FROM EMERGY ANALYSIS TO PUBLIC POLICY: SOYBEAN IN BRAZIL

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ABSTRACT

An emergy analysis was accomplished to compare the main technological options of soybean cultivation in Brazil: (a) "chemical inputs and machinery intensive", (b) "herbicide and no tillage", (c) "ecological-traditional" and (d) "modern organic enterprise". The effect of farm size on sustainability, profitability and job density was evaluated, by comparing emergy, economic and social indices of small farms (30 ha, ecological), medium farms (300 ha, chemical; 300 ha organic enterprise) and large farms (3000 ha, herbicide-no tillage). The results were extrapolated to encompass the whole country with one stand-alone production type to build agricultural scenarios that allow us to visualize the environmental and social impacts. Doing so it has been possible to demonstrate that small ecological-organic producers have the greatest renewability and profitability per area and the smallest environmental impact and the minimum dependence on industrial inputs. They use more labor per hectare, basically family members. Therefore, at time of great need of jobs and low monetary resources, the best option is the small ecological-organic family farm because it offers rural jobs with an acceptable pattern of life under sustainable parameters. The research lead us to make the following suggestions: to avoid the use of the herbicide-no tillage option because it increases rural exodus and promotes more wealth concentration; to give support to ecological-organic family operated systems due to its multi-purpose benefic characteristics; to study and discuss public policy to fix prices and incentives to farmers that preserve nature and recycle materials and to tax producers that damage the environment and do not generate jobs.

Keywords: soybean, emergy, public policy, environmental impact, social appraisal, Brazil.

INTRODUCTION

The aim of this research is to compare the main four methods for soybean production used in Brazil. To accomplish this objective we have analyzed: (1) the traditional ecological-organic method used by farmers of European origin in the Southern States of Brazil; (2) the chemical method corresponding to the "green revolution", promoted in the 70´s; (3) the herbicide and no tillage model, the "new green revolution" introduced in the last decade (that can use transgenic seeds, now forbidden) and, (4) the "organic modern enterprise", a new rural system now appearing and adopted in medium and big size farms.

Table 1. Characteristics of soybean production systems studied from the states of Rio Grande do Sul (RS), Paraná and Mato Grosso (MT).

Name	Technology \ Size	Low scale intensive systems **3 ha**	Family operated systems **30 ha**	Family or enterprise system **300 ha**	Enterprise system **3000 ha**	Enterprise system **More than 3000 ha**	Dangers
Chemical options – intensive use of fossil energy							
New Green Revolution (Biotechnology model)	Chemical fertilizers No tillage-herbicide Less machine use Transgenic seeds risk	Not studied	Not studied	Not studied	MT “frontier farmers” who come from RS and PR farms	Not studied	Genetic erosion Social exclusion Biodiversity loss
Green Revolution farm	Chemical fertilizers Pesticides Machine intensive Certified seeds	Not studied	Not studied	“Modern” farmers in RS, PR, MT	Not studied	Not studied	Soil erosion Social exclusion Biodiversity loss
Biological options – intensive use of ecosystem energy							
Organic trend	Organic fertilizers, Pest management Less machine use Organic seeds	Not studied	Not studied	“Organic” farmers in RS, PR, MT	Not studied	Not studied	Social exclusion Biodiversity loss
Ecological farming	Ecological inputs Biological control Few industrial inputs Labor intensive Organic seeds	Not studied	“Traditional European immigrant” farms in RS and PR	Not studied	Not studied	Not studied	Risk of loss of competitiveness if price reduces due to offering of “organic” enterprises.
		Nowadays below ecological and economical levels.	Ecological and social standards.	Some can achieve ecological standards. High profits.	Some achieve ecological but not social standards. Very high profits.	Usually below social and ecological levels. Excessive profits.	

METHODS

As first step, we prepared a traditional economic report with monetary flows. After that, all the physical, biological and monetary inputs of the agricultural systems studied were converted into emergy flows (emergy = necessary Joules of solar energy to produce a product or a service, abbreviated sej). The Emergy Flows Table let us calculate Emergy Indices and make an Ecological Diagnosis (Odum, 1996). Farm inputs data relative to years 1999, 2000 and 2001 was obtained from yearbooks and contacts with farmers.

