

## AGRICULTURAL ECONOMICS

# Agro-ecological evaluation of tropical farming systems using emergy: in Rio de Janeiro – Brazil

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## Abstract

The article is based on an agro-ecological evaluation of seven different agricultural systems in Teresópolis, Rio de Janeiro. The studied systems are dealing with: vegetable production system, ecological husbandry, cattle production system, sylvopastoral approaches as well as citrus cropping systems. The main objective is to evaluate the environmental impact of these systems using the “Emergy Analysis” as methodology. For this purpose, input data as materials, services, natural renewable/nonrenewable sources of 42 crops were analyzed. This method is based on energy flows, transforming all inputs and outputs in a common unit. This analysis allows comparisons across agricultural systems and their environmental impacts, as well as, makes possible the identification of scenarios to achieve greater sustainability. The main conclusions of this study are: the vegetable systems have large amounts of energy invested in irrigation, fertilizers and fuels; the largest value of sustainability corresponds to the ecological systems and it has the capacity to save capital in form of biomass in the system; cattle system causes bigger environmental damage and have the smallest yield per hectare in economic and energy terms; as for the citrus systems, a low investment rate was found and the use of renewable resources from this system is comparable to the vegetable systems.

*Key words:* Emergy analysis, Farming systems, Agro-ecology, Atlantic Forest

## Introduction

This study was carried out in the basin of Córrego Sujo, in the municipality of Teresópolis, located in the Atlantic rainforest, in the hinterland of Rio de Janeiro. The basin is composed for 9 micro-basins, covering an area of 53 km<sup>2</sup> (Homma, 2003; Gaese et al., 2009). The agriculture in the region is characterized by intensive, small (less than one ha) but often irrigated horticultural production systems (Gaese et al., 2005). This horticultural system has little or none interaction with the cattle and forest subsystem. The inputs such as organic and inorganic fertilizers are introduced to the system (Torrico, 2009). The plants are produced in the region using good quality seed. Most of the young plantlets are produced locally in specialized nurseries. The products of the

system are marketed by different channels, mostly dominated by middlemen who take the production to the surrounding markets. The productive units generally opt for diversification market strategies, since the prices are quite fluctuating during the whole year (Blumen, 2006).

The horticultural systems in the region are highly intensive, especially the horticultural systems based on either fruit, leaf or mixed that make high use of inputs like nitrogen fertilizers, pesticides and herbicides. These systems are also the most common ones in the region. The ecological system hardly makes use of external inputs. The cattle system occupies notably the biggest territorial extension, 83.7% of the total agricultural area (Meier et al., 2006) and it uses low external inputs as is also the case for the sylvopastoral and citrus systems (Torrico, 2004a).

The objective of this paper is to evaluate the environmental impact of the seven farming systems, the load capacity and the use of natural and economic resources using a common unit, based on the solar energy reaching the earth. The hypothesis is: quantifying inputs of agricultural systems on a common basis using emergy analysis, will facilitate comparisons across agricultural systems and its environmental impacts, as well as,

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make possible the identification of scenarios to achieve greater sustainability (Odum, 1988, 1996). It is assumed that agricultural systems can be compared not only with each other but also with the surrounding natural systems, using the same units. This comparison is possible through the emergy theory that is a powerful method to measure the environmental and economic impacts caused by agricultural systems. This hypothesis also refers to the loss of natural capital of a region, and to the quality of the inputs. It allows identifying different scenarios, within which it is possible to replace less efficient systems through others with the objective to increase sustainability and to balance natural and agricultural systems.

### Materials and Methods

This study was carried out in the Córrego Sujo Basin in Teresópolis. In the municipality of Teresópolis in the mountain region of the Atlantic Forest, emergy analysis was accomplished to compare the main Farming systems in the Córrego Sujo basin. To evaluate the environmental impact, the input data and average yields of 42 crops. To accomplish this objective we have analyzed: (a) ecological (bio) farm, (b) cattle systems, (c) fruit vegetables, (d) leaf vegetables, (e) vegetables mixed systems and (f) citrus plantation. As materials we consider: seeds, limestone, fertilizers, pesticides, herbicide, fuels, and machinery (the latter one considered as depreciation of capital investment); as services we consider: manpower, administration, transport, taxes, insurance, and social security. The manpower data have been expressed in terms of working days of 8 hours  $\text{ha}^{-1}\text{year}^{-1}$  i.e.  $\text{md ha}^{-1}\text{y}^{-1}$ .

