CERTIFICATION OF FOOD PRODUCTS USING EMERGY ANALYSIS

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ABSTRACT

In the commerce of food products there is an urgent need for a certification procedure to make it possible to distinguish products according to the different technical, environmental and social characteristics of their production systems. Food products can be grouped into three main types, according to their origin: ecological, organic and agrochemical. Up to now, ecological farmers have obtained a better price for their products but, as the number of agrochemical farmers that adopt organic techniques increases, the price paid for ecological products may decrease, jeopardizing ecological family managed farms. The ecological farm is quite different from other kinds of farm. It is a farm with a small or medium area (10-30 ha), managed by a family group who lives there, usually obeying environmental laws, preserving and using properly the natural resources. It is not fully oriented to the market, it produces for self consumption and exchanges many things without the use of money. The majority of its products are consumed in the region and part is exported. The ratio people/ha is high even if it is not_formal employment. On the other hand, an agrochemical farm can be of medium (30 ha), large (300 ha) or very big size (3000 ha or more) and is operated by an urban enterprise. Decisions are taken outside the rural area, even outside the region or the country. It uses industrial chemical inputs and machinery intensively; it employs few workers and causes a huge environmental impact. When this type of farm becomes organic, it substitutes chemical inputs with organic inputs, but maintains its other characteristics, So, it does not create jobs and its degree of autonomy and self-sufficiency remain low, keeping the system not sustainable. In this study, new emergy parameters were developed and used to enrich emergy methodology. They were applied to several cases studied in Brazil. The proposed emergy indices were able to characterize each agricultural system into the categories proposed. The results, until now, seem satisfactory.

Keywords:

Certification, Food Quality, Sustainability, Emergy, Agroecology, Rural Systems.

INTRODUCTION

Wackernagel and Rees (1997) consider that neoclassical economy vision of the flows in a production-consumption cycle (Figure 1) is unable to represent neither the inputs and outputs of economy resources nor the flows of natural resources. The neoclassical methodology cannot be used to calculate sustainability parameters (Ulgiati, 1998).

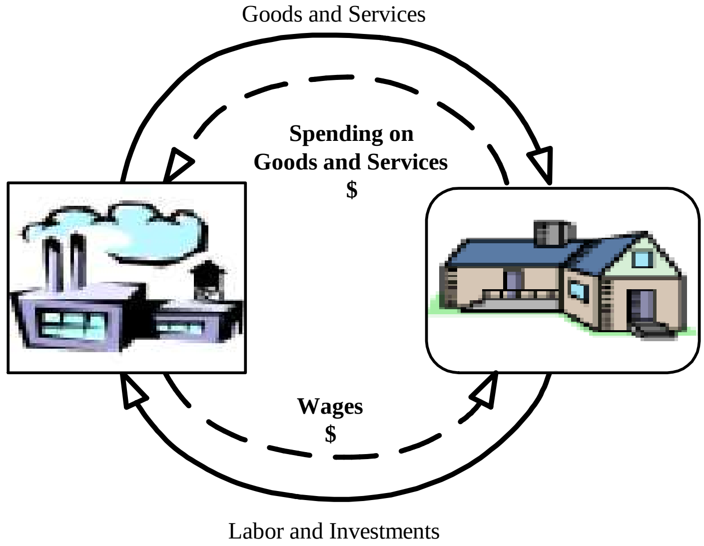

Figure 1. The economic perspective: circular flows
(adapted from Wackernagel & Rees, 1996)

New tools are required to deal with the inherent complexity of ecological-economic systems. One of these tools is the Emergy methodology (Odum, 1996), a very powerful method. Since this evaluation technique was mainly applied to analyze fossil fuel energy intensive agriculture systems in Europe and the USA, the procedures had to be improved to deal with the complex agricultural systems based on ecology and family work from the southern hemisphere (Ortega and Polidoro, 2002). Altieri (1998) reported that, in order to survive, ecological agriculture systems have to be prepared to compete with traditional fossil fuel energy intensive systems, and that this can be possible if inputs and outputs are priced and taxed appropriately, as well as the accounting should also consider subsidies, incentives and externalities. Time of conversion (Altieri, 1994) must be taken into account in the evaluation of production systems (Figure 2). The richness transfer established by increasing costs of chemical inputs and decreasing prices for agricultural products is shown in a very interesting graph (Figure 3) prepared by Gliessman (1998), using the Smith data (1992). Odum (2000) prepared a simulation program, whose results (Figure 4) show that raw-material prices decrease while fossil fuels are being consumed, but will recover later.