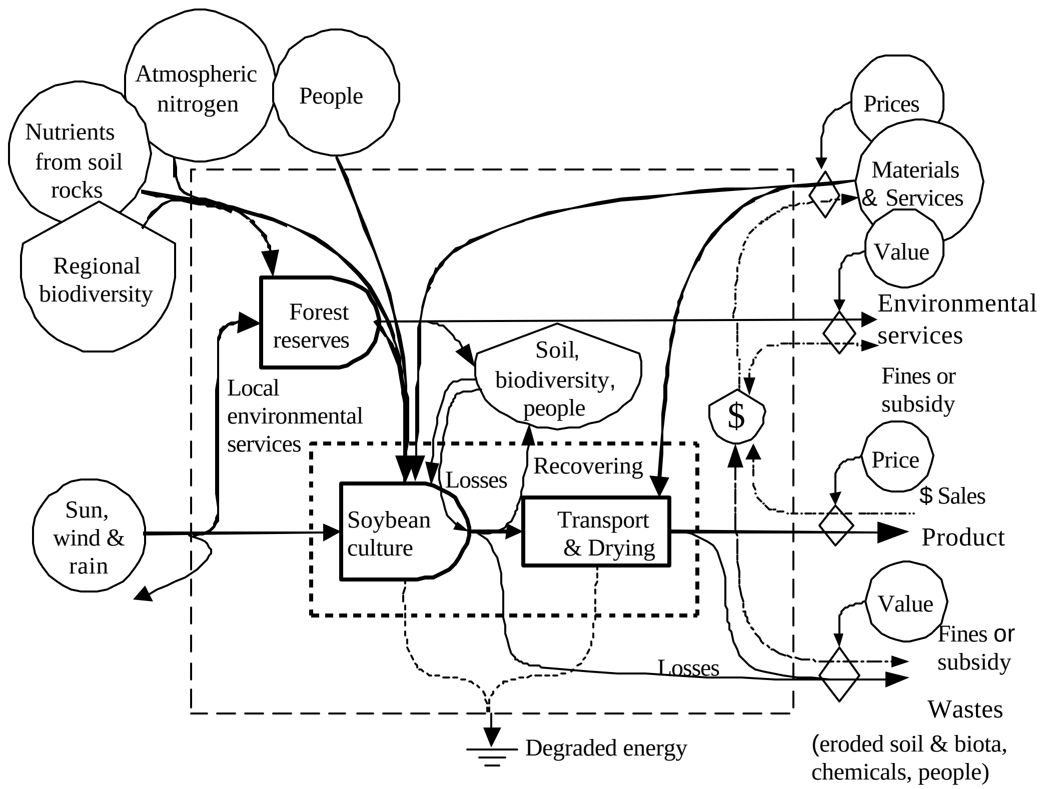

Figure 1. Soybean production system emergy flow diagram.

The emergy flows has been calculated taking into account the amounts of natural resources, material inputs and services involved in each type of production (Ortega, Miller & Anami, 2000; Miller & Ortega, 2001). Those tables contain data of inputs per hectare of soybean production in the period of one year.

To evaluate the impact on the country, the data with the inputs corresponding to usual yields of each soybean production system analyzed has been extrapolated to encompass the whole area cultivated with soybean in Brazil (12.6 million ha in 1999 and 13.6 million in 2000).

RESULTS AND DISCUSSION

Considerations regarding economic and social aspects

Economic Inputs

Table 2. Inputs for the four systems of soy production expressed in US$ x 10^9 /year.

	30 ha Ecological Family Farm	300 ha Organic Enterprise	300 ha Chemical Enterprise	3 000 ha Herbicide Enterprise
Materials	1.79	1.83	2.73	3.62
Services	1.22	1.06	1.11	9.14
Economy feedback	3.01	2.90	3.84	4.53

Source: FNP, 1999; Agrorgânica, 2000; Terra Preservada, 2002.

