EMERGY SYNTHESIS 5:
Theory and Applications of the Emergy Methodology

Proceedings from the Fifth Biennial Emergy Conference,
Gainesville, Florida

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December 2009

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Emergy and Economic Assessment of Apple Production Systems in the South of Brazil

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ABSTRACT

The apple production in Brazil is located mainly in the Southern states due to the need of cold climate. The Fraiburgo County is the most important producing region distributed in the most of times into small growers (family-managed farms) or very large industrial farms. To assess the environmental performance of some different apple production management in Fraiburgo County, Emergy indices were calculated considering three main systems: (i) Organic small scale; (ii) Conventional small scale; and (iii) Conventional large scale. The indices showed that small scales have better emergy performance than large scale, and that organic management has better Renewability (55%), lower Environmental Loading Ratio (0.84) and better Emergy Yield ratio (2.24) compared with other two systems. To complement this discussion, the economic profitability was calculated in two ways: considering and not considering additional services (negative externalities and environmental services). The results showed that industrial systems have higher economic performance than the other systems when the additional services are not considered. In the other hand, when the additional services were considered, the small farms showed best performance.
Keywords: Apple production; Emergy; Sustainable agriculture.

INTRODUCTION

The conventional Brazilian apple *(Malus domestica)* production is not different from other agricultural production systems that use conventional management. This is because all of them use a large quantity of materials and services derived from fossil fuels. In a future perspective where less fossil fuel will be available, food production will have to be supported by higher portion of renewable resources. This situation brings uncertainties about the limits to the human existence on the planet (MEA, 2005; Wackernagel et al., 1999; WCED, 1987; Meadows et al., 1972).

Perhaps locally, apple production causes low impact on the environment, but when a systemic analysis is considered, the following doubts appear: How much energy was indirectly necessary to produce materials used by the system? Was this energy accounted for in the market price of these materials? Assessment tools must consider a systemic analysis and accounting for all forms of matter and energy (from nature and from economy) that were directly and indirectly used in the process.

In this way, emergy analysis is an assessment tool that accounts for all energy used by a process (Odum, 1996). Emergy measurements of natural and economic resources are expressed in a common basis: solar equivalent Joules (seJ). It supplies environmental performance indices that can be used on the discussion of sustainability. Other tools that supply different sustainability indices also have been used to discuss the sustainability of the productive systems (e.g.: Ecological Footprint - Wackernegal and Rees, 1996; Environmental Sustainability Index - Samuel-Johnson and Esty, 2000; Environmental

Performance Index - Esty et al., 2006), but only Emergy analysis considers the “energy quality” concept.

An important paper published by Reganold et al. (2001) about apple production, shows that the great majority of environmental and horticultural criteria did not have significant differences between Organic and Integrated systems, nevertheless industrial system had a poorest performance. In that work the authors used energy analyses and other indicators that did not account for the environment resources and did not use the energy quality concept. Several ecosystems and economic systems emergy evaluations were made all over the world, as well as theoretical studies and discussions. However, there is a lack of emergy studies that evaluated apple agricultural production to discuss its sustainability, mainly considering different agricultural managements and scales.

The aim of this paper is to show the environmental and economic performance between different agricultural models of apple production in south of Brazil. For this, it was used Emergy assessment and, in a parallel way, calculated two economic indicators (Revenues and Profitability) considering and not considering the additional services (negative Externalities and Environmental Services).

METHODOLOGY

Description of the study area

Brazil country had approximately 2253 apple growers in 2007: 32 industries (large areas) and 2221 growers in small scale, comprising 35000 ha with apple plantation. In 2006, the apple market in Brazil was responsible for USD 310 millions. Most apple fruit (65%) is addressed to internal market *in natura*; 20% are used to make concentrated juice; and the other 15% are exported. Fraiburgo County, Santa Catarina state, Brazil (Figure 1) is responsible for 28% of the national apple (*Malus domestica*) production, and it is the Brazil’s main Producer County (ABPM, 2007).

Due to some social, environmental and economic problems from large use of agrochemicals in apple production, a national Brazilian team of researches managed by Embrapa Uva e Vinho organization launched a project called Apple Integrated Production (AIP). The AIP consists in some agricultural techniques to produce high quality food through the protection of natural regulation mechanisms of plagues. As a result, the use of agrochemicals can be reduced as well as social, environmental and economic impacts. That management aims to help the system to obtain an upgrade on a maximum power, that in accordance to Odum and Odum (2006) “successful systems develop structures that maximize useful resource production and consumption, also by feeding back matter and information” and “efficient, maximum production requires that everything be reused or recycled (not accumulating in dumps)”.