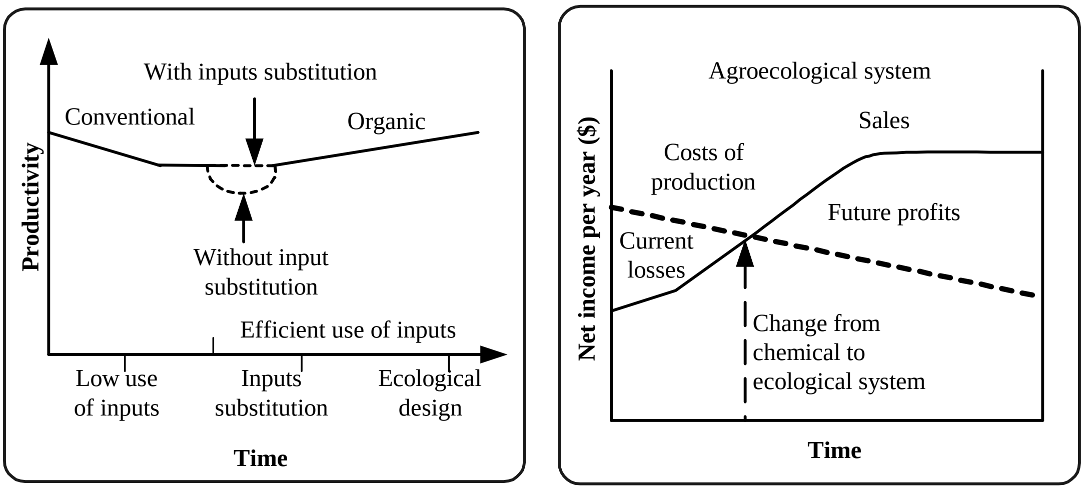

Figure 2. Stages in the agroecological conversion process of conventional agricultural systems (adapted from Altieri,1994).

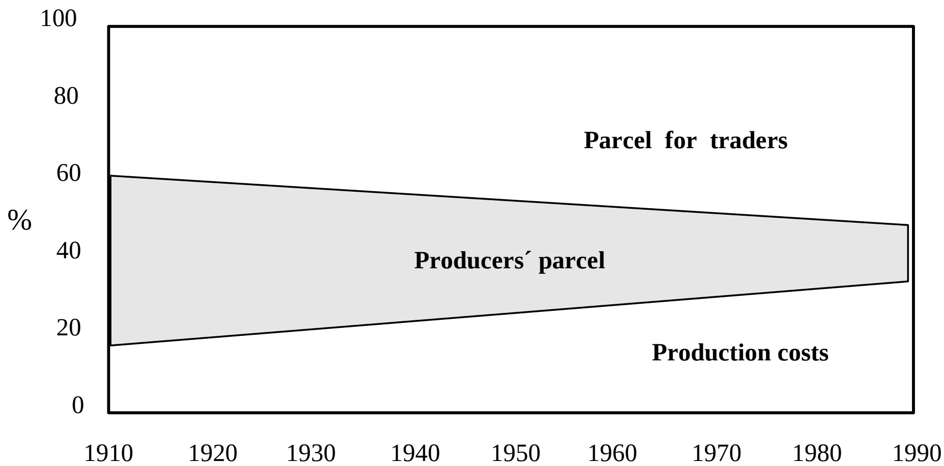

Figure 3. Decreasing parcel received by producers (adapted from Gliessman, 2000; data by Smith, 1992)

