amendment supply all the minerals required by crops. The plant uptake of soil minerals does not exceed the replenishment of them by biological processes, therefore they were considered renewable in the emergy evaluation Table (Table 3).

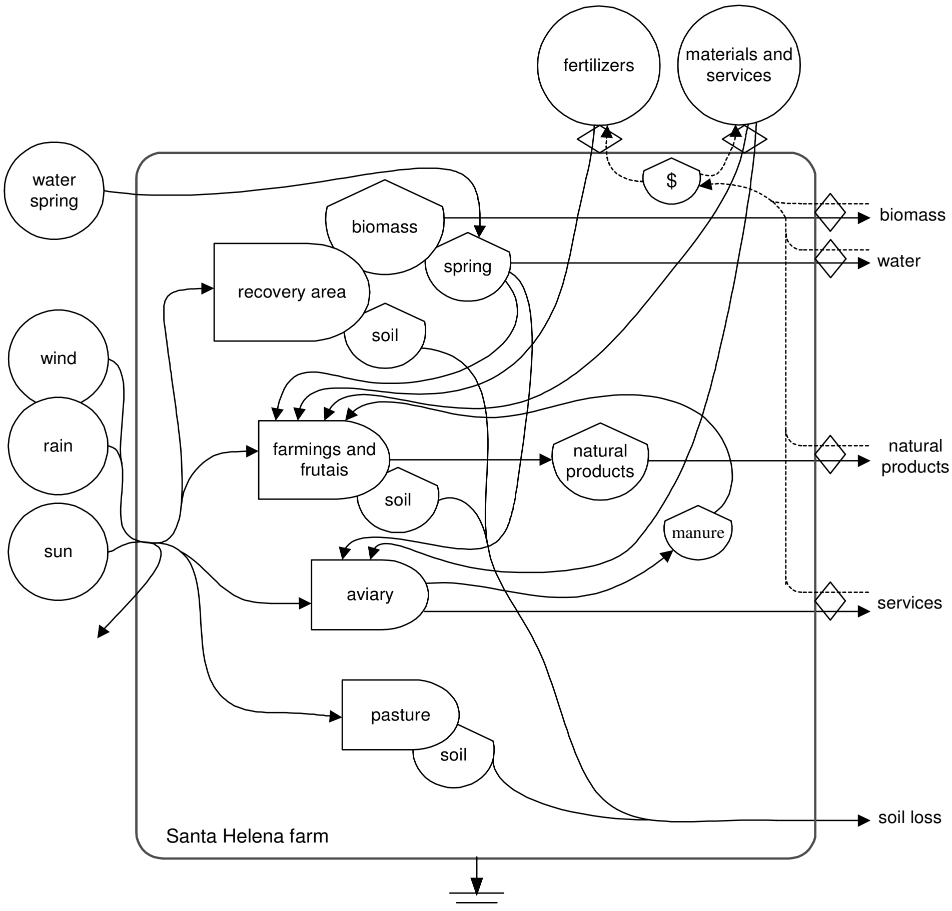



Figure 4. Emergy systems diagram of Santa Helena farm, year 2003

On the contrary, Santa Helena farm is managed by a conventional agricultural practice, characterized by a high input of purchased chemicals (Table 5).

Water springs and a river assures the required water supply for the two farms, and, then, it has been considered as renewable resources.

The soil loss was calculated using the revised universal soil loss equation (RUSLE) in a geographical information systems (GIS). This flow was considered as non-renewable natural resource for the two farms, since it exceed the soil production by the pedogenetic process.

Both, besides vegetable and animal products, groundwater and forest biomass of the two farms have to be considered in the calculation of the energy of the product (Tables 4 and 6), even though they do not have any market price.