Figure 1. *Study area. Brazil country, Santa Catarina state, Fraiburgo County.*

In this paper three agricultural production models for apple production were compared: (a) AIP or Integrated model in small scale and family managed; (b) Organic model in small scale and family managed; and (c) Chemical or conventional model in large scale (industry). The Organic model chosen as case study has certification by a Brazilian Organization and follows international rules to be denominated as Organic. Two agricultural small farms located in Fraiburgo County were evaluated: Integrated (26.5 ha) and Organic (10 ha). The data for these properties were obtained through field work. For the industrial model (100 ha), the used data were obtained through national statistics and some information about the industries located in the same region. This was made due to the difficulty to obtain available industrial data.

Emergy approach

Emergy analysis is based on the works of Odum (1996), Ulgiati and Brown (1998), and Brown and Ulgiati (2004). The first step in the application of the Emergy methodology is to construct system diagram to identify all components and their relationships. Figure 2 shows an aggregated flow diagram that uses a symbolic language to represent the flows and interactions. Table 1 shows the description of the emergy flows.

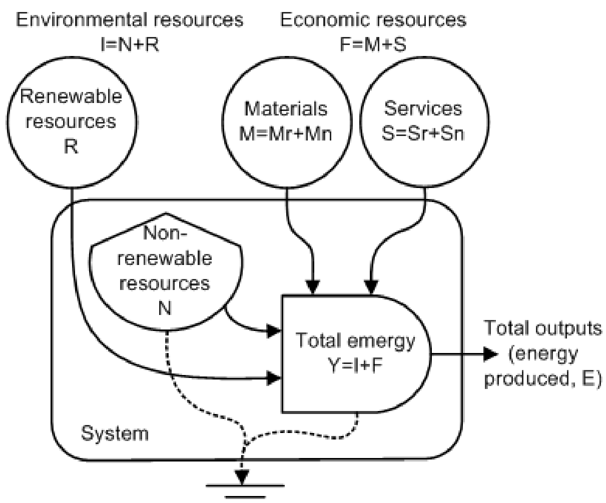

Figure 2. *Emergy system diagram of a generic production system.*

Table 1. Classification of Emergy flows used in environmental accounting.

Inputs and services	Description
I: Nature contributions	R + N
R: Renewable natural resources	Rain, materials and services from preserved areas.
N: Non-renewable natural resources	Soil, people exclusion, etc.
F: Feedback from economy	F = M + S
M: Materials	$M = M_R + M_N$
M_R: Renewable materials and energy	Renewable materials of natural origin.
M_N: Non-renewable materials and energy	Minerals, chemicals, steel, fuel, etc.
S: Services	$S = S_R + S_N$
S_R: Renewable services	Manpower supported by renewable sources.
S_N: Non-renewable services	Other (external) services, taxes, insurance, etc.
Y: Total emergy	Y = I + F

Adapted from Ortega et al., 2002

The second step is to build the Emergy table, placing the numerical value and the units of each flow mentioned in the diagram. The table allows the conversion of all the resources in terms of solar emergy Joules using Emergy Intensities, that can be in energy unit (seJ/J, called Transformity), mass unit (seJ/g, called Specific Emergy) and monetary unit (seJ/currency, called Emergy per Money Ratio). The third step is to obtain the Emergy indices (Table 2) in order to evaluate the system environmental performance.

This work has been incorporated the following changes in Emergy synthesis that are not customary:

(1) The increase of agricultural production brought many damages to the environment. In accordance to Food and Agriculture Organization (FAO), the agriculture is responsible to produce food, but for this, some impacts on natural ecosystem are generated (Pretty et al., 2000). These impacts called as negative externalities are defined as the costs of environment utilization to produce anything. Nowadays, these costs are not considered in the market price of the product; the natural resources are considered as free and are being degraded. Odum and Odum (2006) wrote:

> "To maximize system prosperity, private production must be include public benefit needs in its operation and pricing (not only make the most for the lowest cost to sell for the highest price). Private business can be required to add the costs of environmental protection and social equity costs of recycling materials, restoring land, and replacing destruction. Minimum wages and benefits need to be included in the costs. These costs are not a burden to an individual company if required of all competitors."

Pretty et al. (2000; 2005) estimated the value of 260 USD/ha/yr by the negative externalities from conventional food production at United Kingdom. The authors used different tools from neoclassical economic theory (direct and indirect methods) and considered the damage caused to soil, air, water, landscape and human health. In the present paper, the value of 0.0288 USD/kg_{APPLE} (Pretty et al., 2005) was considered as negative externality. Since that for small properties there are co-products (not only apple), the average between cereal, potato, fruit and vegetable (0.0209 USD/$kg_{PRODUCT}$) was considered to the other products. These monetary flows were considered in Emergy synthesis as additional services;

(2) The renewability factor of each item was first suggested by Ulgiati et al. (1994) and further considered by Ortega et al. (2005; 2002), Ortega and Polidoro (2002), Ulgiati et al. (2005), Cavalett et

Table 2. Emergy indicators.