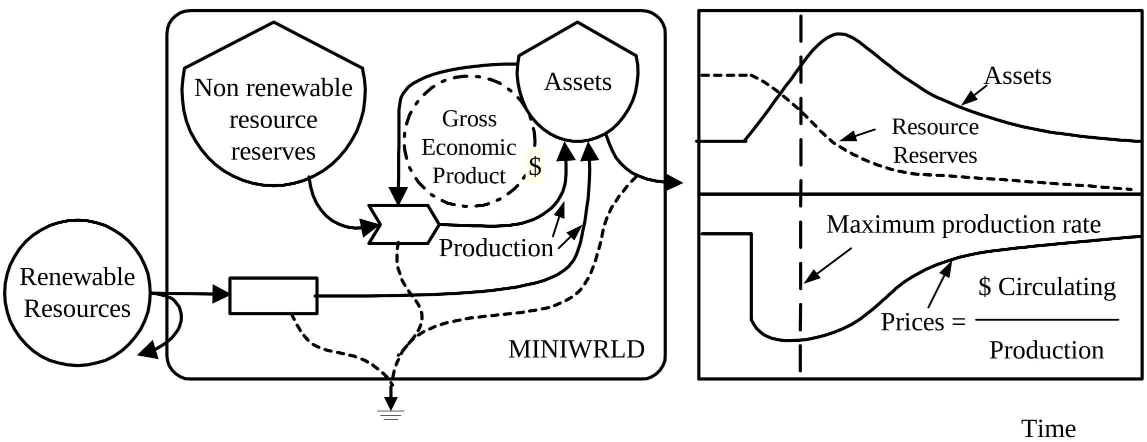

Figure 4. Simulation of the model Mini-World, a revision of the renewable and nonrenewable resources model (Odum, 2000).

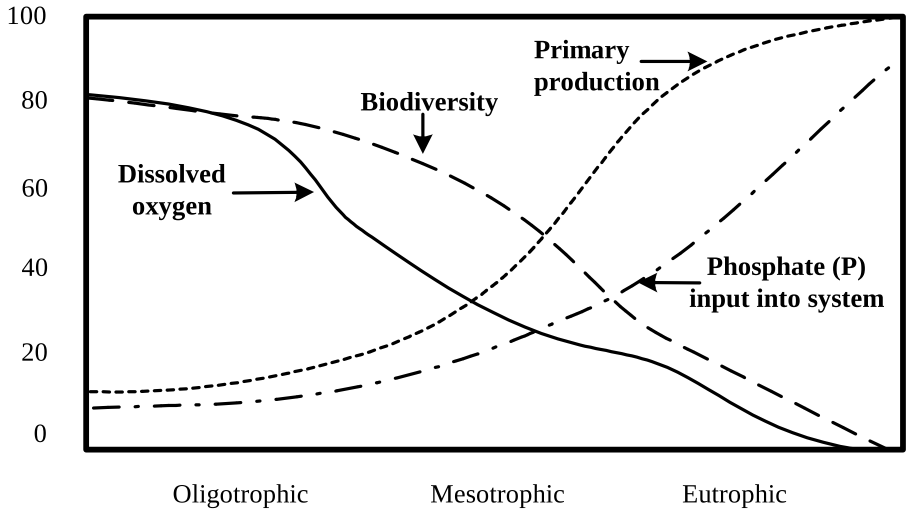

Figure 5. Main processes involved in the eutrophication of hydric resources (adapted from Correll, 1998)

Correll (1998), cited by Ferreira Gomes et al. (2000) showed (Figure 5) the increase in primary production caused by the addition of chemicals (P) and, at the same time, the negative impact on water resources biodiversity by agrochemical pollution. Sustainable development depends on biodiversity recovering and less use of chemicals.

The International Federation of Organic Agriculture Movements (IFOAM, 2000) recognizes the principle of Social Justice and recommends standards to certify that organic producers all over the world do follow this. However, the discussion is far from being closed and there is a need for methodologies to quantify social, ecological and economical cost/benefit ratios.

Questions about the correct characterization of different kinds of organic producers frequently arise during Brazilian organic agriculture meetings (Diniz, 2002). The aim is to determine how to proceed with certification, to suggest proper prices for inputs and products and to establish specific public policies at global and local levels.

Meanwhile, in the recent emergy analysis of soybean production (Ortega et al., 2002) some methodological advances were achieved although new questions appeared:

(a) How to consider the renewability of materials and inputs used?

(b) How can we distinguish products using process parameters?

(c) What is the adequate price for each system product?

MATERIAL AND METHODS

We used the emergy analysis method (Odum, 1996) and also ideas from Ortega et al. (2002). The diagram is shown in Figure 6. The same system in a condensed form appears in Figure 7.