As materials we consider: seeds, limestone, fertilizers, inoculating agent, pesticides, herbicide, fuels, machinery depreciation; as services we consider: manpower, administration, transport, cleaning and drying costs, taxes, insurance, social security and land leasing. The manpower data used have been expressed in terms of number of hours of work/ha/year. As shown in Table 2, chemical and herbicide/no tillage systems use 50% and 100% more materials (almost 0,9 and 1.8 billion of US dollars, respectively), than the ecologic and organic systems. This money is driven abroad, as most of these materials are imported.

Manpower

Table 3. Manpower in the soybean production systems expressed in US$ x 10^6 /year.

Items	Ecological	Organic	Chemical	Herbicide
Unqualified hand labor	520.6	359.0	11.5	1.8
Qualified hand labor	12.6	20.2	453.6	252.4
Administrative labor	46.8	46.8	46.8	46.8
Technical assistance	108.8	108.8	21.8	31.6
Total labor	688.8	534.8	533.6	332.5

Source: FNP 1999, Agrorgânica 2000, Terra Preservada, 2002.

The most significant percentage of the ecological farm expenses is in the unqualified human labor, almost 47% of the value expended with services. That can be explained by the fact that ecological farms are, in its majority, small and the labor is of family origin. The organic farms use a lot of labor but organic enterprises may be energy intensive and do not incorporate labor. There are almost US$ 600 million more in hard work labor expenses in the biological options than in the chemical ones. An estimate of the number of jobs that could be generated with this amount of money can be easily made. If a rural worker earns US$ 100 a month, it means US$ 1200 per year; dividing US$ 600 million by US$ 1200, it leads to 500 000 new jobs in agriculture. In the conventional agriculture (chemical) and also in the new technology based on no-tillage and herbicide (and transgenic seeds, now forbidden) the expenses are mainly due to the administrative labor, since weeds destruction is done chemically or by machine.

Economic and social indices

Table 4. Soybean indicators. Data: FNP 1999, Agrorgânica, 2000, Terra Preservada, 2002.

Economic indices	**Ecological (30 ha)**	**Organic (300 ha)**	**Chemical (300 ha)**	**Herbicide (3000 ha)**
Production (kg/ha/year)	1920	1920	2240	2240
Price (US$/kg)	0.250	0.235	0.170	0.170
Sales (US$/ha)	**480.00**	**451.20**	**380.80**	**380.80**
Costs (US$/ha)	**221.11**	**213,09**	**282.60**	**333.22**
Net income (US$/ha/year)	258.89	238,11	98.2	47.58
Return ratio = sales / costs	**2.17**	**2,12**	**1.35**	**1.14**
Profitability = (sales- costs) / costs	**1.17**	**1,12**	**0.35**	**0.14**
Farm area (ha)	32.5	300	300	3000
Farm annual net income (US$/year)	8 414	71 433	29 461	142 742
Farm month net income (US$/month)	**701**	**5 953**	**2 455**	**11 895**
Work hours/ha/year	147.0	103.2	75.1	40.5
Workers / ha	0.0503	0.0353	0.0257	0.0139
Production/Worker (kg soy/worker)	**38 139**	**54 326**	**87 118**	**161 501**
Output/Input (kg /kg)	**92 728**	**93 082**	**45 479**	**46 381**

Surprisingly the largest economic profit per hectare is obtained by the ecological option. The profitability of ecological and organic farming (1.17 and 1.12) is considerably larger than that for chemical (0.35) and herbicide (0.14) farming. The reason is that some chemical inputs are expensive and ecological and organic products achieve better prices. But the profit per farm is greater for the organic, chemical and herbicide options due only to their bigger size.

The data do not permit to compare the annual income per family because only one of the systems is based on family production; the other two are usually business enterprises. The productivity per labor index is not a convenient ratio to consider because the problem is not of labor productivity but of input productivity and employment per area. Instead, workability and output/input ratios that favor biological systems could be considered.

Considerations about technological and political dependence

In the system of herbicide/no tillage there exists a larger dependence of external inputs, mainly of transgenic seeds and herbicides. This leads to a loss of autonomy of producers and country in relation to technology and prices fixed abroad. Rural workers and small and medium farmers will have troubles to keep their work, their income will decrease and, as a result, agricultural properties will be bought and controlled by a few big owners with big profits. Although these big producers have low productivity per hectare their properties size ensures them high income. Besides that, the chemical and herbicide based systems depend on external inputs. The largest value of sustainability corresponds to the ecological and organic systems. These systems use fewer resources from economy and more natural renewable resources, which guarantee its sustainability. They ensure the survival of the producer throughout the time and the preservation of the biodiversity. If government could support ecological and organic options the country's balance of trade could be improved each year in almost US$ 2.0 billion!