For this purpose, classical economic analysis and emergy analysis was required in order to compare the main farming systems of the basin. The used economical indices were internal rate of return, cash flow, net present value and investment cash flows.

The emergy methodology is a quantitative evaluation method which valorises the nature input to the economic systems. In other words, emergy is a measure of direct and indirect supporting energy needed in different work processes supporting a product or a service (money, mass, energy, information), using a common unit (Odum, 1996; Brown, 2001). In this method, the basic unit of measurement used is the solar emergy joule (sej) (sej = solar energy expressed in Joule), which refers to the accumulated amount of energy used up in the chain behind a good or service (Odum, 1988, Odum and Odum, 2000). The solar transformity of sunlight

absorbed by the earth is defined as the baseline at  $1 \text{ sej J}^{-1}$  Corresponding to a yearly input of  $3.65\text{E}+13 \text{ J/ha}$ . The basic idea is that solar energy is our ultimate energy source and by expressing the value of products in emergy units, it becomes possible to compare apples and pears (Jorgensen, 2001).

The procedure for the emergy evaluation is described and summarized by Haden (2003) in three steps: the first one consists of drawing the energy system diagram, the second one elaborates the emergy evaluation table and the third one the calculation of the emergy indicators as well as the summary diagrams. The summary diagrams shows all aggregated emergy inputs coming from the economy system as services or materials and from the natural system as renewable or not renewable resources. In Figure 1, R is the sum of the renewable emergy flows supporting the economy (i.e. rain, waves, tide); N is the sum of non-renewable resources from within the system (national) boundary; M is the sum of all materials used or paid in the system; S is the sum of all services used or paid in the system; Y is the total consumed emergy; Ep is the total energy produced from the system and C is the capital of the system (biomass, biodiversity, water, soil fertility, etc).

After tabulating the material and energy flow data for the system in question and correcting for their emergy contributions using transformities<sup>1</sup> (Odum, 1988; Scienceman, 1987, 1989), a number of emergy ratios and indices were calculated (Table 1). For all these calculations emergy related indices have been introduced to assess various aspects of the sustainability for farming systems. The transformity is the inverse value of the system efficiency for a product or service). In 1996 H. T. Odum defined transformity as, "the emergy of one type required to make a unit of energy of another type. For example, since 3 coal emjoules (sej) of coal and 1 sej of services are required to generate 1 J of electricity, the coal transformity of electricity is  $4 \text{ sej J}^{-1}$ ". The Emergy Yield Ratio evaluates the efficiency of a production unit or process. If the relationship is smaller than 1 the system consumes more than what it produces (Ortega, 2001). The Environmental Load Ratio measures the environmental impact, especially through soil loss (Chen, 2003; Lal, 2003). When the relation has a

<sup>1</sup> In Scienceman (1987) proposed that the phrases, "energy quality", "energy quality factor", and "energy transformation ratio", all used by Odum, be replaced by the word "transformity" (p. 261). This approach aims to solve a long standing issue about the relation of qualitative phenomena to quantitative phenomena often analysed in the physical sciences, which in turn is a synthesis of rationalism with phenomenology. That is to say that it aims to quantify quality.

high value it suggests that the system uses high technological levels in terms of energy. The Energy Investment Ratio measures the dependence of the system from bought products, and indirectly measures the environmental loads. The value increases proportionally with the dependence. The Energy Exchange Ratio measures the capital loss

of the system (Cavaletta, 2004). If the values are smaller than 1, it means that the system transfers positively to the economic urban system. The Renewability indicates the percentage of renewable energy in relation to the total energy used from the system.