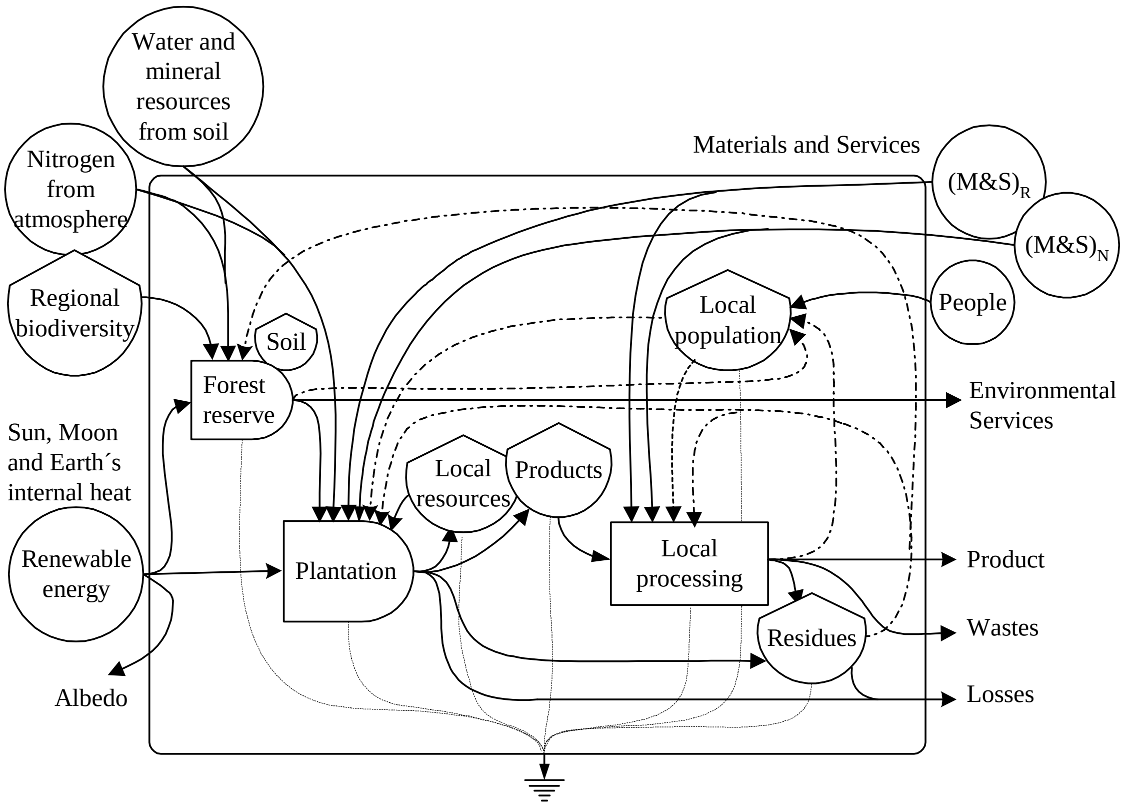

Figure 6. Energy flows diagram of rural system.

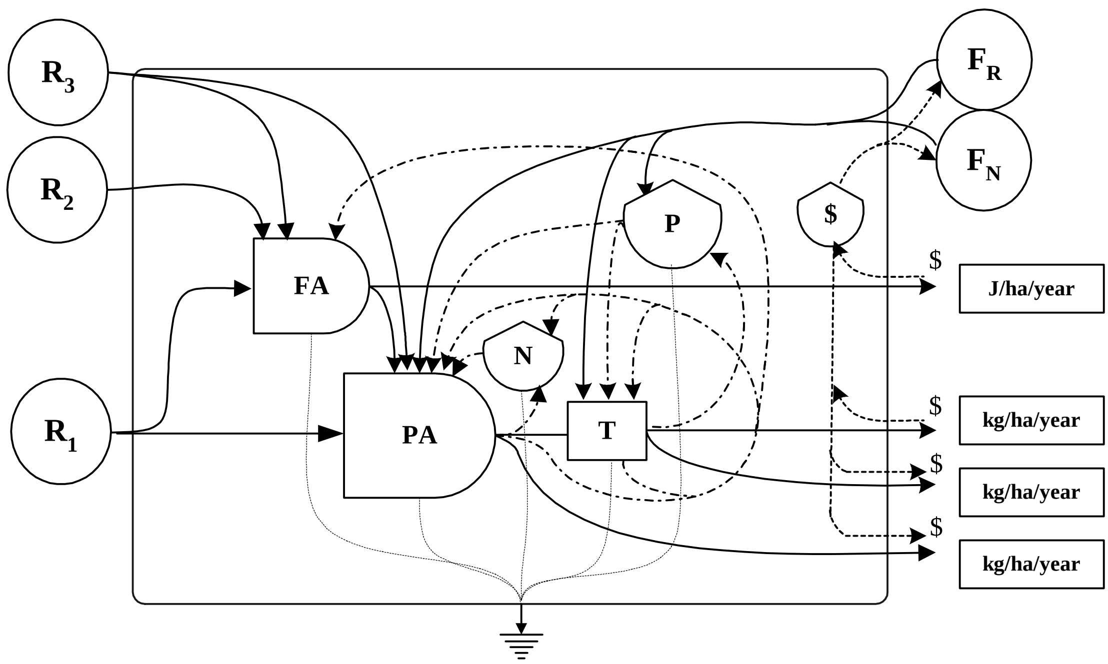

Figure 7. Aggregated energy flows diagram.