Considerations regarding emergy indices

Table 5. Aggregated emergy flows

Emergy Flows (sej/ha/year)	Ecological	Organic	Chemical	Herbicide
Renewable resources (R)	1.18E+15	9.98E+14	8.04E+14	8.08E+14
Non renewable resources (N)	5.34E+13	5.34E+13	6.98E+14	8.60E+13
Nature contribution (I)	1.23E+15	1.05E+15	1.50E+15	8.94E+14
Material inputs (M)	1.07E+15	1.09E+15	1.75E+15	2.72E+15
Services (S)	2.68E+14	2.47E+14	2.80E+14	1.87E+14
Feedback from Economy (F)	1.34E+15	1.34E+15	2.03E+15	2.90E+15
Total emergy incorporated (Y)	2.57E+15	2.39E+15	3.54E+15	3.80E+15

Table 6. Emergy indices

Emergy Indices	Ecological	Organic	Chemical	Herbicide
Transformity (Tr, sej/J)	**88 146**	**81 957**	**103 904**	**111 527**
Net Emergy Yield Ratio (EYR)	**1.92**	**1.78**	**1.74**	**1.31**
Emergy Investment Ratio (EIR)	**1.09**	**1.27**	**1.35**	**3.25**
Environmental Loading (ELR)	**1.19**	**1.40**	**3.40**	**3.70**
Renewability (R)	**0.46**	**0.42**	**0.23**	**0.21**
Emergy Exchange Ratio (EER)	**1.45**	**1.35**	**2.51**	**2.69**

Transformity (Tr)

$Tr = Y / Ep = \Sigma$ (Emergy used) / energy of main product = $\{ \Sigma (J_i * Tr_i)\} / Ep$

The transformity is the inverse value of the system efficiency for a specific product. Transformity values vary from 80 000 to 110 000. The transformity values of ecological and organic options (88 146 and 81 957, respectively) are lower than of herbicide/no tillage and chemical options (103 904 and 111 527); this means that biological systems are more efficient.

Renewability (R/Y)

This ratio measures the sustainability of the system, because it represents the proportion of all the resources used that are renewable. As renewable resources we consider: rain, nutrients captured from air (nitrogen) and soil rocks (minerals), products and services obtained from the farm area under preservation (at least 20% of total area according to Brazilian law). Usually ecological farmers keep this forest area and take benefit of it. Agricultural enterprises, as a general rule, do not obey the law and are not strongly forced to do that.

The chemical system renewability is slightly bigger (0.23) than for herbicide/no tillage (0.21) but both are much lower than the values for ecological and organic options (0.46 and 0.42). In the organic option, almost half of the natural resources come from renewable sources, which give to this system a higher autonomy. This index would be even larger if the methodology could consider the purchased manure as a renewable resource and not as a non-renewable input obtained from the urban economy.

Net Emergy Yield Ratio (EYR=Y/F)

The EYR ratio typical values for agricultural products vary from 1 to 4. The lowest value is one, which happens when nature inputs are null (R+N = 0). The difference above the minimum value measures the cost-free contribution of the environment to production.

The value of EYR for the herbicide/no tillage method is the closest to unity (1.31); it means that the nature contribution is low when compared to resources from economy; so, this system is not able to deliver too much net emergy to consumer systems because most part of inputs are not renewable (e.g.: herbicide, fuel, fertilizers, pesticides, etc.). For the chemical option the value is slightly higher (1.74), as economy inputs decrease (less herbicide) and natural resources increase, even if these were not renewable (soil). The ecological option has the highest value (1.92). This indicates its ability to incorporate free resources from nature. The ecological system has strong internal recycling which renders economic benefit to the farmer and ecological benefit to environment. The organic option value (1.78) is slightly lower than the ecological value of EYR.