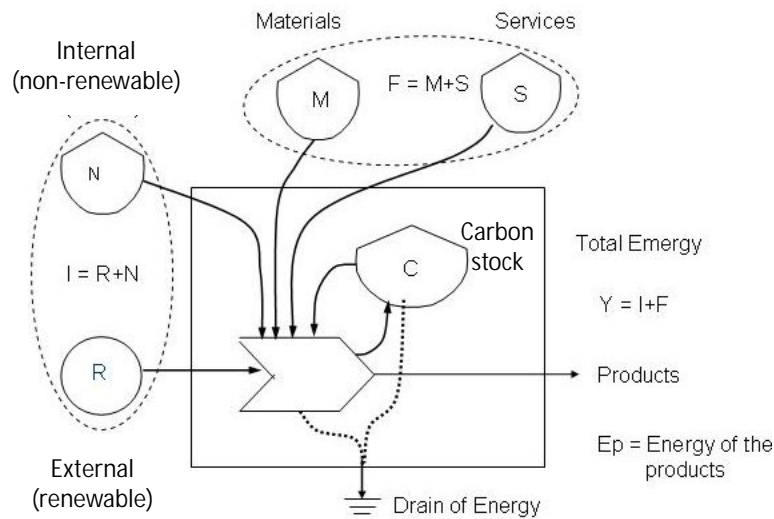


Figure 1. Aggregated energy input and outputs from the economy (service and materials) and renewable and not renewable resources from natural systems.

Table 1. Summary of the emergy indices used in this study.

Indices	Form	Description
Emergy Yield Ratio	$EYR = Y/F$	Evaluates the efficiency of a production unit or process. If the relationship is smaller than 1 the system consumes more than it produces;
Environmental Load Ratio	$ELR = (N+F)/R$	A measure of environmental impact. A high value indicates heavy dependency on non renewable energy sources.
Emergetic Investment Ratio	$EIR = F/I$	Measures the dependence of the system on purchases material and services, and indirectly measures the environmental loads;
Emergy Exchange Ratio	$EER = Y/income * 3.18E12$	Measures the capital loss of the system. If the value is lower than 1, it means that the system transfers positively to the urban economy;
Transformity	$Tr = Y/E_p \text{ (sej/J)}$	Is the amount of energy (expressed in sej/J or sej/g), which has been used to create a flow or resource;
Renewability	$\%R = R/Y * 100 \text{ (\%)}$	Indicates the percentage of renewable emergy in relation to the total emergy used from the system.

Source: Adapted from Odum (1996)

sej = Solar energy expressed in Joule

3.18E12 = setting value from regression of Brazilian GDP

## Results and Discussions

### Farming systems

All physical, biological and monetary inputs of the studied agricultural systems were converted into energy flows and are aggregated as shown in Figure 2 drawn based on Odum (1994) and Ortega, (2001). The principal renewable flows are sunlight, rainfall and minerals. Purchased goods, fertilizers, fuels, and services are also shown. Internal production systems include forests and forest in regeneration (1 to 3 years old), citrus orchards, intensive and ecological-organic farming systems; livestock are also shown in Figure 2.

Positive economic indices were recorded for all crops cultivated as a monoculture system. The relationship costs benefit indicates that all crops recover more money than the amount invested. The cultivations with more values are: Onion Evergreen (9.87), Paprika (3.7), and Tomato (2.99). The cultivations that present smaller relations of benefit cost are: cabbage (1.12), endive (1.18) and beet (1.22) (Table 2). Because the crop cycle is always smaller than 1 year, the recovery of capital is quick.

From that point of view the Net Present Value as well as the Internal Rate of Return are highly positive (77), whereas the average net income per hectare and per year is R\$ 15,500 for average production costs amounting to R\$ 8,200 per ha and year.

The intensive horticultural systems for fruits, leaves or mixed systems are presenting big economic returns, varying according to the fluctuating market prices. The revenues can reach 3,600 up to 13,480 US\$ ha<sup>-1</sup>. On average, revenues for the horticultural systems based on fruit, on leaf or on mixed production amount to 6,760, 4,770 and 5,110 US\$ ha<sup>-1</sup> respectively. From the economic point of view, large differences exist with the less intensive systems, like the ecological systems with 2 to 6 months fallow and having a net annual income of 899 US\$ ha<sup>-1</sup> on average. Finally, the systems that present very low income per hectare and per year are the Cattle, Sylvopastoral and Citrus systems with 78, 84, and 146 US\$ ha<sup>-1</sup>y<sup>-1</sup>, respectively (Table 3).