Table 3. Emergy flows supporting 1 hectare of land at Duas Cachoeiras farm in 2003

| Note | Item | Amount (unit/yr) | Unit | Emergy intensity (seJ/unit) | Reference for seJ/unit | Solar emergy (seJ/yr) $x10^{13}$ |
|---|---|---|---|---|---|---|
| **Renewable Natural Resources (R):** | | | | | | |
| 1 | Sun | 1.52E+11 | J | 1 | definition | 0.0152 |
| 2 | Rain | 6.25E+10 | J | 3.10E+04 | [7] | 194 |
| 3 | Wind | 1.51E+10 | J | 2.45E+03 | [7] | 3.69 |
| 4 | Water spring | 2.28E+09 | J | 8.15E+04 | [8] | 18.6 |
| 5 | River water | 1.09E+08 | J | 4.28E+05 | [8] | 4.67 |
| 6 | Nitrogen | 4.89E+02 | Kg | 4.05E+13 | [9] | 1980 |
| 7 | Phosphor | 7.69E+01 | Kg | 2.20E+13 | [9] | 169 |
| 8 | Potassium | 2.33E+02 | Kg | 2.92E+12 | [9] | 67.9 |
| 9 | Calcium | 2.29E+01 | Kg | 1.00E+12 | [9] | 2.29 |
| **Non-renewable Natural Resources (N):** | | | | | | |
| 10 | Soil loss | 2.98E+10 | J | 1.24E+05 | [9] | 370 |
| **Contribution of the Economy (M):** | | | | | | |
| 11 | Depreciation | 1.23E+02 | US$ | 3.30E+12 | [10] | 40.6 |
| 12 | Fuel | 5.29E+07 | J | 1.11E+05 | [9] | 0.587 |
| 13 | Electricity | 3.88E+08 | J | 2.69E+05 | [9] | 10.4 |
| 14 | Maintenance | 1.29E+01 | US$ | 3.30E+12 | [10] | 4.26 |
| **Contribution of the Economy (S):** | | | | | | |
| 15 | Simple labor | 7.00E+01 | US$ | 3.30E+12 | [10] | 23.1 |
| 16 | Family labor | 7.00E+01 | US$ | 3.30E+12 | [10] | 23.1 |
| 17 | Maintenance | 1.01E+01 | US$ | 3.30E+12 | [10] | 3.33 |
| 18 | Tax | 2.24E+00 | US$ | 3.30E+12 | [10] | 0.741 |
| 19 | Private services | 1.35E+00 | US$ | 3.30E+12 | [10] | 0.444 |
| 20 | Phone | 1.62E+01 | US$ | 3.30E+12 | [10] | 5.33 |
| | | | | | **Total Emergy (Y):** | **2925** |

Table 4. Total energy produced by the Duas Cachoeiras farm in the year 2003

| Product | Production [A] [kg/year] | Caloric value of the product [B] [kcal/kg] | Energy of the product [D] [J/ha.year] |
|---|---|---|---|
| Corn | 2400 | 3500 | 1.18E+09 |
| Sunflower | 710 | 4750 | 4.75E+08 |
| Sunflower oil | 213 | 9000 | 2.70E+08 |
| Sunflower pie | 497 | 2692 | 1.89E+08 |
| Beans | 387 | 2620 | 1.43E+08 |
| Pumpkin | 280 | 150 | 5.92E+06 |
| Cassava | 2000 | 1330 | 3.75E+08 |
| Potato Candy | 500 | 1140 | 8.03E+07 |
| Rice | 400 | 3620 | 2.04E+08 |
| Soy | 192 | 3630 | 9.82E+07 |
| Vegetables | 3900 | 80 | 4.40E+07 |
| Fruits | 5000 | 500 | 3.52E+08 |
| Wool | 36 | 4500 | 2.28E+07 |
| Wool carpets | 24 | 4500 | 1.52E+07 |
| Wool clothes | 60 | 4500 | 3.81E+07 |
| Honey | 600 | 3125 | 2.64E+08 |
| Propolis | 10 | 5000 | 7.05E+06 |
| Wax | 20 | 8000 | 2.26E+07 |
| Water | - | - | 1.25E+10 [E] |
| Biomass | - | - | 1.79E+10 [F] |
| **Product** | **Production [A] [hour/year]** | **Caloric value of the product [C] [kcal/hour]** | **Energy of the product [J/ha.year]** |
| Environmental education | 4800 | 146 | 9.88E+07 |
| Search | 600 | 146 | 1.23E+07 |
| | | **Total energy produced:** | **3.43E+10** |

[A] Data supplied by the proprietor.