Indicator	Expression	Meaning
Solar transformity (Tr)	Y/E	The ratio of the emergy of the output divided by the energy of the products.
Renewability (%R)	$100x(R+M_R+S_R)/Y$	The ratio of the renewable inputs divided by the total emergy of the system.
Emergy yield ratio (EYR)	Y/F	The ratio of total emergy used divided by the emergy from the economy.
Emergy investment ratio (EIR)	F/I	Emergy from economy divided by the emergy from nature.
Emergy exchange ratio (EER)	Y/[($)x(seJ/$)]	The ratio of emergy delivered by the producer to the economy divided by the emergy received from the buyer.
Environmental loading ratio (ELR)	$(N+M_N+S_N)$ / $(R+M_R+S_R)$	The ratio of nonrenewable emergy and renewable inputs.
Emergy sustainability index (ESI)	EYR/ELR	Indicates the cost/benefit relation.

Source: Ortega et al., 2002; based on Odum, 1996.

al. (2006) and Agostinho et al. (2008). The Emergy indices %R, ELR and ESI were slightly changed to consider the renewability of each resource used. The incorporation of the renewability factor is particularly valid when the system uses materials and services, purchased at the local or regional economy, that are not totally considered as nonrenewable resource (such as labor, electricity power, manure and services; Ortega et al., 2005; 2002);

(3) One characteristic of small family farms in Brazil is the diversity of their production and the presence of native vegetation areas in a greater proportion than the chemical farming enterprises. This occur because the small farms obey environmental laws and they need the environmental services of preserved forested areas more than the conventional farms that uses chemical resources instead natural ones. As suggested by Agostinho et al. (2008), the biomass present on the properties was accounted as a renewable resource from nature in this paper. This energy flow (from internal biomass stock) is very important to produce several environmental services that are used by the system, mainly in the small farms. To estimate the biomass quantity, the area of each land use was obtained and multiplied by its respective value of Net Primary Productivity (NPP). The following NPP data were used in this work (Aber and Melillo, 2001): Natural cover = 800gC/m^2/yr; Pasture = 225 gC/m^2/yr; Crops = 290 gC/m^2/yr; Lake = 225 gC/m^2/yr.

Economic approach

All processes require material and energy inputs. Natural non-renewable and purchased inputs are usually recognized and accounted for as driving inputs, i.e. inputs that are needed for the process to take place (for instance fuels, electricity, machinery, fertilizer). On the other hand, free environmental inputs are often not recognized as driving inputs, even if they are also fundamental services, like topsoil used up in agriculture, or cooling water in power plants (Ulgiati and Brown, 2002). In recent years, as a result of increasing attention to the limits of environmental support, the concept of environmental services is gaining a more attention. An important work on this sense was published by Costanza and coworkers (1997) that defined ecosystems services as the "flows of materials, energy, and information from natural capital stocks which combine with manufactured and human capital services to produce human welfare". The authors estimated the monetary value of the environmental services for some biomes around the world; they used economy conventional tools (basically willing to pay) and obtained the total value of USD 33 trillion per year in the planet.

Considering the importance of environmental services, their monetary values were considered in this work. For this, the area of each land use and the following data published by Costanza et al. (1997) were used: Natural cover = 2007 USD/ha/yr; Crops = 92 USD/ha/yr; Lake = 7603 USD/ha/yr; Pasture = 232 USD/ha/yr.

Economic indices used in this paper are Revenues and Profitability (Eqs. 1 and 2), as used by Cuadra and Björklund (2007). Revenues represent the amount of money received by the farmer after all costs have been paid. Profitability is the economic benefit received by the farmer and expressed as a percentage of the total cost.

Revenues (USD/ha/yr) = Gross income – Total costs (1)

Profitability (%) = (Revenues / Total costs)*100 (2)

To show the importance in accounting the energy embodied at a product, the economic indices were calculated through two approaches: (a) Conventional and (b) Ecological. Conventional approach considers only the materials and services used by system and its monetary value obtained from market price. Ecological approach was separated in: (i) the monetary value of negative externalities and the environmental services was considered; these inputs was add to the costs and gross income calculated in a conventional way; (ii) all energy used (from nature and economy) was accounted and its conversion in emergy flows was made; it was used the Brazil's emdollar (3.2E+12 seJ/USD; Coelho et al., 2003) to convert these emergy flow in monetary flow; this approach was called as "Emergy" approach. In this case, the total emergy flow was considered as total costs (negative externality as an additional service input); the products were transformed in emergy flows and the environmental services were added to calculate the gross income.

