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EXPANDED EMERGY ANALYSIS OF SOYBEAN PRODUCTION IN BRAZIL

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ABSTRACT

In this paper we offer the results of emergy analysis used to evaluate four different soybean production systems in Brazil, that were divided in two main categories, the biological models (organic and ecological farms) and the industrial models (green revolution chemical farms, using herbicide without tilling). The biological options showed better environmental, economical and social performance indicators. However, at national level, the discussion of transgenic soybean seeds release considers only the industrial models without mention biological models. The classic emergy analysis point out that the biological options are the better alternatives, but do not explain why the decisions taken by farmers and government in Brazil were in an opposite way. Because of that, a new area of research has been proposed in this paper to identify and quantify the external forces that strongly interfere with the definition of public policy for soybean production. Besides that, new parameters were proposed to enrich emergy methodology. Basically, we made two innovations: (a) the renewability of each input was considered in emergy calculations and (b) the negative externalities were included as additional services. The proposed emergy indicators are able to better characterize each agricultural system.

1. INTRODUCTION

The industrial agriculture had been the main support of Brazilian economy in the last thirty years. This kind of agriculture is responsible of 42% of exports and 37% of jobs. Soybean is leading exports with a fast growing production, from 2 millions tons in the beginning of the 70`s to 53 million tons in 2003. Brazil is the second largest soybean producer, behind the United States that had a crop of 74 million tons in 2003 (Agrianual, 2004).

The growth of soybean production in Brazil was stimulated by the increase of demand of soybean meal used in industrial farming of pork meat, eggs, milk and beef. Furthermore, the cattle diseases in Europe transmitted by meals made of animal brains, increases the profits of the large-scale soybean producers in Brazil and soybean-consuming reared and poultry farmer in Europe. Brazilian soybean producers invested in lands, farm machinery and more chemical inputs.

The environmental damages caused by monocropping large-scale farms in Brazilian Savanna called Cerrado are not commented by Brazilian authorities, which emphasize the impressive economic results of soybean exports that allow paying the yearly interests of international debt.

The Brazilian government, as well as the individual soybean farmers, is taking important decisions concerning the use of ecosystems, based only on short-term economic profit analysis.

In order to establish long-term sustainable public policy for agriculture, it is necessary to use open-systems to evaluate all the social and ecological benefits and costs. From the point of view of neoclassical economy, neither all the inputs and outputs nor the flows of natural resources needed for production in a production-consumption cycle can be represented (Wackernagel and Rees, 1995). Therefore, the neoclassical economy

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cannot be used to calculate sustainability parameters (Ulgiati, 1998). In this study, the emergy method of accounting developed by Odum (1983; 1996) is selected as it offers means of quantifying the direct and indirect environmental work involved in generating a product. The emergy analysis is a procedure used for planning, management and assessing human ecosystems.

Since emergy accounting was mainly applied to study fossil-fuel energy-intensive agriculture systems in Europe and the USA, the methodology procedures had to be improved to deal with the complex ecological agricultural systems based on family work in the southern hemisphere (Ortega and Polidoro, 2002). In this paper, new emergy indicators were developed and applied to enrich the emergy methodology.

Everywhere, agriculture is jeopardized by the decrease of price of farm products and increase of costs for chemical inputs and commercialization (Figure 1).

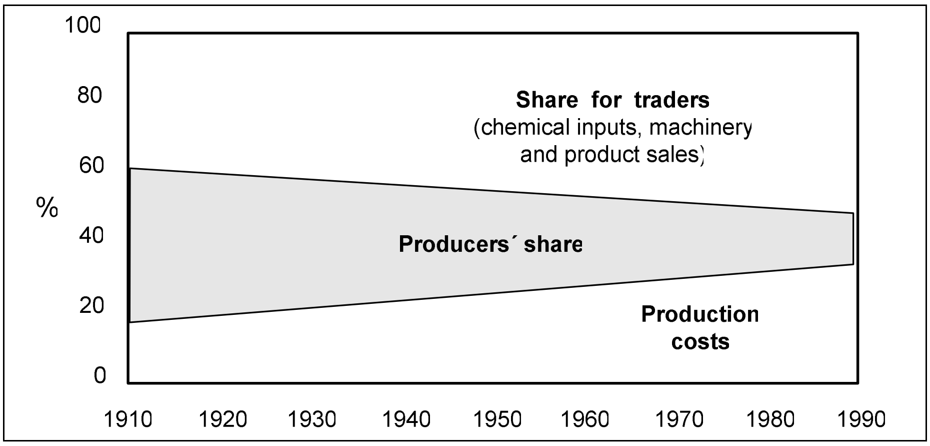

Figure1. Decreasing parcel received by producers (adapted from Gliessman, 2000)

The aim of this study was to discuss the direct and indirect costs and environmental impact of soybean production systems and to justify the initiation of a new topic of research dedicated to the measurement of political forces that act, with great impact, in Brazilian agriculture.

2. METHODOLOGY

2.1 Soybean production systems in Brazil

The agricultural systems studied are classified in two main categories: biological (organic and ecological) and industrial (agro-chemical and no-tilling using herbicides). As biological models, the family-managed ecological farms of the South and the organic enterprises in Central region were considered. The farms that adopted green revolution standards (South) and agricultural enterprises that are adopting no-tilling (with or without use of transgenic seeds) in South and Central region were chosen as representative form of industrial models.