Emergy Investment Ratio (EIR)

EIR = F / I = purchased resources / free resources

This ratio measures the society's effort to produce a given product in relation with nature's contribution; it evaluates if the system uses the investment adequately. A low value means that the environment has a relatively larger contribution than the economy (goods and services), having lower costs and being more competitive. This ratio gives a clear vision of the difference between the systems in relation to the investment needed for production.

The herbicide/no tillage value is high (3.25), thus demonstrating an economically fragile agriculture due to its dependence on purchased inputs from foreign regions. The chemical option has an intermediate value (1.35). Ecological agriculture shows the lowest value (1.09). The small ecological family farm uses nature resources (free) instead of economy resources (expensive) having lower need of external investment and lower production costs. The organic option demands more economy inputs than the ecological option (1.27).

Environmental Loading Rate (ELR = (N + F) / R)

Chemical and herbicide/no tillage methods (3.40 and 3.70) produce great environmental damage. Biological agriculture instead has lower values (1.19 and 1.40), which confirms great use of natural renewable resources by ecological and organic production techniques; practically the same quantity of emergy from renewable sources than from non-renewable, producing reduced environmental impact.

Emergy Exchange Ratio (EER)

All four options give more energy to the buying system than to the producing system. The worst in terms of emergy exchange is the herbicide based system (2.69), followed by the chemical (2.51), the ecological (1.45), and finally by the organic system (1.35). The emergy per dollar ratio of Brazil was considered in the evaluation. If the Europe's ratio were used the results would be three times worse. This means that neither the buyers nor the government take into account the nature's work.

Considerations regarding size of properties

Table 7. Indicators for agriculture reform public policy.

Public Policy Indices	**Ecological**	**Organic**	**Chemical**	**Herbicide**
Country soybean area (ha)	1.36 E+07	1.36 E+07	1.36 E+07	1.36 E+07
Size of farm (ha)	32.5	300	300	3000
Number of farms (ideal value)	**418 462**	**45 333**	**45 333**	**4 533**
Workers / 1000 ha	50.3	35.3	25.7	13.9
Jobs	**684 658**	**480 658**	**29 808**	**7 452**
Job index	**5.5**	**4.0**	**2.2**	**1.0**

The chemical option, if adopted, could sustain 30 000 rural jobs in the whole country. If herbicide option becomes dominant, manpower would decrease to 7 500 workers and a lot of people would migrate to cities. With ecological systems in the whole country there would be almost 685 000 jobs in family farms producing in multi-purpose agriculture. In case of organic enterprises the number of jobs could be 480 000.

The results were plotted to make evident some facts. Figure 2 shows that renewability results are favorable to biological systems. The renewability of a small ecological farm is almost twice the value of a conventional medium property and three times the value of a big herbicide/no tillage property. The medium organic property has also good results in both parameters but can use machinery instead of labor. The results for profitability per hectare also indicate better values for small and medium size biological systems. The market pays more (twice) for organic or ecological soybean destined for human consumption.