RESULTS AND DISCUSSION

Emergy comparison

The raw data used in this study are in Appendix A. The emergy indices obtained for the studied systems are showed in Table 3.

The Integrated apple production systems obtained better performance in Transformity indicator (410,000 seJ/J) than the two another systems; while the Organic system obtained the poorest performance (1,890,000 seJ/J). The Industrial apple production system obtained a moderate performance (639,000 seJ/J), since that values of Transformity for conventional agricultural systems in Brazil can vary from 100,000 to 2,000,000 seJ/J (Agostinho et al., in press). Considering that the Organic system assessed showed to be very inefficient on the transformation of energy (low Transformity), it would be interesting to find a way that increase productivity without appealing to the increase of the use of emergy, especially of the resources that show high transformity.

It is interesting to point out that the Organic system uses less empower density ($8.81\ 10^{15}$ seJ/ha/yr) than the Integrated ($1.16\ 10^{16}$ seJ/ha/yr) and industrial systems ($4.01\ 10^{16}$ seJ/ha/yr). Even that, due to its low productivity, it is lesser efficient than the two others systems assessed in this work.

The renewability ratio (%R) is the percentage of renewable emergy used by the system. Organic system had a good performance (55%) whereas the Integrated system (32%) showed low performance. Conventional agricultural production systems in Brazil have values of renewability from 20 to 30% in average (Agostinho et al., *in press*), whereas agroecologic system has values higher than 50% (Agostinho et al., 2008). Integrated and Industrial systems use many non-renewable resources from nature and economy, therefore unsustainable at long period of time. These results are in accordance with Reganold et al. (2001) who concluded the superior sustainability of Organic over Conventional apple agricultural production system.

The Emergy Yield Ratio (EYR) is a measure of the ability of a process to exploit and make local resources available by investing in outside resources. The results indicate that the Organic system (2.24) uses more natural resources (renewable and non-renewable) than resources of economy. The same does not occur with the Integrated (1.63) and Industrial (1.15) systems because they are highly dependent of resources from economy. The conventional agricultural production systems use a lot of emergy from economy in relation to the emergy they are using from nature, resulting in values of EYR below 2 (Ortega et al., 2002; Ulgiati et al., 1994). It is important to highlight that to Organic system has the best performance regarding to EYR since 56% of its total emergy come from renewable resources and 13% from the non-renewable of the nature.

The Emergy Investment Ratio (EIR) is an index that evaluates if a process is a good user of the invested emergy while compared to other alternatives for the use of same resources (Brown and Ulgiati, 2004). In Brazil, values reported in the literature regards to conventional agricultural production are normally around 2 (Cavalett et al., 2006; Ortega et al., 2005). As expected, the Organic

Table 3. Emergy index for studied systems.

Emergy indices	Organic	Integrated	Industrial
Tr (seJ/J)	1,890,000	410,000	639,000
%R	54.2	31.8	19.7
EYR	2.24	1.63	1.15
EIR	0.80	1.58	6.47
ELR	0.84	2.14	4.08
ESI	2.66	0.76	0.28
EER	2.82	1.63	1.84

system (0.80) had better performance than Integrated (1.58) and Industrial (6.47) systems, indicating that Organic system uses higher amounts of free emergy from nature compared to the purchasedemergy from economy. It is notable the inverse relation between the indices EIR, %R and EYR; the higher EIR the lower values of %R and EYR. Production systems based on non-renewable natural resources may not be able to compete with systems characterized by lower economic investment and greater renewable nature contribution, and might become unsustainable in the coming future.

Emergy Loading Ratio (ELR) is an index of pressure that the system carries out on the environment and can be considered as a measure of ecosystem stress. Values of ELR lesser than 2 indicate low impact to the environment; values between 2 and 10 mean moderate impact; up to 10 mean that the system causes large impact (Brown and Ulgiati, 2004). In the Organic system, the ELR (0.84) indicates low impact on the environment and for the other systems (Integrated = 2.14; Industrial = 4.08) the ELR indicates a moderate impact. Using different approach, Reganold et al. (2001) assessed the environmental impact of apple production using an index[1] similar to Cornell University's Environmental Impact Quotient, but updated to include fruit thinners and certified organic products. The index showed an environmental impact for Conventional system about 6.2 times bigger than for Organic system, whereas the Integrated system showed to be 4.7 times greater than Organic one. These results affirm that Organic management causes lower impact on the environment than Conventional ones.

The Emergy Exchange Ratio (EER) measures the advantage of one partner over the other, providing a measure of who "wins" and who "loses" in economic trade (Brown and Ulgiati, 2004). The index was greater than one for the three properties, indicating that all supply more emergy to the consumer than the emergy they receive in exchange.