The ecological farm has a small or medium area (10-50 ha), it is managed by a family group who lives in the farm, usually obeying environmental laws, preserving and using properly the natural resources they have. It is not fully oriented to the market; it produces for self-consumption and exchanges many things with their neighbors, without the use of money. The main part of their products is consumed within the region. The ratio people/ha is high, even if it is not formal employment.

The industrial farm can be medium (50 ha), large (300 ha) or have a very big size (3000 ha or more). It is operated by an urban enterprise and management decisions are taken outside of the farm area, even outside the region or even outside the country. It uses intensively industrial chemicals and machinery, employs fewer workers, aims at maximizing the economic benefit and causes a huge environmental impact. Examples of the environmental impact are: decrease of soil fertility, erosion of nutrients, water pollution, biodiversity loss, lower plant resistance to predators, health problems due to contamination, among others (Altieri, 2000; Nilsson, 2004). Another important characteristic of industrial agriculture is the great amount of fossil energy used in production. This is an overwhelming question when one considers the inevitable lower availability of the fossil fuels forecasted in the future.

When the industrial farm becomes organic, it substitutes chemical for organic inputs, but maintains many other characteristics. Therefore, it does not create jobs and its material and energy self-sufficiency remains low, keeping the system non-sustainable.

In order to survive in the future, the biological agricultural systems must be able to compete with industrial systems; this requires the proper taxation of inputs and output. Therefore, the accounting should consider the real values of inputs; take into account the damage done to the environment (externalities). For the elaboration of public polices in agriculture, one has to take into consideration that the industrial farming systems diminish their potential productivity due to physical and biological degradation of soil. And finally, the increasing costs of chemical inputs and decreasing prices for agricultural products transfers the richness to central countries (Altieri, 2000).

Until 2005, in case of transgenic soybean, there are limitations imposed by federal and state governmental regulations as well as by external markets. Federal regulations avoided its production and trading, however transgenic seeds were planted in the southern region. The seeds were smuggled from Argentina and the Brazilian farmers did not pay any royalties (or penalties) for their use.

2.2 Emergy analysis

Emergy methodology converts all forms of energy, materials and human services into equivalents of one form of energy (solar emergy). The units of solar emergy are solar emjoules (abbreviated sej). The description of emergy methodology has been provided in details by Odum (1996) and in several papers (Brown and Ulgiati, 2004; Ulgiati et al., 1994; Higgins, 2003; Lefroy and Rydberg, 2003; Panzzieri et al., 2000).

In the industrial agricultural economy, the price considers material inputs and human work in an aggregated form, but neither the external energy used in the formation of the biosphere’s resources nor the costs of negative externalities (paid by local society).

This research analyses how emergy analysis could improve the indicators of performance of agricultural ecosystems by including externalities and considering new specific biological inputs. For emergy calculations, the partial renewability of each of the materials and services was considered, as proposed by Ortega et al. (2002) and suggested by several other researchers (Ortega and Polidoro, 2002; Panzieri et al.,2002; Bastianoni et al., 2001). This approach constitutes an evolution in the emergy methodology, representing a forward step in the direction of describing with greater accuracy the sustainability of complex systems.

A new energy flow diagram is used (Figure 2).

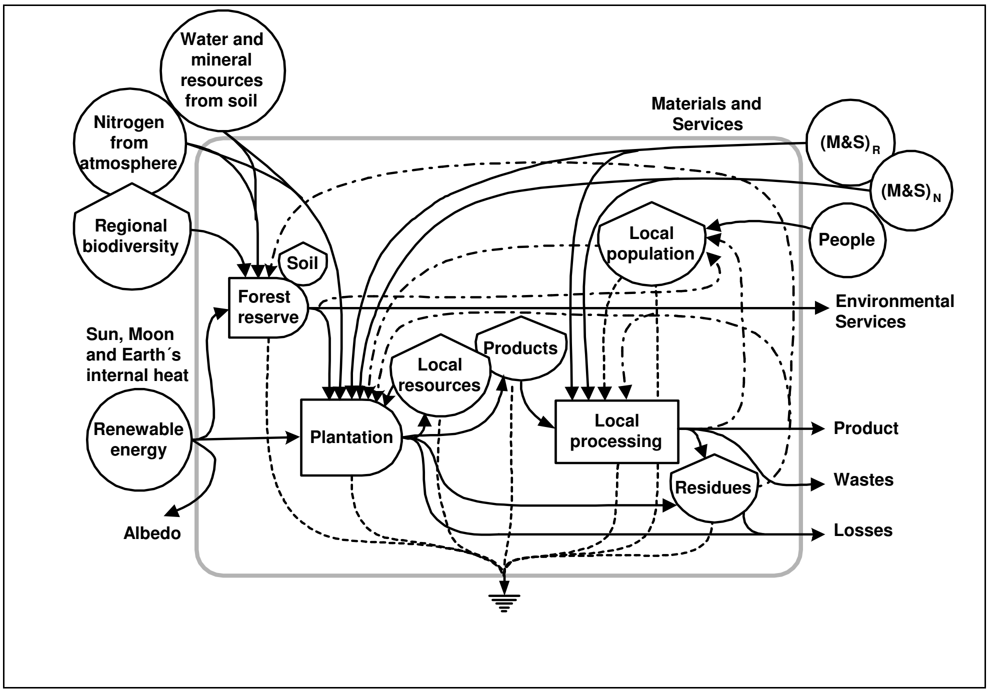

Figure 2. Emergy flows diagram of a typical system of soybean production

Table 1 shows the classification of emergy flows that allows considering the partial renewabilities of materials and services.