The Emergy Table proposed below makes it possible to consider renewability of materials, labor with more detail, and also to include externalities as additional services

Table 1. Classification of Emergy flows

Inputs and services	Description
I: Nature contribution	**R + N**
$R = R_1 + R_2 + R_3$ Renewable resources from nature	Rain; Materials and Services from preserved areas; Nutrients from soil minerals and air.
N: Non-renewable 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: Non-renewable Materials and energy	Minerals, Chemicals, Steel, Fuel, etc.
S: Services (total)	$\mathbf{S = S_R + S_N + S_A}$
S_R: Labor Services (renewable)	Labor (local and external): $S_R = S_{RL} + S_{RE}$
S_N: Other Services (basically non renewable)	Taxes, money costs, insurance, etc.
S_A: Additional Services (non renewable)	Externalities: effluents, medical and job costs,
Y: Total Emergy	**Y = I + F**

The Emergy Indices were slightly changed in order to evaluate Sustainability more properly, by considering renewability of each of the economic resources used. Labor was split into Local and External. Externalities were considered as additional services

Table 2. Proposals for Emergy Indices

Modified Emergy Indices	Formula	Concept
Renewability*	$\mathbf{R^* = (R + M_R + S_R) / Y}$	Renewable/Total
Environmental Loading ratio*	$\mathbf{ELR^* = (N+M_N+S_N) / (R+M_R+S_R)}$	Non renewable/renewable

New Emergy Indices	Formula	Concept
Labor Services Ratio	$\mathbf{LSR = S_R / S}$	Labor/Services
Labor Empower Ratio	$\mathbf{LER = S_R / Y}$	Labor/Empower
Local Work Ratio	$\mathbf{LWR = S_{RL} / (S_R+S_N)}$	Local labor/Labor
Externalities Empower Ratio	$\mathbf{ExER = S_A / Y}$	Externalities/Empower

<u>RESULTS</u>

The values of goods and services for soybean production farms (Ortega et al. (2002) were multiplied by their respective renewability (centesimal). W used results from previous calculations and common sense. In future works, we hope, these values will be confirmed.