The Emergy Sustainability Index (ESI) is showed in a ternary diagram (see Figure 3). This diagram has three components according to emergy indicators: R, N and F. Each corner of the triangle represents a component and each side a binary system. The composition of any system plotted on a ternary diagram can be determined by reading from zero along the basal line at the bottom line of the diagram to 100% at the vertex of the triangle (Giannetti et al., 2006).

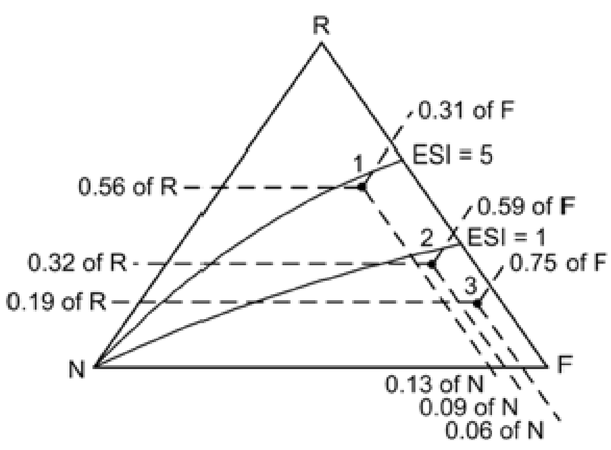

Figure 3. *Ternary emergy diagram for assessment of farms in 2006. (1) Organic; (2) Integrated; (3) Industrial. R, renewable resources; N, non-renewable natural resources; F, non-renewable economic resources; ESI, emergy sustainability inde*

[1] That index takes into account chemical efficacy, potential worker and consumer exposure, leaching potential, soil absorption index, chemical half-time and the effects of chemicals on beneficial organisms, all based on toxicological studies and chemical characteristics of each product.

Emergy Sustainability Index (ESI) measures the potential contribution of a resource or process to the economy per unit of Environmental Loading (Brown and Ulgiati, 2004). ESI indicates the system benefit/cost ratio; e.g., the benefit proportioned by a process to the economy in relation to its environmental impact. Figure 3 shows that Industrial system (number #3) presents the lowest ESI value, but the Integrated system (number #2) also obtained ESI less than one, indicating low benefit/cost ratio. The diagram shows that the three systems use 6 to 13% of non-renewable natural resources (6 to 13%), but Organic uses a greater amount of renewable inputs (56%) than Industrial (19%). The Integrated uses a moderate proportion of the renewable input (32%), but uses greater amount of non-renewable economic resources (59%). This explains the position on the ternary diagram of these systems, where the Organic is closer to "R" vertex, Industrial is closer to "F" vertex and the Integrated is located at an intermediary position.

Economic comparison

Money circulates among people who use it to acquire goods. Money quantifies what people are willing to pay for the products and services whereas emergy quantify the real wealth. Real wealth or wealth potential are food, minerals, fuels, information, art, biodiversity, etc., and can be scientifically measured using emergy (Odum, 1996). The potential wealth is the natural resources of base, local and imported useful to the society.

Aiming to study the inadequateness regarding to the price paid to the products, in this work it was calculated what the balanced price is to be accepted for the grower system (Table 4). It occurs when Emergy Exchange Ratio is equal to 1, or the emergy of the products is equal to the emergy received by the money paid for them. The balanced price of different systems was calculated as a product of EER by the price of market sale. Similar work was made by Cuadra and Rydberg (2006) considering the coffee exportation.

Table 4 shows that the price of sale of Organic apple should be 2.8 times the current price, 1.6 times for the Integrated system and 1.8 for Industrial one.

Figure 4 shows the results of economic analyses. Considering the Ecologic and Emergetic approach, the gross profit and total costs greatly differ from the calculated by the Conventional approach. In the meantime, the Industrial apple production system showed higher values for the three approaches than the Organic and Integrated systems.

At Table 5, the Industrial system has higher net profit than the others systems by the conventional approach, reaching 9 times the profit of the Organic system and 4.5 times the Integrated system. Through the ecologic approach its net profit is still superior to others systems but the difference decreases in 2.3 times. On the other hand, the emergetic approach shows that the net profit for the Industrial system is 1.4 times inferior to the Integrated system and approximately the same as the Organic system.

The same analyses could be done to the profitability where the Industrial system shows 129%, the Organic 77% and Integrated system 70% calculated by conventional economic approach. This situation is inverted when it is calculated through ecologic approach where the Organic system has 264%, the Integrated system 123% and Industrial system 98%. In the emergetic approach the Organic and Integrated systems have values close to 40%, while the industrial system shows a decrease up to 9%.