Table 1. Classification of Emergy flows

Inputs and services	**Description**
I: Nature contribution	**R + N**
R: Renewable resources from nature	Rain; Materials and Services from preserved areas; Nutrients from soil minerals and air
N: Nonrenewable resources from nature	Soil, Biodiversity, People exclusion
F: Feedback from economy	**F = M + S**
M: Materials	**$M = M_R + M_N$**
M_R: Renewable materials and energy	Renewable materials from natural origin.
M_N: Nonrenewable materials and energy	Minerals, Chemicals, Steel, Fuel, etc.
S: Services	**$S = S_R + S_N + S_A$**
S_R: Labor services (renewable)	Familiar labor (local and external) $S_R = S_{RL}$+SRE
S_N: Other services (basically nonrenewable)	Taxes, money costs, insurance, etc.
S_A: Additional services (nonrenewable)	Externalities: effluents, medical and job costs, etc.
Y: Total emergy	**Y = I + F**

In Table 2, the emergy indicators were slightly modified in order to evaluate more properly the performance of the system, by considering the renewability of each of the resources used.

Table 2. Emergy indicators used for the emergy analysis

Indicators	Expression	Signification
Traditional emergy indicators		
Tr (solar transformity)	Y/E	Empower/Energy of products
%R (renewability)	100x(R+M_R+S_R)/Y	Renewable inputs/Empower
EYR (emergy yield ratio)	Y/(M_N+S_N+S_A)	Empower/Purchased inputs
EIR (emergy investment ratio)	(M_N+S_N+S_A)/(R+M_R+S_R+N)	Purchased inputs/free inputs
ELR (environmental loading ratio)	(N+M_N+S_N+S_A)/(R+M_R+S_R)	Nonrenewable/Renewable inputs
EER (emergy exchange ratio)	Y/[($)x(sej/$)]	Emergy delivered by the system to economy divided by the emergy received by the sales
New social and externality emergy indicators		
LSR (labor services ratio)	S_R/S	Labor/Services
LER (labor empower ratio)	S_R/Y	Labor/Empower
LWR (labor work ratio)	S_{RL}/(S_R+S_N+S_A)	Local labor/Labor
ExER (externalities empower ratio)	S_A/Y	Externalities/Empower

3. RESULTS AND DISCUSSION

3.1. Emergy analysis of soybean production systems

Data for items used in different categories of soybean production were obtained in other papers (Ortega et al., 2001; Ortega et al., 2002), manuals of agriculture and by contacts with farmers. Table 3 shows all inputs (material, services and nature) used in soybean production (per hectare, in the period of one year) and a conversion factor used to transform these inputs into solar emergy (transformity in sej/unit).

Data of soybean production farms were used to calculate solar emergy flows (Table 4) in a slightly adapted manner: the values for the emergy flows of materials and services were multiplied by the renewability ratios of the respective input. For the renewability ratios results from previous calculations were used and also derived from experience with common sense.

Table 4 shows values of renewable and nonrenewable emergy flows for the four types of soybean systems studied. The externalities were incorporated in this accounting procedure as additional services (S_A). The values of externalities were based on European (Pretty et al., 2000) as well as Brazilian research studies.

Table 3. Inputs (in unit/ha/year) and respective factor of sej/unit of soybean production systems