Table 3. Inputs and transformity of four soybean production systems in Brazil

	Flows	Units	Ecol	Org	Chem.	Herb	Transformity	Ref
Materials (Economy Resources)								
M1	Farmer seeds	kg/ha/yr	8	8	0	0	**1.00E+12**	1
M2	Certified seeds	kg/ha/yr	56	56	56	68	**1.00E+12**	1
M3	Transgenic seeds	kg/ha/yr	0	0	0	0	**1.00E+13**	2
M4	Limestone	kg/ha/yr	0	0	800	800	**1.00E+12**	1
M5	Nitrogen fertilizer	kg/ha/yr	0	0	0	0	**3.80E+12**	1
M6	Phosphate fertilizer	kg/ha/yr	120	120	120	200	**3.90E+12**	1
M7	Potassium fertilizer	kg/ha/yr	40	40	120	80	**1.10E+12**	1
M8	Inoculating agent	kg/ha/yr	0.8	0.8	1.36	1.36	**3.18E+13**	1
M9	Herbicides	kg/ha/yr	0	0	3.44	6.64	**1.48E+13**	3
M10	Insecticides	kg/ha/yr	0.8	0.8	1.44	1.44	**1.48E+13**	3
M11	Formicides	kg/ha/yr	0	0	0.8	0.8	**1.48E+13**	3
M12	Fungicides	kg/ha/yr	0	0	0.16	0.16	**1.48E+13**	3
M13	Petroleum fuels	kg/ha/yr	24	32	64	32	**2.76E+12**	1
M14	Steel (depreciation)	kg/ha/yr	1.04	2.16	2.16	2.16	**6.70E+12**	1
M15	Manure (20% humidity)	kg/ha/yr	2133.6	2133.6	0	0	**1.45E+11**	2
Services (Economy resources)								
S1	Unqualified manpower	hours/ha/yr	116.0	80.0	2.6	0.4	**6.28E+11**	1
S2	Qualified manpower	hours/ha/yr	1.6	2.6	57.5	32.0	**1.88E+12**	1
S3	Administrative labor	US$/ha/yr	3.4	3.4	3.4	3.4	**3.70E+12**	4
S4	Technical assistance	US$/ha/yr	8.0	8.0	1.6	2.3	**3.70E+12**	4
S5	Accounting labor	US$/ha/yr	0.6	0.6	0.6	0.6	**3.70E+12**	4
S6	Costs of trips	US$/ha/yr	0.3	0.3	0.3	0.3	**3.70E+12**	4
S7	Governmental taxes	US$/ha/yr	7.6	7.6	10.9	10.9	**3.70E+12**	4
S8	Circulating capital costs	US$/ha/yr	2.4	2.4	2.4	2.4	**3.70E+12**	4
S9	Insurance costs	US$/ha/yr	0.8	0.8	0.5	0.8	**3.70E+12**	4
S10	Transportation costs	US$/ha/yr	5.4	5.4	5.4	5.4	**3.70E+12**	4
S11	Drying and storage costs	US$/ha/yr	11.4	11.4	11.4	11.4	**3.70E+12**	4
S12	Social security taxes	US$/ha/yr	10.2	10.2	10.9	10.9	**3.70E+12**	4
S13	Land leasing	US$/ha/yr	0	0	0	0	**3.70E+12**	4
Additional services								
S20	Governmental subsidies	US$/ha/yr	0	0	0	0	**3.70E+12**	4
S21	Effluent treatment	US$/ha/yr	0	0	16	8	**3.70E+12**	4
S22	Health treatment	US$/ha/yr	8	8	16	40	**3.70E+12**	4
Natural renewable resources								
R1	Rain	kg/ha/yr	1.5E+06	1.5E+06	1.5E+06	1.5E+06	**9.10E+07**	1
R2	Nutrients from rocks	kg/ha/yr	10	10	1	3	**1.71E+12**	1
R3	Atmospheric Nitrogen	kg/ha/yr	144.8	144.8	144.8	144.8	**4.60E+12**	1
R4	Sediments (rivers)	kg/ha/yr	0.1	0.1	0.1	0.1	**1.71E+12**	1
R5a	Forest products: seeds	kg/ha/yr	2	1	0	0	**1.48E+12**	1
R5b	Forest products: food	kg/ha/yr	20	10	0	0	**4.50E+11**	1
R5c	Forest products: biomass	kg/ha/yr	400	200	0	0	**3.69E+11**	1
R6a	Forest services: water	kg/ha/yr	12	6	0	0	**5.50E+08**	1
R6b	Forest services: leisure	US$/ha/yr	3.3	1.65	0	0	**3.70E+12**	4
R6c	F. s: biological control	US$/ha/yr	50	25	0	0	**3.70E+12**	4
Non-renewable natural resources								
N1	Soil loss	kg/ha/yr	800	800	10000	1200	**6.67E+10**	1
N2	Biodiversity loss	kg/ha/yr	0	0	80	15.2	**3.90E+11**	1