[B] The caloric value of the products was extracted by Brazilian Table Food Composition. http://www.fcf.usp.br/tabela. Access 20/05/2004.

[C] 3,500kcal/day.person.

[D] Energy [J/ha/year]=production [kg/year]*caloric value [kcal/kg]*4,186 [J/kcal]/farm area[29.7ha]

[E] Water infiltration in the soil = 20% of all annual rain ([11], [12], [13], [14] e [15]). Rain in the region is 1,250 mm/year (1.95E+08 liter/year in 15.6 ha). Water infiltrated is 7.43E+07 liter/year.

Water = 7.43E+04 m3/year* (1/29.7 ha)*(1,000kg/$m^3$)* (5,000J/kg)= 1.25E+10 J/ha/year.

[F] Biomass = 6,870 kJ/$m^2$.year* ($10^4 m^2$/ha)*(7.75ha/29.7 ha)*(1,000J/1kJ)= 1.79E+10 J/ha/year.

Annual average of liquid productivity of a tropical forest (100 year) = 36,160 [kJ/$m^2$.year]. Source: Ecologia: Aventura na Ciência. Editora Globo, pág.8. 1994. The area of recovery of the farm measure 7.75 ha and is 19 years old.

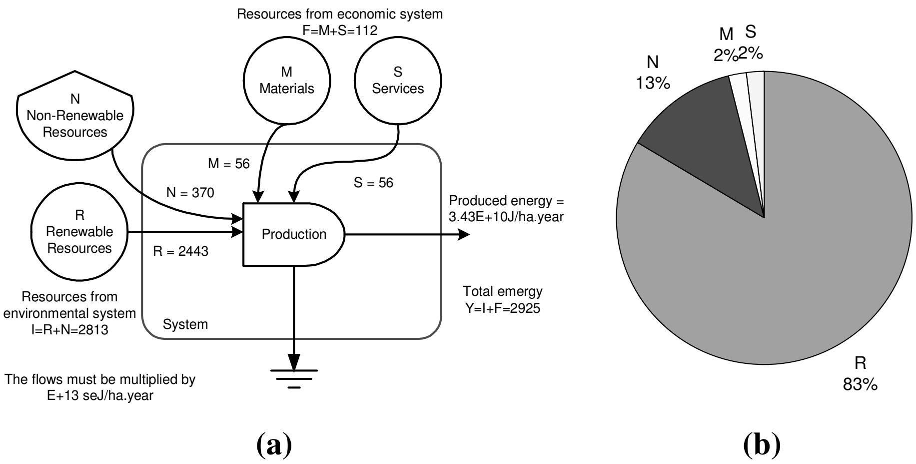



Figure 5. Duas Cachoeiras farm in the year 2003: (a) Emergy systems diagram; (b) Percentage of each one of incoming emergy flows in relation to the total emergy

Table 5.Emergy flows supporting 1 ha of land in Santa Helena farm (SH) in the year 2003