Item	Unit	Biological		Industrial		sej/unit	Reference
		Ecological	**Organic**	**Chemical**	**Herbicide**		
Renewable (R)							
Rain	Kg	1.50E+06	1.50E+06	1.50E+06	1.50E+06	1.50E+07	1
Atmospheric nitrogen	Kg	180	180	180	180	6.38E+12	1
Biologic control	US$	50	25.00	0	0	3.70E+12	2
Nonrenewable (N)							
Soil loss	J	0	0	3.00E+04	0	1.24E+05	1
Materials (M)							
Local seeds	Kg	10	10	0	0	4.95E+12	3
Certified seeds	Kg	70	70	70	85.00	4.04E+12	3
Limestone	J	0	0	6.11E+08	6.11E+08	2.72E+06	1
Phosphate fertilizer	Kg	0	0	150	250	6.55E+12	1
Potash fertilizer	Kg	50	50	150	100	2.96E+12	4
Manure	Kg	2660	2660	0	0	1.27E+11	5
Inoculum	Kg	1.00	1.00	1.70	1.70	2.49E+13	1
Herbicides	Kg	0	0	4.30	5.30	2.49E+13	1
Insecticides	Kg	0	0	1.80	1.80	2.49E+13	1
Formicides	Kg	0	0	1.00	1.00	2.49E+13	1
Fungicides	Kg	0	0	0.20	0.20	2.49E+13	1
Petroleum fuels	J	1.43E+09	1.91E+09	3.82E+09	1.91E+09	1.11E+05	1
Steel	Kg	1.00	2.70	2.70	2.70	1.13E+13	1
Services (S)							
Unqualified manpower	years	1.66E-02	1.14E-02	3.65E-04	5.71E-05	6.32E+16	1
Qualified manpower	years	2.28E-04	3.65E-04	8.22E-03	4.57E-03	6.32E+16	1
Administrative labor	US$	4.00	4.30	4.30	4.30	3.70E+12	2
Technical assistance	US$	10	10	2.00	2.90	3.70E+12	2
Accounting services	US$	0.80	0.80	0.80	0.80	3.70E+12	2
Costs of trips	US$	0.40	0.40	0.40	0.40	3.70E+12	2
Governmental taxes	US$	9.50	9.50	13.60	13.60	3.70E+12	2
Circulating capital costs	US$	2.95	2.95	2.95	2.95	3.70E+12	2
Insurance	US$	1.00	1.00	0.60	1.00	3.70E+12	2
Transportation	US$	6.80	6.80	6.80	6.80	3.70E+12	2
Drying & storage	US$	14.30	14.30	14.30	14.30	3.70E+12	2
Social security	US$	12.80	12.80	13.60	13.60	3.70E+12	2
Additional services (S_A)							
Jobs lost	US$	0	20	40	40	3.70E+12	2
Health treatment	US$	0	0	50	50	3.70E+12	2
Effluent treatment	US$	0	0	50	50	3.70E+12	2
Environmental restore	US$	0	20	20	20	3.70E+12	2
Environ. services losses	US$	0	20	20	20	3.70E+12	2
Products (Y)							
Soybean	Kg	2240	2240	2400	2400	-	
Wood	Kg	1000	100	0	0	-	
Water	Kg	225000	75000	0	0	-	

(1) Brown and Ulgiati, 2004; (2) Ortega, 1998; (3) Estimated from Ortega et al., 2002; (4) Panzieri et al., 2000; (5) Bastianoni et al. 2001

Table 4. Emergy analysis of soybean production systems (emergy flows x10^{13} sej/ha/year)

Item	**Renew. Fraction**	**Renewable emergy flows**				**Nonrenewable emergy flows**			
		Biological		**Industrial**		**Biological**		**Industrial**	
		Ecol	**Org**	**Chem**	**Herb**	**Ecol**	**Org**	**Chem**	**Herb**
Renewable (R)									
Rain	1.00	2.25	2.25	2.25	2.25	0	0	0	0
Atmospheric nitrogen	1.00	114.84	114.84	114.84	114.84	0	0	0	0
Biologic control	1.00	18.50	9.25	0	0	0	0	0	0
Nonrenewable (N)									
Soil loss	0	0	0	0	0	0	0	336.43	0
Materials (M)									
Local seeds	0.90	4.46	4.70	0	0	0.50	0.25	0	0
Certified seeds	0.70	19.80	19.80	19.80	24.04	8.48	8.48	8.48	10.30
Limestone	0.01	0	0	1.66	1.66	0	0	164.53	164.53
Phosphate fertilizer	0.01	0	0	0.98	1.64	0	0	97.27	162.11
Potash fertilizer	0.01	0.05	0.05	0.14	0.09	4.69	4.69	14.07	9.38
Manure	0.70	551.15	535.40	0	0	236.21	251.96	0	0
Inoculum	0.70	1.74	2.24	3.81	3.81	0.75	0.25	0.42	0.42
Herbicides	0.01	0	0	0.11	0.13	0	0	10.60	13.07
Insecticides	0.01	0	0	0.04	0.04	0	0	4.44	4.44
Formicides	0.01	0	0	0.02	0.02	0	0	2.47	2.47
Fungicides	0.01	0	0	0	0	0	0	0.49	0.49
Petroleum fuels	0.01	0.16	0.21	0.42	0.21	15.59	20.79	41.57	20.79
Steel	0.05	0.06	0.15	0.15	0.15	1.07	2.90	2.90	2.90
Services (S)									
Unqualified manpower	0.80	83.69	57.72	1.85	0.29	20.92	14.43	0.46	0.07
Qualified manpower	0.60	0.87	1.39	31.17	17.32	0.58	0.92	20.78	11.54
Administrative labor	0.60	0.89	0.95	0.95	0.95	0.59	0.64	0.64	0.64
Technical assistance	0.60	2.22	2.22	0.44	0.64	1.48	1.48	0.30	0.43
Accounting services	0.60	0.18	0.18	0.18	0.18	0.12	0.12	0.12	0.12
Costs of trips	0.05	0.01	0.01	0.01	0.01	0.14	0.14	0.14	0.14
Governmental taxes	0.60	2.11	2.11	3.02	3.02	1.41	1.41	2.01	2.01
Circulating capital costs	0.10	0.11	0.11	0.11	0.11	0.98	0.98	0.98	0.98
Insurance	0.60	0.22	0.22	0.13	0.22	0.15	0.15	0.09	0.15
Transportation	0.10	0.25	0.25	0.25	0.25	2.26	2.26	2.26	2.26
Drying & storage	0.40	2.12	2.12	2.12	2.12	3.17	3.17	3.17	3.17
Social security	0.60	2.84	2.84	3.02	3.02	1.89	1.89	2.01	2.01
Additional services (S_A)									
Jobs lost	0	0	0	0	0	0	7.40	14.80	14.80
Health treatments	0	0	0	0	0	0	0	18.50	18.50
Effluent treatment	0	0	0	0	0	0	0	18.50	18.50
Environmental restoration	0	0	0	0	0	0	7.40	7.40	7.40
Environmental services loss	0	0	0	0	0	0	7.40	7.40	7.40