In general, the Industrial apple production system showed higher net profit and profitability when it is used tools from the conventional economy. On the other hand, when it is considered the negative externality, the environment services and all the incorporated energy that the system acquired, the Organic and Integrated system showed better performance. This result was expected and indicates potential mistakes in the conventional economy, once this also should account the energy from nature and from all environment costs generated by the system.

Table 4. Price received, Emergy Exchange ratio and Balanced Price calculated for the apple fruit production.

System	Actual apple price (USD/kg)	EER[A]	Balanced apple fruit price [B] (USD/kg)
Organic	0.46	2.82	1.30
Integrated	0.28	1.63	0.46
Industrial	0.28	1.84	0.51

[A] EER from Table 3;
[B] Balanced apple price = Actual apple price * EER. This value means that all emergy used in the apple production is received as emergy incorporated in the monetary flow in the fruit sale.

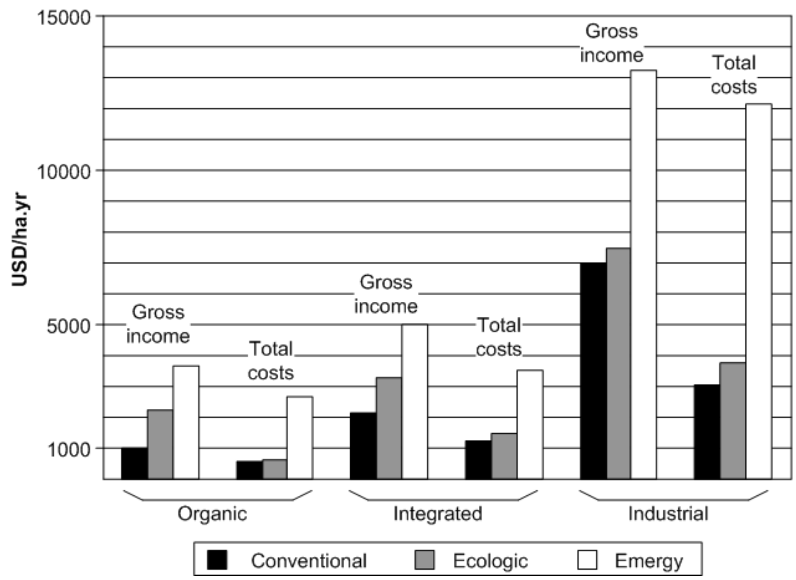

Figure 4. *Gross income and total costs for Organic, Integrated and industrial systems calculated through three approaches: conventional; ecologic; and emergy.*

Table 5. Revenues and profitability for apple fruit production calculated through conventional and ecologic approaches.

Economic approaches	Apple production systems		
	Organic	Integrated	Industrial
Conventional:			
Revenues (USD/ha/yr)	436.41	873.35	3951.79
Profitability (%)	76.8	69.7	129.6
Ecologic:			
Revenues (USD/ha/yr)	1637.35	1820.55	3704.03
Profitability (%)	264.0	122.6	98.3
Emergy:			
Revenues (USD/ha/yr)	1002.11	1498.08	1059.60
Profitability (%)	37.5	42.6	8.7

Two practices can be suggested to improve the economic performance of the assessed systems: (a) To use higher amounts of renewable resources and lower amount of non-renewable; (b) To increase the sale price of the products.

While the second one is very difficult to be done due to market rules (offer and demand), the first one can be done easily by a land's owner. Using higher amounts of renewable resources by agroecologic management, the impact on the environmental will decrease. Furthermore, the costs associated to the use of materials and services of economy and the production of negative externalities will also decrease, increasing the profitability. According to Odum and Odum (2006), "rising fuel costs and the need for preserving the quality of soil will force agriculture toward a lower intensity with less technology, fertilizer, and pesticide and more labor, provided by people leaving the cities where employment is decreasing".

The second practice is a polemic question. In the current market whether the grower increases the price of his products the consumers will look for other cheaper products showing the same quality. The system itself has no power to change the market mechanisms. Therefore, a change on the world economy is necessary to the real payment of the products and accounted all energy spent in their production.

Brown (2006) reported that the new world "need political leaders who can see the big picture, who understand the relationship between the economy and its environmental support systems"…."we need economists who can think like ecologists"…"we continue to teach economics students to trust the *invisible hand* of the market, when *invisible hand* is clearly blind to the externalities, and treats massive subsidies..". The same author cites "the key to building the new economy is getting the market to tell the ecological truth. The dysfunctional global economy of today has been shaped by distorted market prices that do not incorporate environmental costs".