| N. | Item | Amount (unit/yr) | Unit | Emergy intensity (seJ/unit) | Reference for seJ/unit | Solar emergy (seJ/yr) x10$^{13}$ |
|---|---|---|---|---|---|---|
| **Renewable Natural Resources (R):** | | | | | | |
| 1 | Sun | 1.52E+11 | J | 1 | definition | 0.0152 |
| 2 | Rain | 6.25E+10 | J | 3.10E+04 | [7] | 194 |
| 3 | Wind | 1.51E+10 | J | 2.45E+03 | [7] | 3.69 |
| 4 | River water | 1.25E+09 | J | 4,28E+05 | [8] | 53.4 |
| **Non-renewable Natural Resources (N):** | | | | | | |
| 5 | Soil loss | 5.33E+10 | J | 1.24E+05 | [9] | 661 |
| **Contribution of the Economy (M):** | | | | | | |
| 6 | Depreciation | 4.77E+02 | US$ | 3.30E+12 | [10] | 157 |
| 7 | Fuel | 2.29E+08 | J | 1.11E+05 | [9] | 2.55 |
| 8 | Electricity | 1.73E+09 | J | 2.69E+05 | [9] | 46.6 |
| 9 | Materials of maintains | 4.27E+01 | US$ | 3.30E+12 | [10] | 14.1 |
| 10 | Fungicide | 3.33E+01 | Kg | 2.49E+13 | [9] | 82.8 |
| 11 | Herbicide | 4.98E-01 | Kg | 2.49E+13 | [9] | 1.24 |
| 12 | Calcium | 2.40E-01 | Kg | 1.00E+12 | [9] | 0.0240 |
| 13 | Calcium nitrate | 1.58E+00 | US$ | 3.30E+12 | [10] | 0.522 |
| 14 | Potassium nitrate | 2.14E+00 | US$ | 3.30E+12 | [10] | 0.705 |
| **Contribution of the Economy (S):** | | | | | | |
| 15 | Family labor | 2.67E+02 | US$ | 3.30E+12 | [10] | 88.0 |
| 16 | Tax | 2.46E+00 | US$ | 3.30E+12 | [10] | 0.811 |
| 17 | Private service | 8.33E+01 | US$ | 3.30E+12 | [10] | 27.5 |
| 18 | Phone | 1.54E+01 | US$ | 3.30E+12 | [10] | 5.08 |
| | | | | | **Total Emergy (Y):** | **1340** |

Table 6. Total energy produced by the Santa Helena farm in the year 2003

| Product | Production [A] [kg/year] | Caloric value of the product [B] [kcal/kg] | Energy of the product [C] [J/ha.year] |
|---|---|---|---|
| Coffee | 8000 | 1660 | 3.56E+09 |
| Chayote | 66000 | 160 | 2.83E+09 |
| Tomato | 9000 | 150 | 3.62E+08 |
| Peach | 350 | 410 | 3.85E+07 |
| Pimiento | 2750 | 80 | 5.90E+07 |
| Cucumber | 11000 | 60 | 1.77E+08 |
| Water | - | - | 6.25E+09 [D] |
| Biomass | - | - | 5.57E+08 [E] |
| | | **Total energy produced:** | **1.38E+10** |

[A] Data supplied by the proprietor.

[B] The caloric value of the products was extracted by Brazilian Table Food Composition. http://www.fcf.usp.br/tabela. Last Access: 20/05/2004.

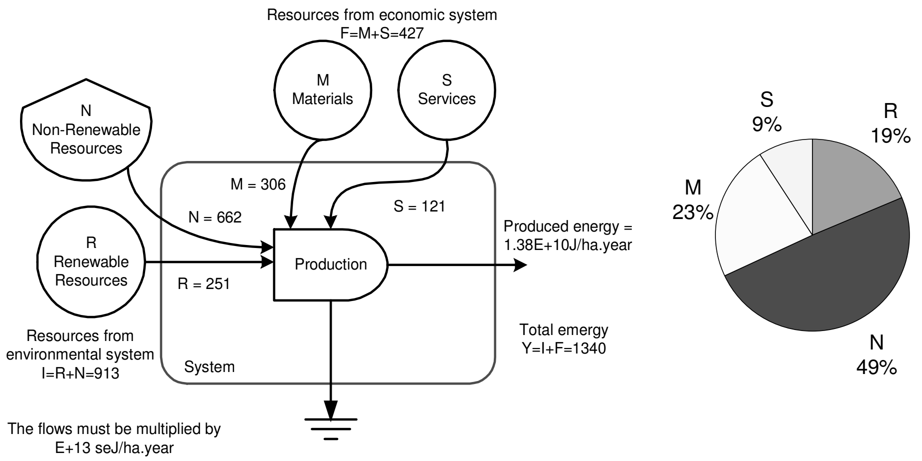
[C] Energy [J/ha/yr]=production [kg/year]*caloric value [kcal/kg]*4186 [J/kcal]/farm area [15.6 ha]

[D] Water infiltration in the soil = 10% of all annual rain in compacted soil ([11], [12], [13], [14] and [15]). Rain in the region is 1250 mm/year (1.95E+08 liter/year in 15.6 ha). The value of water infiltration is 1.95+E07 liter/year (1.95E+04 $m^3$/year).