Table 5 shows internal and external labor used in soybean production.

Table 5. Manpower used in agricultural systems studied

	Biological		Industrial	
	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 shows the aggregated emergy flows.

Table 6. Aggregated emergy flows for Soybean production systems

	Biological		Industrial	
Emergy flows	**Ecological**	**Organic**	**Chemical**	**Herbicide**
Renewable resources (R)	1.36E+15	1.26E+15	1.17E+15	1.17E+15
Nonrenewable resources (N)	0,00E+00	0,00E+00	3,36E+15	0,00E+00
Nature contribution (I)	1.36E+15	1.26E+15	2.34E+15	2.34E+15
Renewable materials (M_R)	5.77E+15	5.63E+15	2.71E+14	3.18E+14
Nonrenewable materials (M_N)	2.67E+15	2.89E+15	3.47E+15	3.91E+15
Total materials (M)	8.45E+15	8.52E+15	3.74E+15	4.23E+15
Labor services (S_R)	9.55E+14	7.01E+14	4.32E+14	2.81E+14
Nonrenewable services (S_N)	3.37E+14	2.76E+14	3.30E+14	2.35E+14
Additional services (A_S)	0.00E+00	2.22E+14	6.66E+14	6.66E+14
Total services (S)	1.29E+15	1.20E+15	1.43E+15	1.18E+15
Feedback from economy (F)	3.01E+15	3.39E+15	4.47E+15	4.81E+15
Total emergy (Y)	1.11E+16	1.10E+16	9.71E+15	6.58E+15

Emergy indicators calculated for the different categories of soybean production are presented in Table 7.

Table 7. Net set of emergy indicators for soybean production systems

Emergy indicators	**BIOLOGICAL**		**INDUSTRIAL**	
	Ecological	**Organic**	**Chemical**	**Herbicide**
Traditional emergy indicators				
TR	147,660	248,210	223,613	151,587
EYR	3.69	3.24	2.17	1.37
EIR	0.37	0.45	0.85	2.72
%R	72.9	69.1	19.3	26.9
EER	6.69	6.62	5.47	3.71
ELR	0.37	0.45	4.18	2.72
New social and externality emergy indicators				
LSR	0.74	0.58	0.30	0.24
LER	0.09	0.06	0.04	0.04
LWR	0.28	0.01	0.00	0.00
ExER	0.00	0.02	0.07	0.10

Emergy analysis using traditional indicators

The solar transformity (Tr) measures how much emergy it takes to generate one unit of output, regardless the renewability of the resources used. It indicates the hierarchical position of a resource in the thermodynamic scale of the biosphere and can be regarded as a quality factor from the point of view of biosphere dynamics (Brown and Ulgiati, 2004). Transformity can be seen as an inverse value of system efficiency. Therefore, the higher the transformity value, the lower the efficiency of the system in producing the same output. Our results indicate the following transformity and order of efficiency: ecological (1.47×10^5), herbicide (1.51×10^5), chemical (2.23×10^5) and organic (2.48×10^5) systems. This shows that the ecological system is the most efficient in the use of emergy flows. The values calculated were similar to those found in literature for cereals, usually between 2×10^5 and 7×10^5 seJ/J (Brown and Ulgiati, 2004; Ortega et al., 2002, Panzieri et al., 2000, Brandt-Williams, 2002).

The Emergy Yield Ratio (EYR) indicates the efficiency of the farm in using purchased inputs. Primary energy sources (oil, coal, gas) show EYR greater than 5. Secondary energy sources and primary materials like cement and steel show EYR in the range from 2 to 5, indicating moderate contribution to the economy (Brown and Ulgiati, 2004). The EYR for agricultural raw materials varies from 1.2 to 2.0 (Bastianoni et al., 2001; Ortega et al., 2002, Panzieri et al., 2000). The EYR value obtained for biological soybean systems (3.69 for ecological and 3.24 for organic) were better than industrial ones (2.17 for chemical and 1.37 for herbicide). It shows a good ability of biological systems to obtain local resources as response to invested outside resources.