Table 4. Emergy analysis of soybean production in Brazil

		Renew ability R	Renewable Emergy E13 sej/ha/yr				Non renewable emergy E13 sej/ha/yr			
			Ecol	Org	Chem.	Herb	Ecol	Org	Chem.	Herb
M			34.87	34.93	8.68	9.75	64.66	67.56	169.01	191.84
M1	Farmer seeds	0.95	0.76	0.76	0.00	0.00	0.04	0.04	0.00	0.00
M2	Certified seeds	0.70	3.92	3.92	3.92	4.76	1.68	1.68	1.68	2.04
M3	Transgenic seeds	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M4	Limestone	0.01	0.00	0.00	0.80	0.80	0.00	0.00	79.20	79.20
M5	Nitrogen fertilizer	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M6	Phosphate fertilizer	0.01	0.47	0.47	0.47	0.78	46.33	46.33	46.33	77.22
M7	Potassium fertilizer	0.01	0.04	0.04	0.13	0.09	4.36	4.36	13.07	8.71
M8	Inoculating agent	0.70	1.78	1.78	3.03	3.03	0.76	0.76	1.30	1.30
M9	Herbicides	0.01	0.00	0.00	0.05	0.10	0.00	0.00	5.04	9.73
M10	Insecticides	0.01	0.01	0.01	0.02	0.02	1.17	1.17	2.11	2.11
M11	Formicides	0.01	0.00	0.00	0.01	0.01	0.00	0.00	1.17	1.17
M12	Fungicides	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.23
M13	Petroleum fuels	0.01	0.07	0.09	0.18	0.09	6.56	8.75	17.50	8.75
M14	Steel (depreciation)	0.05	0.03	0.07	0.07	0.07	0.66	1.37	1.37	1.37
M15	Manure (20% humidity)	0.90	27.78	27.78	0.00	0.00	3.09	3.09	0.00	0.00
S			14.82	13.12	14.81	12.06	11.38	11.00	13.75	11.95
S1	Unqualified manpower	0.80	5.83	4.02	0.13	0.02	1.46	1.00	0.03	0.01
S2	Qualified manpower	0.60	0.18	0.29	6.50	3.62	0.12	0.19	4.33	2.41
S3	Administrative labor	0.60	0.76	0.76	0.76	0.76	0.51	0.51	0.51	0.51
S4	Technical assistance	0.60	1.78	1.78	0.36	0.52	1.18	1.18	0.24	0.34
S5	Accounting labor	0.60	0.14	0.14	0.14	0.14	0.09	0.09	0.09	0.09
S6	Costs of trips	0.05	0.01	0.01	0.01	0.01	0.11	0.11	0.11	0.11
S7	Governmental taxes	0.60	1.69	1.69	2.42	2.42	1.12	1.12	1.61	1.61
S8	Circulating capital costs	0.10	0.09	0.09	0.09	0.09	0.79	0.79	0.79	0.79
S9	Insurance costs	0.60	0.18	0.18	0.10	0.18	0.12	0.12	0.07	0.12
S10	Transportation costs	0.10	0.20	0.20	0.20	0.20	1.81	1.81	1.81	1.81
S11	Drying & storage costs	0.40	1.69	1.69	1.69	1.69	2.54	2.54	2.54	2.54
S12	Social security taxes	0.60	2.27	2.27	2.42	2.42	1.52	1.52	1.61	1.61
S13	Land leasing	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S			0.00	0.00	0.00	0.00	2.96	2.96	11.84	17.76
S20	Governmental subsidies	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S21	Effluent treatment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.92	2.96
S22	Health treatment	0.00	0.00	0.00	0.00	0.00	2.96	2.96	5.92	14.80
E	**without externalities**		49.68	48.04	23.50	21.81	76.03	78.55	182.76	203.80
E	**including externalities**		49.68	48.04	48.04	48.04	78.99	81.51	194.60	221.56
R			117.66	99.82	80.45	80.79	0.00	0.00	0.00	0.00
R1	Rain	1.00	13.65	13.65	13.65	13.65	0.00	0.00	0.00	0.00
R2	Nutrients from rocks	1.00	1.71	1.71	0.17	0.51	0.00	0.00	0.00	0.00
R3	Atmospheric Nitrogen	1.00	66.61	66.61	66.61	66.61	0.00	0.00	0.00	0.00
R4	Sediments (rivers)	1.00	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00
R5a	Forest: seeds	1.00	0.30	0.15	0.00	0.00	0.00	0.00	0.00	0.00
R5b	Forest: food	1.00	0.90	0.45	0.00	0.00	0.00	0.00	0.00	0.00
R5c	Forest: biomass	1.00	14.76	7.38	0.00	0.00	0.00	0.00	0.00	0.00
R6a	Forest: water	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R6b	Forest: leisure	1.00	1.22	0.61	0.00	0.00	0.00	0.00	0.00	0.00
R6c	Forest: boil. control	1.00	18.50	9.25	0.00	0.00	0.00	0.00	0.00	0.00
N			0.00	0.00	0.00	0.00	5.34	5.34	69.85	8.60
N1	Soil loss	0.00	0.00	0.00	0.00	0.00	5.34	5.34	66.73	8.01
N2	Biodiversity loss	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.12	0.59
I			117.66	99.82	80.45	80.79	5.34	5.34	69.85	8.60
Y			167.35	147.87	128.49	128.83	84.33	86.85	264.45	230.16

Table 5. Manpower in agricultural systems

	Ecological	Organic	Chemical	Herbicide
Internal manpower	Unqualified labor Qualified labor (machine operators Administrative labor	Qualified labor (machine operators) Administrative labor		
External manpower	Accounting labor Technical assistance	Unqualified labor Accounting labor Technical assistance	Unqualified labor Qualified labor Administrative labor Accounting labor Technical assistance	Unqualified labor Qualified manpower Administrative labor Accounting labor Technical assistance