Water = 1.95E+04 $m^3$/year * (1/15.6 ha)*(1000 kg/$m^3$)* (5000 J/kg)= 6.25E+09 J/ha/year.

[E] Biomass = 1447 kJ/$m^2$.year * ($10^4 m^2$/ha)*(0.6 ha/15.6 ha)*(1000J/1kJ)= 5.57E+08 J/ha/year.

Annual average of liquid productivity of a tropical forest (100 year) = 36160 [kJ/$m^2$.year]. Source: Ecologia: Aventura na Ciência. Editora Globo. Page 8. 1994. The forest recovery area of this farm measures 0.6 ha and is 4 years old.




**(a)** **(b)**

Figure 6. Santa Helena farm in the year 2003: (a) Aggregated emergy systems diagram; (b) Percentage of the incoming emergy flows in relation to the total emergy

In Tables 7 and 9 the farm emergy evaluations has been also carried out considering the partial renewabilities of each incoming flow in the system.

Table 7. Emergy flows supporting 1 hectare of land in Duas Cachoeiras farm (DC) in the year 2003, accounting for the partial renewabilities of each component

| N. | Item | Ren.[A] | Numerical Value [B] | Unit | Emergy intensity [B] [seJ/Unit.] | Renew. Emergy [C] | Non-renew. Emergy [C] | Y [C] |
|---|---|---|---|---|---|---|---|---|
| **Renewable Natural Resources (R):** | | | | | | | | |
| 1 | Sun | 1 | 1.52E+11 | J | 1 | 0.0152 | 0.0 | 0.0152 |
| 2 | Rain | 1 | 6.25E+10 | J | 3.10E+04 | 194 | 0.0 | 194 |
| 3 | Wind | 1 | 1.51E+10 | J | 2.45E+03 | 3.69 | 0.0 | 3.69 |
| 4 | Water spring | 1 | 2.28E+09 | J | 8.15E+04 | 18.6 | 0.0 | 18.6 |
| 5 | River water | 1 | 1.09E+08 | J | 4.28E+05 | 4.67 | 0.0 | 4.67 |
| 6 | nitrogen | 1 | 4.89E+02 | kg | 4.05E+13 | 1980 | 0.0 | 1980 |
| 7 | Phosphorous | 1 | 7.69E+01 | kg | 2.20E+13 | 169 | 0.0 | 169 |
| 8 | Potassium | 1 | 2.33E+02 | kg | 2.92E+12 | 67.9 | 0.0 | 67.9 |
| 9 | Calcium | 1 | 2.29E+01 | kg | 1.00E+12 | 2.29 | 0.0 | 2.29 |
| **Non-renewable Natural Resources (N):** | | | | | | | | |
| 10 | Soil loss | 0 | 2.98E+10 | J | 1.24E+05 | 0.0 | 370 | 370 |
| **Contribution of the Economy (M):** | | | | | | | | |
| 11 | Depreciation | 0.05 | 1.23E+02 | US$ | 3.30E+12 | 2.03 | 38.6 | 40.6 |
| 12 | Fuel | 0 | 5.29E+07 | J | 1.11E+05 | 0.0 | 0.587 | 0.587 |
| 13 | Electricity | 0.7 | 3.88E+08 | J | 2.69E+05 | 7.30 | 3.13 | 10.4 |
| 14 | Materials | 0.1 | 1.29E+01 | US$ | 3.30E+12 | 0.426 | 3.83 | 4.26 |
| **Contribution of the Economy (S):** | | | | | | | | |
| 15 | Simple labor | 0.6 | 7.00E+01 | US$ | 3.30E+12 | 13.9 | 9.24 | 23.1 |
| 16 | Family labor | 0.9 | 7.00E+01 | US$ | 3.30E+12 | 20.8 | 2.31 | 23.1 |
| 17 | Maintenance | 0.1 | 1.01E+01 | US$ | 3.30E+12 | 0.333 | 3.00 | 3.33 |
| 18 | Tax | 0.05 | 2.24E+00 | US$ | 3.30E+12 | 0.0370 | 0.704 | 0.741 |
| 19 | Service | 0.05 | 1.35E+00 | US$ | 3.30E+12 | 0.0222 | 0.422 | 0.444 |
| 20 | Phone | 0.05 | 1.62E+01 | US$ | 3.30E+12 | 0.267 | 5.07 | 5.33 |
| | | | | | | | **Total Emergy (Y):** | **2925** |