The Emergy Investment Ratio (EIR) measures the demand of monetary investment per unit of product. A lower value means better use of renewable resources, where the renewable energy can be replenished to continually feed the system. The biological systems have better EIR values: (0.37 for ecological and 0.45 for organic) than industrial ones (0.85 for chemical and 2.72 for herbicide) since industrial systems consume more fossil energy in direct and indirect form. Therefore, the biological options have lower production cost than the industrial ones. The global trends indicate that non-renewable energy will be less available and more costly in the future. Apparently, agricultural production systems based on non-renewable resources will not be able to compete with systems characterized by lower economic investment (F) and bigger nature contribution (I). New farm designs combined with regional planning and fair trade rules must initiate adaptation strategies for systems that presently demand high rates of non-renewable inputs (Odum, 1996).

In the long run, systems with higher renewability will prevail in case they were able to survive the economical stress that they are suffering nowadays. Renewability ratios (% of renewable resources used) reported for cereals vary from 19% to 72% (Ortega et al., 2002, Panzieri et al., 2000). This study shows that renewability (%R) is higher in biological options (73% for ecological and 69% for organic) than in the industrial ones (19% for chemical and 27% for herbicide). The Emergy Exchange Ratio (EER) provides a measure of who looses in economic trade. Results show that farmers of biological systems are losing more emergy in exchange with the external market. The EER values were found to be 6.69 for ecological, 6.62 for organic, 5.47 for chemical and 3.71 for herbicide. Biological systems spend around 6.6 times more emergy to produce their products against what they receive from sales. It shows that prices of farming products are under rated. Usually, agricultural systems transfer emergy to urban system. It is evident that prices of biological products should be higher. Agricultural products are low priced while the costs of purchased inputs increase every year. It results in a reduction of profits of a great part of farmers.

The Emergy Loading Ratio (ELR) calculated for biological systems (0.37 for ecological and 0.45 for organic) were better than for the industrial systems (4.18 for chemical and 2.72 for herbicide). This ratio is a measure of ecosystem stress due to the process: the higher the value the greater the pressure of the economic system on the local environment (Panzieri et al., 2002). The ELR value indicates that biological options cause lower pressure on the environment. In the Brazilian case, the ELR appears even lower than those reported by the literature, varying from 1.2 to 5.6 (Lefroy and Rydberg, 2003; Panzieri et al., 2000; Bastianoni et al., 2001; Ortega et al., 2002).

Emergy analysis using indicators that incorporate local labor and externalities

New emergy indicators (LSR, LER, LWR) were used in order to evaluate the farm performance related to social justice. They consider the intensity and characteristics of labor used in farming. The Labor/Services Ratio (LSR) is the ratio of manpower labor to total services used. The values calculated ranged from 0.74 for ecological and 0.58 for organic to 0.30 for chemical and 0.24 for herbicide systems (Table 7). These results indicate the lower use of labor by the industrial systems, and, at same time, the lower use of other services by the biological systems. This is not surprising since the industrial systems are characterized by heavy use of machinery and chemicals that replace human labor. The Labor Empower Ratio (LER) is the ratio of labor to the total empower. It is 0.04 for industrial systems, 0.09 for ecological and 0.06 for organic systems, indicating, that the use of labor is rather small for all alternatives. Nevertheless the biological values are three times greater than industrial systems values.

The Local Work Ratio (LWR) is the ratio of local labor to total labor. It is an important indicator when evaluating social justice. It is a measure of the independence of the farm: the lower the LWR, the greater the dependence of the farm on external labor force. It indicates that the farm is really family managed. The LWR values observed for industrial systems indicate low use of local or internal labor (0.01) while ecological systems uses it a lot (0.28). In this study, another new indicator has been developed and applied that measures the ratio between externalities and total empower (ExER). The industrial farming systems generates more negative externalities (0.07 for chemical and 0.10 for herbicide) than biological ones (0 for ecological and 0.02 for organic). The consideration of these additional services as real costs could promote better social and environmental behavior of the farming systems. The monetary evaluation of the negative externalities still deserves a great research effort. We use a very conservative value for the externalities in the calculation of additional services emergy flows (US$ 180.00/ha/year) that corresponds to 60% of the value obtained by Pretty and co-workers (2000). Table 8 presents a calculation of the money value of externalities for soybean in Brazil is around 346 US$/ha/year, almost the same as accounted by Pretty (330 US$ /ha/year).

Table 8. Values of Externalities for Brazilian Agriculture

Effect measured	Value (US$/ha/yr)	Source
Soil erosion	83.00	Santos et al., 2000
Nutrients loss due to erosion	13.60	Pretty et al., 2000
Carbon dioxide emission	7.84	Brazil - Ministry of Science and Technology, 2004
Methane emission	20.52	Brazil - Ministry of Science and Technology, 2004
Nitrous oxide emission	32.00	Brazil - Ministry of Science and Technology, 2004
Effluent treatment	39.70	Pretty et al., 2000
Savanna destruction	98.50	Ortega et al. (this paper). See note bellow
Intoxication, invalidity and deaths by pesticide use	0.20	Pretty et al., 2000
Rural exodus (jobless costs)	50.00	Ortega, 2002
Total	345,36	

Calculation of unitary value of savanna destruction using emergy analysis:

The value of one hectare of deforested savanna can be estimated considering the time needed to recover its biodiversity, soil quality and water aquifer. It could take at least 80 years if there are seed stocks in the region. The succession will take 8 decades to reach the climax, but the rate of biomass production will be different every year, therefore a mean value was applied. If assumed that the land will be left to rest, letting the nature slowly invade the area to enrich the soil and its covering, according to emergy analysis the main energy input will be the water of rain. Besides that, in a detailed analysis, the minerals solubilized by soil biota to furnish nutrients to plants (N, P, K) could also be considered.