Considering all the discussion above, we can say that it is necessary the inclusion of agroecological concepts in productive systems. The increase of sustainability in apple production is indispensable, however, as discussed by Elliot and Mumford (2002), this can not be simply done by promoting a niche organic market and hoping this will produce an optimal environmental outcome. A good initiative in this sense is being done in the region assessed in this study (Fraiburgo County): there is a state's law (so-called "consent agreement") that obligates the land's owner to fulfill some documents each two years to describe the changes on land use and to list the quantity and type of chemicals that are being used on agricultural production. Even that it is not enough to reach the sustainability, it is considered a good database for policy makers.

CONCLUSIONS

(a) The studied Organic system obtained better emergy performance compared to the other systems except to the Transformity index and Emergy Exchange Ratio. The indicators showed that the Organic system has elevated Renewability (%R=55%) and does not far depend on resources from economy (EYR=2.24) but it is both inefficient on the energy transformation (Tr=1,890,000 se/J) and it is prejudiced in the sale of products (EER=2.82);

(b) The Integrated and Industrial systems do not differ significantly in the results from Emergy Analysis, and despite that the Integrated system may be considered more sustainable than the Industrial system;

(c) The calculation of the balanced price of the sale of apples showed that the Organic system should sell their products 2.8 times the current price; for the Integrated and Industrial systems this value is 1.6 and 1.8 respectively;

(d) The Industrial system has higher net profit and profitability than the others systems when calculated by conventional approach. Considering the negative externalities, the environment services and the embodied energy, the performance of Organic and Integrated systems are better than the Industrial one.

ACKNOWLEDGEMENTS

The authors are grateful to Leodir Francescatto and Manoel Nascimento Pereira for their help in collecting data. Thanks to the CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) by financial support.

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Appendix A. Raw data and Emergy Intensity values used in Emergy synthesis.

Item	Unit	Organic (10,0ha)	Integrated (26,5ha)	Industrial (100,0ha)	Emergy Intensity seJ/Unit.	Unit	Reference for seJ/unit
1. Solar insolation	$kWh.m^{-2}.year^{-1}$	4.31	4.31	4.31	1.00E+00	J	Odum, 1996
2. Rain	$m^{3}.m^{-2}.year^{-1}$	1.38	1.27	1.27	3.10E+04	J	Odum et al., 2000
3. Wind	$m.s^{-1}$	1.78	0.71	0.71	2.45E+03	J	Odum et al., 2000
4. Irrigation water	$L.ha^{-1}.year^{-1}$	4000.00	9430.00	28300.00	2.55E+05	J	Bastianoni and Marchetini, 2000
5. Biomass	$kg.ha^{-1}.year^{-1}$	9622.73	8404.80	6969.09	1.00E+04	J	Estimated, Brown and Bardi, 2001
6. Soil loss	$kg.ha^{-1}.year^{-1}$	10000.00	10000.00	20000.00	1.24E+05	J	Brandt-Williams, 2002
7. Fossil fuel	$L.ha^{-1}.year^{-1}$	35.00	125.08	250.00	5.50E+05	J	Bastianoni et al., 2005
8. Dolomitic limestone	$kg.ha^{-1}.year^{-1}$	500.00	226.42	400.00	1.00E+12	kg	Brandt-Williams, 2002
9. Cow manure	$kg.ha^{-1}.year^{-1}$	250.00	-	-	1.27E+11	kg	Bastianoni et al., 2001
10. Turkey manure	$kg.ha^{-1}.year^{-1}$	450.00	-	-	2.96E+12	kg	Castellini et al., 2006
11. Potassium sulphate	$kg.ha^{-1}.year^{-1}$	15.00	-	-	1.74E+13	kg	Brandt-Williams, 2002
12. Natural phosphate	$kg.ha^{-1}.year^{-1}$	20.00	-	-	6.55E+12	kg	Odum et al., 2000
13. Fertilizer *super magro*:	-	-	-	-	-	-	-
13. 1. Molasses	$kg.ha^{-1}.year^{-1}$	0.60	-	-	8.97E+04	kg	Estimated, Ortega, 2000
13. 2. Milk	$kg.ha^{-1}.year^{-1}$	0.62	-	-	2.10E+06	kg	Ortega and Wada, 2000
13. 3. Zinc sulphate	$kg.ha^{-1}.year^{-1}$	0.60	-	-	3.80E+11	kg	Cuadra and Rydberg, 1999
13. 4. Calcium chloride	$kg.ha^{-1}.year^{-1}$	0.60	-	-	3.80E+11	kg	Cuadra and Rydberg, 1999
13. 5. Boric acid	$kg.ha^{-1}.year^{-1}$	0.45	-	-	1.48E+13	kg	Estimated, Sarcinelli and Ortega, 2004
13. 6. Magnesium sulphate	$kg.ha^{-1}.year^{-1}$	0.60	-	-	3.80E+11	kg	Cuadra and Rydberg, 1999
14. Lime sulphur:	-	-	-	-	-	-	-
14.1. Lime	$kg.ha^{-1}.year^{-1}$	3.75	-	-	1.00E+12	kg	Brandt-Williams, 2002
14.2. Sulfur	$kg.ha^{-1}.year^{-1}$	7.50	-	-	9.13E+10	kg	Odum et al., 2000
15. Bordeaux Mixture:	-	-	-	-	-	-	-
15.1. Cupper sulphate	$kg.ha^{-1}.year^{-1}$	2.00	-	-	6.38E+12	kg	Estimated, Coelho et al., 2003
15.2. Lime	$kg.ha^{-1}.year^{-1}$	3.00	-	-	1.00E+12	kg	Brandt-Williams, 2002
16. Oil *neem*	$L.ha^{-1}.year^{-1}$	2.00	-	-	1.71E+05	kg	Estimated, Cavalett and Ortega, 2006
17. Nitrogen	$kg.ha^{-1}.year^{-1}$	-	33.96	180.00	2.41E+13	kg	Brandt-Williams, 2002
18. Phosphorus	$kg.ha^{-1}.year^{-1}$	-	45.28	150.00	2.20E+13	kg	Brandt-Williams, 2002
19. Potassium	$kg.ha^{-1}.year^{-1}$	-	45.28	120.00	1.74E+12	kg	Brandt-Williams, 2002
20. Pest management	$kg.ha^{-1}.year^{-1}$	-	22.00	30.51	2.49E+13	kg	Brown and Arding, 1991