[A] Extract from [6] and common sense.
[B] The numeric value and emergy intensity are the same as in Table 3.
[C] These flows are multiplied by $10^{13}$ [seJ/ha/year].

Table 8. Aggregate flows of Duas Cachoeiras farm (DC) considering partial renewabilities in the year 2003

| **Renewable** [A] | | | **Non-Renewable** [A] | | |
|---|---|---|---|---|---|
| Rr = | 2.443E+16 | seJ/ha/year | Rn = | 0.0 | seJ/ha/year |
| Nr = | 0.0 | seJ/ha/year | Nn = | 3.70E+15 | seJ/ha/year |
| Mr = | 9.760E+13 | seJ/ha/year | Mn = | 4.61E+14 | seJ/ha/year |
| Sr = | 3.533E+14 | seJ/ha/year | Sn = | 2.07E+14 | seJ/ha/year |

[A] Data come from of Table 7.

The next step was the calculation of emergy and economic indices (Tables 11 and 12).

Table 9. Emergy flows supporting 1 hectare of land in Santa Helena farm in the year 2003, accounting for the partial renewabilities of each component

| N. | Item | R[A] | Numerical Value [B] | Unit | Emergy intensity [B] [seJ/Unit.] | Ren. Em. [C] | Non-ren. Em [C] | Y [C] |
|---|---|---|---|---|---|---|---|---|
| **Renewable Natural Resources (R):** | | | | | | | | |
| 1 | Sun | 1 | 1.52E+11 | J | 1 | 0.0152 | 0.0 | 0.0152 |
| 2 | Rain | 1 | 6.25E+10 | J | 3.10E+04 | 194 | 0.0 | 194 |
| 3 | Wind | 1 | 1.51E+10 | J | 2.45E+03 | 3.69 | 0.0 | 3.69 |
| 4 | River water | 1 | 1.25E+09 | J | 4.28E+05 | 53.4 | 0.0 | 53.4 |
| **Non-Renewable Natural Resources (N):** | | | | | | | | |
| 5 | Soil loss | 0 | 5.33E+10 | J | 1.24E+05 | 0.0 | 661 | 661 |
| **Contribution of the Economy (M):** | | | | | | | | |
| 6 | Depreciation | 0.05 | 4.77E+02 | US$ | 3.30E+12 | 7.87 | 150 | 157 |
| 7 | Fuel | 0 | 2.29E+08 | J | 1.11E+05 | 0.0 | 2.55 | 2.55 |
| 8 | Electricity | 0.7 | 1.73E+09 | J | 2.69E+05 | 32.6 | 14.0 | 46.6 |
| 9 | Materials | 0.1 | 4.27E+01 | US$ | 3.30E+12 | 1.41 | 12.7 | 14.1 |
| 10 | Fungicide | 0.05 | 3.33E+01 | kg | 2.49E+13 | 4.14 | 78.7 | 82.8 |
| 11 | Herbicide | 0.05 | 4.98E-01 | kg | 2.49E+13 | 0.0620 | 1.18 | 1.24 |
| 12 | Calcium | 0.05 | 2.40E-01 | kg | 1.00E+12 | 0.0012 | 0.0228 | 0.0240 |
| 13 | Nitr. Calcium | 0.05 | 1.58E+00 | US$ | 3.30E+12 | 0.0261 | 0.496 | 0.522 |
| 14 | Nitr. Potass. | 0.05 | 2.14E+00 | US$ | 3.30E+12 | 0.0353 | 0.670 | 0.705 |
| **Contribution of the Economy (S):** | | | | | | | | |
| 15 | Family labor | 0.9 | 2.67E+02 | US$ | 3.30E+12 | 79.2 | 8.80 | 88.0 |
| 16 | Tax | 0.05 | 2.46E+00 | US$ | 3.30E+12 | 0.0405 | 0.770 | 0.811 |
| 17 | Service | 0.05 | 8.33E+01 | US$ | 3.30E+12 | 1.38 | 26.1 | 27.5 |
| 18 | Phone | 0.05 | 1.54E+01 | US$ | 3.30E+12 | 0.254 | 4.82 | 5.08 |
| | | | | | | | **Total Emergy (Y):** | **1340** |