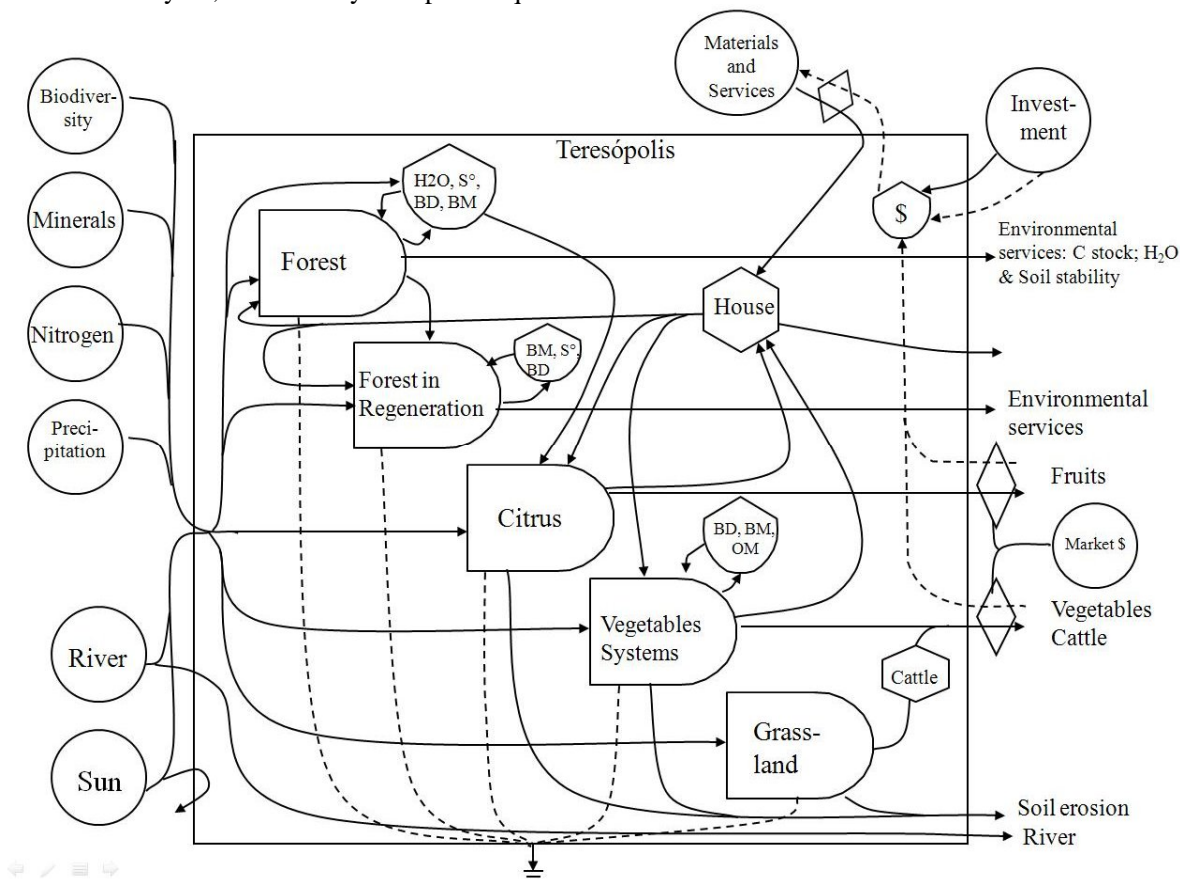


Figure 2. Teresopolitan environmental/economic system depicting resource flows entering the system and the organization of major internal components that utilize those resources. BD: Biodiversity, BM: Biomass, OM: Organic Matter and S: Soil.

(Diagram based on Odum 1994 and Ortega 2001).

Table 2. Calculation of economic indicators of the most important crops (as monoculture).