Data:

- Precipitation: 0.8 $m^3/m^2/$ year
- Area conversion factor: 10^4 m^2 / ha
- Water density: 1000 kg / m^3
- Gibbs free energy of water: 5000 joules/kg.
- Water transformity: 18 200 sej/J
- Dollar equivalence in emergy (in 2004): 3.7 x 10^{+12} sej/dollar
- Time to recover stocks: 80 years

Emergy Stock = Energy of water x transformity x time x dollar equivalence
= [(0.8 m^3/m^2.year) x (10^4 m^2 / ha) x (10^3 kg/m^3) x (5000 J/kg)] x 18200 seJ/J
= 7.28 x 10^{+14} (sej/ha/year) x 80 years / [3,7 x 10^{+12} (sej/US$)]
= 15 740 (US$/ha)

US$/ha/year = Emergy of stock (water accumulated and transformed) / Time
= 15 740 (US$/ha) / 80 years
=197.00 (US$/ha/year)

Half space allowed by law = 98.50 (US$/ha/year)

3.2. Expanding the scope of analysis soybean production systems

There is an important public debate about the release of transgenic soybean seeds in Brazil. However, the discussion limits its scope to compare industrial options and does not take into consideration the biological production (with better environmental and social qualities). Farming systems that adopt transgenic seeds become dependent on external systems because they no longer produce seeds. They instead buy them every year from foreign enterprises that will control their price (it depends on the structure of the concurrence). As consequence it means ultimately a loss of autonomy. Besides that, small farmers will have to indebt themselves to buy the equipment and inputs to produce with transgenic technology; they will have to compete with bigger farms in an unfavorable situation. After some years, many of them will have to sell their lands and get out of work.

In the emergy analysis of agricultural systems, the political and technological forces are identified just as another external force ("info"), related with information and usually not quantified. Because of its importance, the complex net of influences that affects soybean-cropping systems is introduced in this paper, as a first step of a study that will be devoted to identify and measure in emergy terms all the factors that define public policy and private decisions in soybean production.

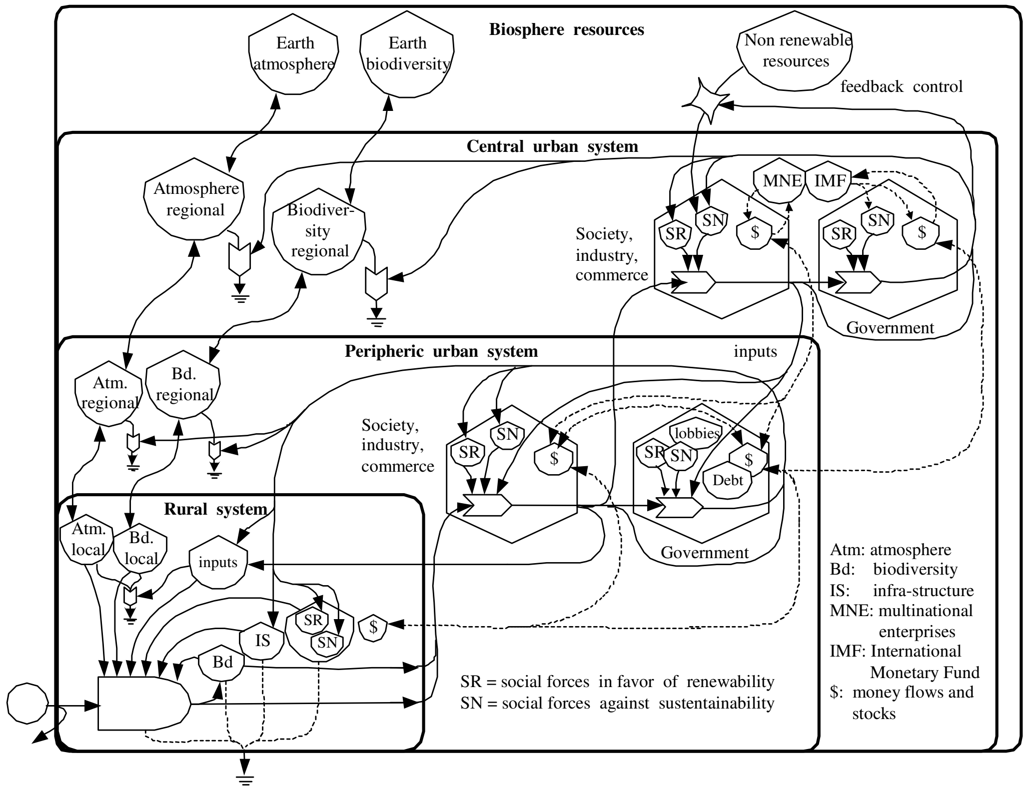

Figure 3. Emergy flows diagram of global system of soybean

A system diagram (Figure 3) has been prepared that shows the forces that drive the farming system, beyond its borders. It depicts the structure of soybean production for export, with the main external forces and some of its most characteristic internal elements. It contains the peripheral urban system, where the agricultural system is located. It obeys national laws of production, commercialization, research and financing. This frame is close to the agricultural system and has a considerable impact on it. Social associations and the government are the main actors. In the local society there are groups with opposing their scientific and political proposals, some in favor of more renewability (MR) and other in favor of some economic arrangements to be more competitive and clearly against sustainable proposals (SN).