APPENDIX A. Continued.

Item	Unit	Organic (10,0ha)	Integrated (26,5ha)	Industrial (100,0ha)	Emergy Intensity seJ/Unit.	Unit	Reference for seJ/unit
22. Seeds	$kg.ha^{-1}.year^{-1}$	1.10	2.11	-	5.85E+04	J	Odum et al., 2000
23. Pyroligneous extract	$USD.ha^{-1}.year^{-1}$	24.55	-	-	3.11E+12	USD	Coelho et al., 2003
24. Chelate calcium	$L.ha^{-1}.year^{-1}$	-	5.71	6.00	3.80E+11	kg	Estimated, Cuadra and Rydberg, 2005
25. Magnesium sulphate	$kg.ha^{-1}.year^{-1}$	-	8.15	9.00	3.80E+11	kg	Estimated, Cuadra and Rydberg, 2005
26. Trees	$Unit.ha^{-1}.year^{-1}$	-	22.83	1400.00	3.11E+12	USD	Coelho et al., 2003
27. Hormones	$USD.ha^{-1}.year^{-1}$	9.20	52.70	52.70	3.11E+12	USD	Coelho et al., 2003
28. Wine (Grape)	$kg.ha^{-1}.year^{-1}$	15.00	-	-	9.91E+11	kg	Bastianoni et al., 2001
29. Trichoderma	$USD.ha^{-1}.year^{-1}$	1.53	-	-	3.11E+12	USD	Coelho et al., 2003
30. Steel	$kg.ha^{-1}.year^{-1}$	22.50	19.17	40.00	5.51E+12	kg	Bargigli and Ulgiati, 2003
31. Concrete	$m^3.ha^{-1}.year^{-1}$		0.06	0.10	2.59E+12	kg	Brown and Buranakarn, 2003
32. Electricity	$kWh.ha^{-1}.year^{-1}$	9.00	8.54	80.00	2.77E+05	J	Brown and Ulgiati, 2004
33. Other materials	$USD.ha^{-1}.year^{-1}$	78.00	-	1150.00	3.11E+12	USD	Coelho et al., 2003
34. Taxes	$USD.ha^{-1}.year^{-1}$	0.00	66.85	665.00	3.11E+12	USD	Coelho et al., 2003
35. Simple labor	$h.ha^{-1}.year^{-1}$	173.50	173.72	612.00	2.80E+06	J	Brown, 2003
36. Negative externality	$USD.ha^{-1}.year^{-1}$	51.98	231.18	720.00	3.11E+12	USD	Coelho et al., 2003
37. Environmental services	$USD.ha^{-1}.year^{-1}$	1252.92	1178.38	472.24	3.11E+12	USD	Coelho et al., 2003
38. Produced energy*	$J.ha^{-1}.year^{-1}$	4,66E+9	2,83E+10	6,28E+10	-	-	-
39. Income (from Sales)**	$USD.ha^{-1}.year^{-1}$	1004,60	2294,36	7000,00	-	-	-

* Only agricultural products;

** Negative externalities and environmental services were not accounted here