Crop	Production Cost (R\$ <sup>(3)</sup> ha <sup>-1</sup> )	Gross income (R\$ ha <sup>-1</sup> y <sup>-1</sup> )	Indicators	
			IRR <sup>(1)</sup>	C/B <sup>(2)</sup>
Lettuce	4,869	8,478	35	1.74
Water cress	6,201	16,744	54	2.70
Broccoli	10,255	20,513	15	2.00
Onion Evergreen	12,350	121,900	71	9.87
Chicory	7,061	19,110	83	2.71
Lady finger	12,652	23,360	29	1.85
Chinacol	14,833	35,633	47	2.40
Cilantro	6,236	19,295	164	3.09
Spinach	6,883	18,272	135	2.65
Paprika	10,826	40,016	74	3.70
Tomato	14,004	41,939	111	2.99
Carrot	2,433	5,760	28	2.37
Zucchini	3,758	7,336	38	1.95
Endive	5,743	6,750	33	1.18
Beet	5,223	6,380	41	1.22
Col	5,427	15,170	102	2.80
Mint	8,435	2,620	88	1.50
Leek	12,067	42,140	79	3.49
Rocket	5,728	15,189	54	2.65
Cabbage	13,200	14,750	62	1.12
Rocket	5,728	9,600	65	1.68

(1) Intern Rate of Return,

(2) Cost/Benefit,

(3) 1.00 BRL = 0.583245 USD FEB 21, 2012)

Table 3. Average Net Income of the most important farming systems in Córrego Sujo

Farming system	Range of Net Income (US\$ ha <sup>-1</sup> y <sup>-1</sup> )	Average Income (US\$ ha <sup>-1</sup> y <sup>-1</sup> )
Bio-farm	120 to 2,450	899
Cattle	66 to 98	78
Sylvopastoral	66 to 102	84
Fruit Vegetables	4,440 to 10,220	6,760
Leaf Vegetables	3,600 to 12,780	4,770
Mixed Vegetables	4,800 to 13,480	5,110
Citrus	130 to 189	146

Source: author based on Torrico (2004a and 2004b)

## Manpower

The agricultural systems that use more manpower are those based on horticulture, either for fruit, vegetable leaves or mixed production, using in total 118 workers/100 hectares, corresponding to 80% of the available household manpower. The vegetable systems that conserve a forest fragment (60% of the area) in the production unit use considerably less manpower, approximately 45 workers per 100 ha, of which 65% correspond to family manpower. The ecological systems use low quantity of manpower per production unit, since usually the areas dedicated to the agricultural production do not surpass 10% of the total area (Figure 3).

The horticultural systems of the region are highly intensive, especially the horticultural systems based on either fruit, leaf or mixed production that make high use of inputs like nitrogen fertilizers, pesticides and herbicides. These systems are also the most common ones in the region. The ecological system hardly makes use of external inputs. The cattle system occupies notably the biggest territorial extension (83.7% of the total agricultural area) and it uses low external inputs as is also the case for the sylvopastoral and citrus systems. A general overview of the farming systems in Córrego Sujo Basin is presented in the Table 4.

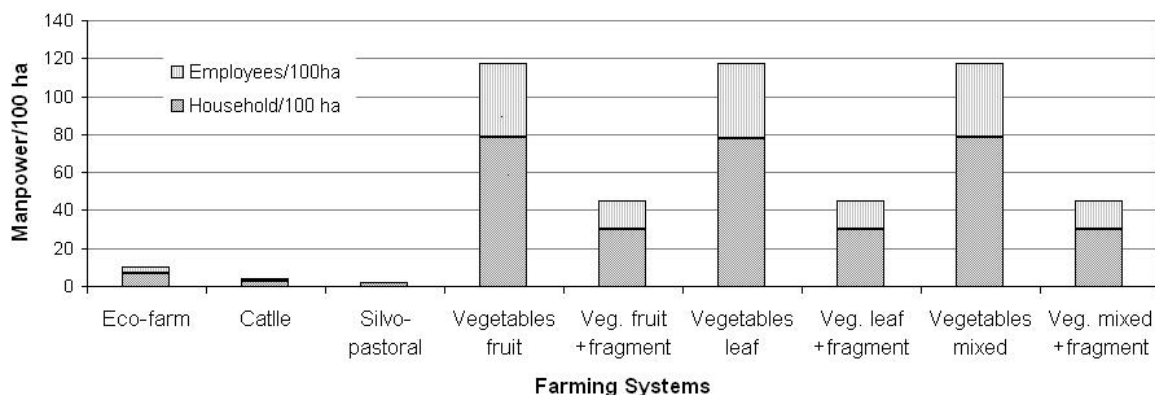


Figure 3. Family and employed manpower in different farming systems.