In the federal government, there are strong links established between the payment of the external debt and the use of transgenic technology. The payment of the external debt implies as highest priority the export of agricultural products (as raw materials) to generate a balance-of-trade surplus. Thus, the mechanisms of investment in agriculture privilege the big mono-cropping farms that use industrial inputs. An opposite pressure comes from certain ecologically oriented groups of society to limit the expansion of the industrial agriculture to the forested areas in the Central and Northern areas (Cerrado and Amazon Basin). Moreover, ecological concerns are increasing because it is evident that large-scale farmers will not improve by themselves the environmental and social performance of industrial soybean farms.

The peripheral urban system has many links with the central urban system. The government and social groups of the central urban system are represented in the diagram. The central system is composed of “developed countries”. The peripheral rural system (“Third World”) is dependent on impositions and interests of the central system (“First World”). Many times, Countries of the peripheral system have debts with countries of the central system. The central system has the power to interfere with and influence periphery governmental decisions; for example: the pressures on public policy by multinational enterprises (MNE) and International Monetary Fund (IMF).

The central urban system prefers to purchase cheap raw-material in the periphery instead of producing its own food and fiber. This creates an incentive for maintenance of the current agricultural structure based on the industrial model of production, in Brazil as well as in Europe. Part of the biosphere resources are or could be renewable (biodiversity and atmosphere) and others are non-renewable (fossil fuels). Nowadays, the non-renewable resources support the global industrial system, and at the same time their consumption contributes to destruction of the remaining renewable resources. This complex relation between components is shown in the diagram.

From this large-scale point of view, it is possible to identify several political forces: (a) Industrial agriculture congressmen group, a relevant force in the configuration of Brazilian legislation related to soybean production; (b) Transnational industries having economic power to affect policy and investments of local governments; (c) The World Monetary Fund forcing Brazil to pay the external debt (at least yearly interests); as result the country has huge needs of economic resources and maintains the current structure of land tenure and the chemical agricultural model. To pay the debt, the Brazilian government requires a high volume of exports and low social investments; the export oriented agricultural business is able to contribute to this.

Despite to all these factors, the ecological group of the federal government, who has knowledge of the social and environmental advantages of biological agriculture, however, it is overwhelmed by the economic group of the same government that imposes the transgenic modality of industrial agriculture. The observed result is that the external forces generate strong pressures that modify the Brazilian rural structure and increase the use of industrial chemical inputs even if it is neither the best economic solution nor the better ecological and social alternative.

4. CONCLUSIONS

Emergy methodology allowed the characterization of the four different systems of soybean production and shows that the biological options have better performance than the industrial systems. The incorporation of renewability factors to improve calculations and refine the results of system indicators is convenient and valid, considering the use of renewable inputs purchased in the local or the regional economy.

The biological systems are most efficient in the use of energy flows and require less monetary investments per unit of emergy produced. On the other hand, industrial systems consume more fossil energy in direct and indirect form. Biological systems are more renewable than industrial ones. The results indicate that biological options cause lower pressure on the environment and better exploit and make available local resources by investing outside resources. This means that the biological system delivers more emergy per economic input. On the other side, results show that farmers of biological systems are losing more emergy in exchange of their products with the external market. The local work ratio (LWR) uses the distinction between local and external share labor force and allows identifying family managed systems. Biological systems are more labor intensive and employ more local people, resulting in wide-ranging benefits for the region and an increased local-added value.

The inclusion of externalities as additional services enables a better social assessment of the 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 main characteristic of the biological models is large share of used available natural resources from the ecosystems where the farm is located instead of purchased inputs. This results in a reduction of the production costs, besides an increase in the number of jobs per unit of area. Furthermore, biological systems preserve soil and forest reserves and generate less negative externalities. This system directly benefits the producer and indirectly the society. The best performance of the biological models is obtained by the increasing the use of renewable resources, reducing the use of marketable materials and services (non renewable), loss of topsoil by erosion and externalities. The best option is an agricultural system based on small farms with produce ecological or organic cultures. It provides the farmer has an acceptable quality of life, by using more ecologically and by recycling the natural resources and economic resources. Small ecological farms can produce for regional and external markets with a productivity equivalent to industrial systems (Odum, 2001).

The emergy methodology provides the identification of the macro structure and factors determining the way soybeans are produced in Brazil. It is necessary to have a broad point of view to allow the identification and to visualize all the external forces that act on the agricultural systems. From this point of view, it was evident that there are significant forces have been identified. Those shape the system and are not considered in the traditional emergy analysis. Behind these forces, several lobbies and interests can be named: the agricultural congressmen group, the International Monetary Fund (IMF), the International Banks, the producers of agricultural inputs and finally the favored external market.

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