Table 6. Aggregated Emergy flows for soybean production in Brazil

Flows	**Ecological**	**Organic**	**Chemical**	**Herbicide**
R	1.18E+15	9.98E+14	8.04E+14	8.08E+14
N	5.34E+13	5.34E+13	6.98E+14	8.60E+13
I	**1.23E+15**	**1.05E+15**	**1.50E+15**	**8.94E+14**
MR	3.49E+14	3.49E+14	8.68E+13	9.75E+13
MN	6.47E+14	6.76E+15	1.69E+16	1.92E+16
M	**9.95E+14**	**1.02E+15**	**1.78E+15**	**2.02E+15**
SR	1.48E+14	1.31E+14	1.48E+14	1.21E+14
SN	1.14E+14	1.10E+15	1.37E+15	1.20E+15
SA	2.96E+13	2.96E+13	1.18E+14	1.78E+14
S	**2.92E+14**	**1.26E+15**	**1.64E+15**	**1.49E+15**
F	**1.58E+15**	**3.55E+15**	**5.06E+15**	**5.00E+15**
Y	**2.81E+15**	**4.60E+15**	**6.56E+15**	**5.90E+15**

Table 7. New set of Emergy indices for soybean production in Brazil

Indices	**Ecological**	**Organic**	**Chemical**	**Herbicide**
Tr*	96 000	157 000	192 000	173 000
EYR*	1.78	1.30	1.30	1.18
EIR*	1.28	3.37	3.37	5.60
EER*	1.58	2.59	4.66	4.19
R*	0.60	0.32	0.16	0.17
ELR*	0.41	1.00	1.06	1.02
LSR	0.51	0.10	0.09	0.08
LER	0.05	0.03	0.02	0.02
LWR	0.34	0.05	0.01	0.00
ExER	0.01	0.01	0.02	0.03

DISCUSSION

With the same data but using the original procedures and definitions proposed by Odum (1996), Ortega et al. (2002) obtained the emergy indices shown in Table 8.

Table 8. Emergy indices for soybean production in Brazil

Indices	Ecological	Organic	Chemical	Herbicide
Tr	88 000	82 000	104 000	112 000
EYR	1.92	1.78	1.74	1.31
EIR	1.09	1.27	1.35	3.25
ELR	1.19	1.40	3.40	3.70
R	0.46	0.42	0.23	0.21
EER	1.45	1.35	2.51	2.69

If we compare the values obtained using both approaches, there are significant and meaningful differences between the emergy indices, especially in those under discussion (R, ELR) and Transformity. Transformity can be seen as an inverse value of agro-ecosystem efficiency. In decreasing order of efficiency appear: ecological, organic, chemical and herbicide systems. In terms of the Renewability Index (or degree of sustainability) the results seem to be more coherent with the reality observed, so for the self-sustaining ecological farmer the value goes up to 60% instead of 46%. We can observe that modifications also give better ELR indices, mainly for ecological farmers. The social indices (LSR, LER, LWR) help to identify job intensive systems and labor of internal origin (family system). Externalities detected by the new index (ExER) should be considered in market price, in order to decrease it, making the consumer an inductor of technical changes, This fact can promote better social and environmental behavior of farming producers.

Table 9. A suggestion: prices corrected by externalities.

	Em-dollars			
	Ecological	**Organic**	**Chemical**	**Herbicide**
Basic Price	**0.25**	**0.25**	**0.25**	**0.25**
Discounts				
Effluent treatment	0	0.01	0.04	0.02
Health treatment	0	0.03	0.04	0.02
Jobs lost	0	0.03	0.03	0.05
Genetic erosion	0	0.01	0.01	0.04
Adjusted price	**0.25**	**0.17**	**0.13**	**0.12**
Additions				
Manual harvest	0.020	0.02	0.02	0.02
Social price	**0.27**	**0.19**	**0.15**	**0.14**

CONCLUSIONS

- The incorporation of a renewability factor in each input to improve calculations of System Renewability (R*) is especially valid considering the use of renewable inputs purchased in the local or regional economy (as manure).
- The separation of labor into local and external allow us to identify family managed systems using local work ratio (**LWR =** $S_{RL} / (S_R + S_N)$**).**
- The inclusion of externalities as additional services makes possible a better social appraisal of production alternatives for agricultural products.
- Considering family managed ecological production as a reference it is possible to suggest fair prices for soybean obtained from different processes.
- Considering the negative externalities it is possible to suggest lower prices for products originating from non-ecological production systems.
- The new emergy indices proposed could be used in certification of food products to quantify social, environmental and economical parameters that could qualify processes of production, and so the product.

SUGGESTION

The results obtained lead us to a better definition of agricultural systems using emergy: However, new studies are necessary to confirm these conclusions, that we consider auspicious. A great improvement can be made if we study more carefully the costs of negative externalities. The values we use in emergy tables were very small in comparison with what could be their real values (Pretty, 2000).

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