Table 4. General overview of the agriculture systems in Córrego Sujo, Teresópolis.

	Ecofarm	Cattle	Sylvo-pastoral	Fruit Vegetables	Leaf Vegetables	Mixed Vegetables	Citrus
Area (%)*	0.1	83.7	2.3	2.9	5.8	2.2	2.8
Seeds quality	high	none	none	high	very high	very high	high
Fertilizers	none	none	none	high	high	high	low
Pesticides	none	none	none	high	high	high	none
Herbicides	none	none	none	moderate	moderate	moderate	none
Anti-parasites	none	moderate	moderate	none	none	none	none
% Forest (average)	80	5	15	33	32	32	15
% Crops Area (average)	18	0	0	66	66	66	84
Fallow (months/yr)	2 to 6	0	0	0	0	0	0
Production Losses (%)	18	0	0	14	11	11	10
Market destination (%)	20	100	100	99	100	100	98
Irrigation	low	none	none	high	high	high	None
Principal product	diversified	meat	meat	Chayote, tomato	salad, cabbage	Chayote, salad	Mandarin

\* Percent of the total agricultural area in Teresópolis

### Emergy synthesis

A farming system is a natural resource management unit operated by a farm household, and includes the entire range of economic activities of the family members (on-farm, off-farm agricultural as well as off-farm non-agricultural activities) to ensure their physical survival as well as their social and economic well-being (Lockeretz, 1982; Chen, 2006).

Emergy synthesis for each farming system is summarized in the Table 5. The long-term sustainability of human economic production and its basis in natural capital stocks is achieved via a suite of emergy-based indices (Unicamp, 2004; Haden, 2003). These indices, which relate flows from the economy to flows to the environment,

were used to compare net yields and environmental loading, and to identify more sustainable agricultural methods. The fraction Renewability (%R) quantifies the reliance of each system on renewable energies. The Emergy Yield Ratio (EYR) compares units of exported energy with emergy invested. For agriculture, an Emergetic Investment Ratio (EIR) from the economy is made in order to capture renewable emergy from the environment. This ratio quantifies the effectiveness of non-renewable resources to capture renewable resources. The Environmental Loading Ratio (ELR) is the ratio of purchased and non-renewable resources to renewable resources (Brown and Ulgiati, 1999; Brown, 2008).

Table 5. Computed transformities and emergy indices for farming systems in Córrego Sujo (Teresópolis) and comparison with literature.

Emergy indices from farming systems in Teresópolis	Indices					
	T <sup>(1)</sup>	%R <sup>(2)</sup>	EYR <sup>(3)</sup>	EIR <sup>(4)</sup>	ELR <sup>(5)</sup>	EER <sup>(6)</sup>
Ecofarm	4.8E4	66	5.34	0.23	0.51	1.23
Cattle	6.3E7	41	22.56	0.05	1.41	0.47
Sylvopastoral	2.3E5	41	19.16	0.06	1.44	0.43
Fruit vegetables	3.1E5	15	1.25	4.02	5.66	0.61
Leaf vegetables	6.7E5	12	1.19	5.26	7.28	0.92
Mixed vegetables	4.3E5	13	1.21	4.68	6.52	0.61
Citrus	3.4E5	43	2.78	0.56	1.35	1.91
Córrego Sujo (average of all farming systems)						
Emergy indices for different farming systems (literature)						
Ecological soybean <sup>(a)</sup>	8.8E4	92	1.09	1.19	0.46	1.45
Organic Soybean <sup>(a)</sup>	8.1E4	78	1.27	1.40	0.42	1.35
Chemical Soybean <sup>(a)</sup>	1.0E5	74	1.35	3.40	0.23	2.51
Herbicide Soybean <sup>(a)</sup>	1.1E5	31	3.25	3.70	0.21	2.69
Ecological farming system <sup>(b)</sup>	2.0E5	69	3.36	0.4	0.82	0.02
Ecofarm integrated system <sup>(c)</sup>	2.8E5	75	11.90	0.09	-	5.52
Sitio Santa Helena <sup>(c)</sup>	8.5E5	27	2.52	0.66	-	2.33
Sitio Três lagos <sup>(c)</sup>	2.3E6	25	7.82	0.15	-	9.91
Bovine meat (sej kg <sup>-1</sup> ) <sup>(d)</sup>	2.1E12*	8	7.83	-	11.0	-
Danish agriculture <sup>(e)</sup>	-	-	1.17	5.91	9.67	-