[A] Extract from [6] and common sense.
[B] The numeric value and emergy intensity are the same as in Table 5.
[C] These flows are multiplied by $10^{13}$ [seJ/ha/year].

Table 10. Aggregate flows of the Santa Helena farm (SH) considering partial renewabilities in the year 2003.

| **Renewable [A]** | | | **Non-Renewable [A]** | | |
|---|---|---|---|---|---|
| Rr = | 2.508E+15 | seJ/ha/year | Rn = | 0.0 | seJ/ha/year |
| Nr = | 0.0 | seJ/ha/year | Nn = | 6.61E+15 | seJ/ha/year |
| Mr = | 4.614E+14 | seJ/ha/year | Mn = | 2.60E+15 | seJ/ha/year |
| Sr = | 8.087E+14 | seJ/ha/year | Sn = | 4.05E+14 | seJ/ha/year |

[A] Data come from Table 9.

Table 11. Emergy indices without considering and considering the partial renewabilities.

| **Indices (traditional)** | **Indices (+renewabilities)** | **traditional** | | **+renewabilities** | |
|---|---|---|---|---|---|
| | | **DC[A]** | **SH[A]** | **DC** | **SH** |
| Tr = Y/Ep [seJ/J] | Tr=Y/Ep [seJ/J] | 851,7 | 968,0 | 851,7 | 968,0 |
| EYR=Y/F | EYR=Y/(Mn+Sn) | 26.12 | 3.13 | 43.73 | 4.46 |
| EIR=F/I | EIR=(Mn+Sn)/(R+Mr+Sr+N) | 0.04 | 0.47 | 0.02 | 0.29 |
| %R=100*(R/Y) | %R=100*(R+Mr+Sr)/Y | 83.52 | 18.72 | 85.06 | 28.20 |
| EER=Y/input.emdollar[B] | EER=Y/input.emdollar[B] | 11.79 | 2.64 | 11.79 | 2.64 |

[A] DC = Duas Cachoeiras farm in the year 2003; SH = Santa Helena farm in the year 2003
[B] emdollar in Brazil (2003) = 3.3 $10^{12}$ seJ/US$. Reference: [10]
input (money): DC = 67 000 R$/year; SH = 71 890 R$/year

Table 12. Economic Indices

| Indices | Equation | DC[A] | SH[A] |
|---|---|---|---|
| Yield [B] | $\frac{(input\ money)-(output\ money)}{(output\ money)}$ | 1.93 | 1.11 |
| Real Yield [C] | $\frac{(input\ money)-(output\ money+negative\ externalities)}{(output\ money+negative\ externalities)}$ | 1.93 | 0.41 |

[A] DC = Duas Cachoeiras farm in the year 2003; SH = Santa Helena farm in the year 2003.
[B] output money: DC = 22 845 R$/year; SH = 34 093 R$/year.
[C] In this calculation the value of the negative externalities was only considered in conventional production. The considered value was 360 US$/ha/year [3, 4].

## 4. DISCUSSION

### 4.1. Transformity

The transformity of Duas Cachoeiras farm (851,000 seJ/J) is 12% lower than Santa Helena farm value (967,000 seJ/J), pointing out a best ecosystem efficiency of DC farm (Table 11), due to the diversification and recycling, which are characteristic of ecological farming. The low values of both transformities can be explained by the small dimension of both farms and the intense use of human labor, mostly provided by family members.