\* sej kg<sup>-1</sup>

(a)Ortega (2001), (b)Unicamp (2004), (c)Roosevelt-Agostino (2001), (d)Serrano (2001), (e)Haden (2003)

(1)Transformity; (2)Renewability; (3)Emergy yield ratio; (4)Emergy investment ratio; (5)Environmental loading ratio; (6)Emergy exchange ratio

### Transformity (Tr)

Transformity values per ha varies from 4.88E4 to 6.30E7 sej J<sup>-1</sup>. The transformity values of ecological systems (4.88E4 sej J<sup>-1</sup>) are lower than that of the systems like cattle (6.30E7 sej J<sup>-1</sup>), Silvopastoral (2.35E5 sej J<sup>-1</sup>), vegetables on average (4.5E5 sej J<sup>-1</sup>), and citrus (3.3E5 sej J<sup>-1</sup>). This means that ecological systems are more efficient, whereas cattle systems are most inefficient. Other agricultural transformities are reported by Brandt-Williams (1999) in Florida for corn (1.26E5 sej J<sup>-1</sup>) and tomatoes (8.6E5 sej J<sup>-1</sup>), by Cohen (2006) for maize in Kenya (1.11E5 sej J<sup>-1</sup>), by Ortega et al. (2001) in Brazil for Ecological soybean (8.8E4 sej J<sup>-1</sup>), for Chemical soybean (1.0E5 sej J<sup>-1</sup>), and by Haden (2003) in Denmark for crops and animal husbandry (2.59E5 sej J<sup>-1</sup>).

### Renewability (%R)

Is the percentage of the total energy driving a process that is derived from renewable sources (%R = R/Y). In the long run, only processes with high %R are sustainable. As renewable resources we consider: rain, uptake of nutrients like nitrogen, minerals from soil rocks, products and services obtained from the farm area under preservation (Ortega, 2001), according to Brazilian law at least 20% of total area (Brazil, 2009).

Because of the large amount of non-renewable inputs relative to renewable inputs, the vegetable system had the lowest fraction of renewable inputs (12%) compared to the citrus system (43%) and to the ecological system (66%). This indicates that the ecological system depended on renewable resources for over 66% of its inputs meaning that from an ecological point of view it is the most sustainable. Other renewability ratios for agricultural systems are presented in Table 4. The EIR, ELR and EYR offer additional information about the ability of each land use to be related to the larger economic system.

### Emergy Yield Ratio (EYR)

Because the cattle and silvopastoral systems are based almost exclusively on natural inputs, the EYR ratios are as high as 22.6 and 19.2, respectively, as would be expected. This indicates that these systems incorporate high free resources from nature in to the society or economy systems, but with a high loss of non-renewable resources (erosion). The ecological system has strong internal recycling which renders economic benefit to the farmer and ecological benefit to environment. The ecological (biological) system value is 5.4. The EYR typical values for agricultural products vary from 1 to 5. The lowest value is one, which happens when nature inputs are null (RN = 0). The

difference above the minimum value measures the cost-free contribution of the environment to production.