### 4.2. Emergy Yield Ratio (EYR)

The EYR is an indicator that measures the ability to exploit local natural energy resources, both renewable and non-renewable. For Duas Cachoeiras farm EYR is 26.1, whereas for Santa Helena farm the value was 3.1 (Table 11). This result points out that the first farm uses much more natural resources, showing less dependence from non-renewable resources. Intensive conventional agricultural systems have EYR values lower of than 1.1 [16].

### 4.3. Emergy Investment Ratio (EIR)

EIR measures the ratio between the investment of society and the contribution of nature to produce a specific good. The EIR index accounted 0.04 for the Duas Cachoeiras farm and 0.47 for the Santa Helena farm. Thus, for the Duas Cachoeiras farm, the environment provides more resources used in the productive process, as compared to the Santa Helena farm. This situation should lower the production costs allowing a better performance on the market. This index accounts, for highly conventional agricultural systems, about 7 [16].

### 4.4. Renewability (%R)

The renewability observed in this study was 83 and 18% for the Duas Cachoeiras farm and the Santa Helena farm, respectively (Table 11). The agroecological management is closer to the self-sustainability, with higher quality of the products, issuing in a higher price on the market, and lower dependence on external resources. The recommendations towards a more sustainable agricultural system, suggested by the Agenda 21, at global and national levels, could lead to adjustments on farms producing conventionally, reducing environmental and social impacts. The use of partial renewability of each input used lead to a better measurement of renewability. Accounting for the renewability of each input can improve emergy evaluations, it is especially for important for semi-renewable inputs (as manure, labor, electricity) purchased at local or regional scales of the economy [6].. The DC index changes from 83% to 85%, while the SH changes from 18% to 28%. There is an important difference in the renewable fraction of family labor

(90% of renewability) and contracted labor (60% of renewability). These farms use family labor or employees living in the same region where the property is located. In conventional systems of production, where all labor force is made by hired workers, these flows are considered not renewable [6].

### 4.5. Emergy Exchange Ratio (EER)

This index verifies if the total emergy used in the system was paid (in monetary terms) by selling the products. The lower this value the better, since it is calculated by dividing the emergy used by the emergy received. The EER obtained were 11.79 for the Duas Cachoeiras farm and 2.64 for the Santa Helena farm (Table 11), indicating a better performance of Santa Helena farm.

### 4.6. Economic yield

The income calculated in this research was 193% for Duas Cachoeiras farm and 111% Santa Helena farm (Table 12). Thus, for each monetary unit spent in the Duas Cachoeiras farm, 2.9 monetary units are earned by products selling, while for the Santa Helena farm, 2.1 monetary units are earned. This result points out that both properties obtain profit. Duas Cachoeiras farm, however, obtains higher profit, protecting nature in the meanwhile. Considering the costs of the negative externalities in the calculation of the income for conventional system (Table 12), the index decreases of 41% for the Santa Helena farm, while in the Duas Cahoeiras farm, the index does not change, because the farm does not produce any negative externality.

## 5. CONCLUSIONS

The quality of farm diagnosis obtained by the interpretation of emergy indices confirms that emergy methodology is useful tool in performing environmental accounting of production systems, since it takes into consideration the contribution of the nature beyond production means, labor and services. The application of emergy analysis could improve the development of planning and administration tools needed to achieve a more sustainable development, following Agenda 21 commitments.

This research leads to the following conclusions: (a) emergy and economic indices showed a better performance for the Duas Cachoeiras farm, indicating that the use of agroecology results in a more balanced relationship between production and natural environment; (b) since both farms are located in the same region and have the same physical characteristics (soil, altitude, climate, solar radiation, rain, regional biodiversity, etc.), the differences in emergy and monetary values between them are only due to the agricultural model adopted; (c) accounting for the partial renewability of each incoming flow allowed a more accurate measurement of the sustainability of the farms under study; (d) emergy methodology could allow a better farm management resulting in higher efficiency and an environmentally friendly approach.

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