The value of EYR for the vegetable systems is closest to unity (1.19, 1.21, 1.25); it means that the nature contribution is low when compared to resources from economy; so, this system is not able to deliver too much net emergy to consumer systems because most parts of inputs are not renewable (e.g.: herbicide, fuel, fertilizers, pesticides, etc.). For the citrus system the value is slightly higher (2.78), this system do not have high economy inputs, and natural resources are bigger. The ecological system has strong internal recycling which renders economic benefit to the farmer and ecological benefit to environment. Bastianoni and Marchettini (2001) found an EYR value of 1.96 for farms with six different crops and livestock in Italy.

#### **Emergy Investment ratio (EIR)**

The intensive vegetable systems values are high (4.02 to 5.26), thus demonstrating an economically fragile agriculture due to its dependence on purchased inputs from foreign regions. The citrus system has good value (0.56). Livestock production, sylvopastoral systems and the Ecological farm show the lowest values, 0.05, 0.06 and 0.23 respectively. Those three systems use nature resources (free) instead of economy resources (expensive) having lower need of external investment and lower production costs. The ecological option demands more economy inputs (services) than the cattle systems. More emergy investment ratios for agricultural systems are presented in Table 5.

#### **Emergy Load Ratio (ELR)**

Vegetables leaf, fruit and mixed systems (7.28, 5.66 and 6.52) produce great environmental damage. Also the cattle systems, sylvopastoral systems and citrus systems (1.41, 1.44 and 1.35) generate high environmental impact. Ecological agriculture instead has lower value (0.51), which confirms greater use of natural renewable resources by ecological and organic production techniques. The greater environmental loading ratios for the intensive vegetable systems and cattle systems compared to the ecological system reflect the environmental cost of using more purchased resources. Similar behaviour in the mountainous region of the Atlantic Forest was observed by Ortega (2001).

#### **Emergy exchange Ratio (EER)**

The emergy exchange ratio shows that the transaction of the ecological production systems

(1.23) and citrus (1.91) do not receive a fair price. The received emergy by the transaction demonstrates that the systems export more emergy than the one received through the payment of the products. The cattle (0.47), sylvopastoral (0.43), vegetables fruit (0.61), leaf (0.92) mixed (0.61) give less energy to the buying system than to the producing system.

#### **Conclusions**

a) The horticultural systems use more manpower in comparison to the other systems; the ones that use less are the cattle systems. Due to the forest handling and agroforestry inside the same property, the ecological systems in general, make low use of manpower per hectare. But if it takes exclusively into account the agricultural area this option uses more manpower than that of all other studied systems.

b) The horticultural intensive systems in general obtain better net income and are also the most dependent in inputs coming from the economy and for this reason more unstable. They contribute also less to the economy of the region, because of their low use of renewable resources.

c) Cattle production is one of the most important components of agriculture in Teresópolis, being the main consumer of natural resources all together. Cattle production contributes to the degradation of resources, namely, land degradation, water scarcity and pollution, global warming, and diminishing biodiversity.

d) The cattle system causes bigger environmental damage and they have the smallest yield per hectare in economic and energy terms. Although these do not depend on resources coming from the economy they use many non-renewable resources. The erosion is the most important factor in terms of non-renewable resources. In economic terms this soil loss represents a very high value.

e) The vegetable systems had large amounts of energy invested in irrigation, fertilizers and fuels, and the cattle systems use great quantities of non-renewable resources, leading to a loss of autonomy of producers in relation to technology and prices fixed abroad. The ecological systems demonstrated potential gains in sustainability by reducing the energy devoted to these inputs. Because large amounts of non-renewable energies are required to supply water and nutrients to fields, finding methods to reduce these inputs has great potential to increase the sustainability and decrease the environmental loading of agricultural production.

f) The largest value of sustainability corresponds to the ecological systems in ecological



terms and also it is the only one that has the capacity to save capital in form of biomass in the system. These systems use fewer resources from economy and more natural renewable resources, which guarantee its sustainability. They ensure the survival of the producer throughout the time and the preservation of the biodiversity.

g) The substitution of the cattle systems by any other agricultural or forest system represents economic and environmental clear gains. The best options are the biological, agroforestry and forest systems.

h) The citrus systems is not the best, but could be also a good alternative, because the low investment rate, and its great aptitude to grow in hills. The use of renewable resources from this system is comparable to the vegetable systems. The use of material and services are very low, the transformity and renewability are better than the vegetable systems.

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