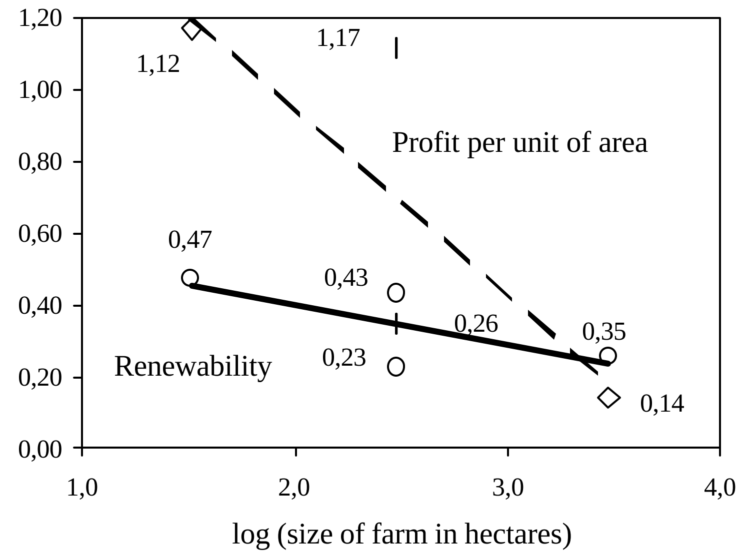

Figure 2. Renewability and Profitability x Size

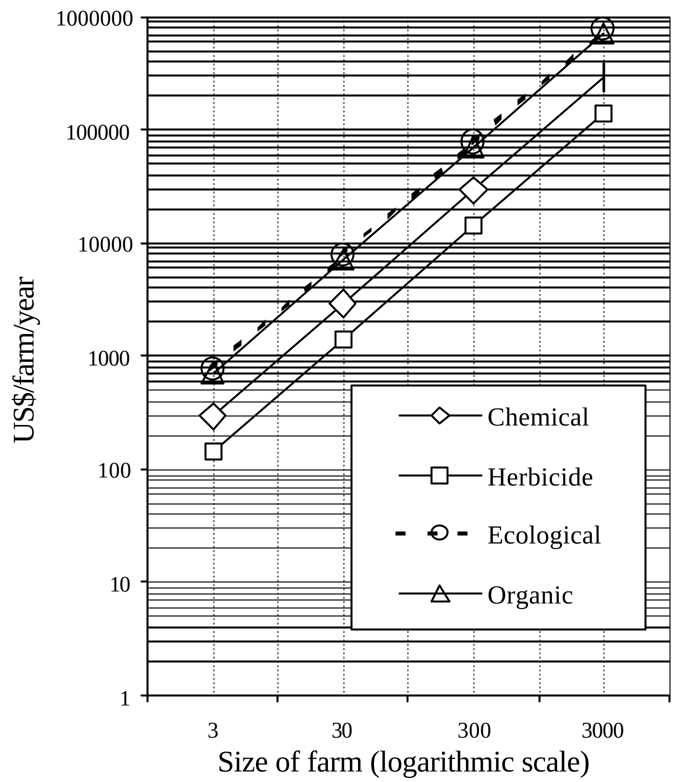

Figure 3. Farm Annual Net Income

Figure 3 makes clear that to make profits comparable to biological systems the chemical intensive options must be of greater scale. The scale factor overwhelms other parameters (efficiency, renewability) and is responsible for big incomes in some areas of Brazil.

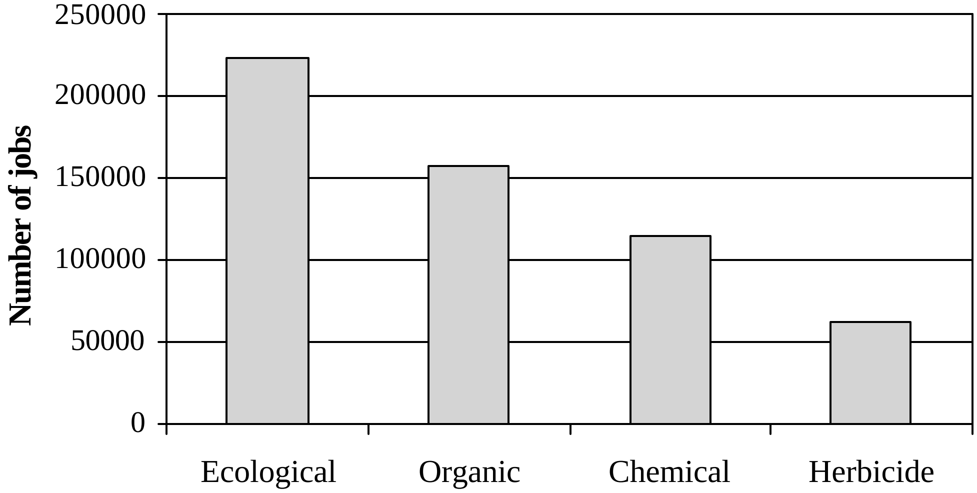

Figure 4. Jobs created by each soybean option at national level

Figure 4 reveals an astonishing trend; the labor in agriculture decreases in direct proportion to the use of industrial inputs. Generally, in areas where agricultural systems are energy-intensive a huge exodus takes place and serious urban problems are created, besides that property and wealth concentrates in less number of individuals.

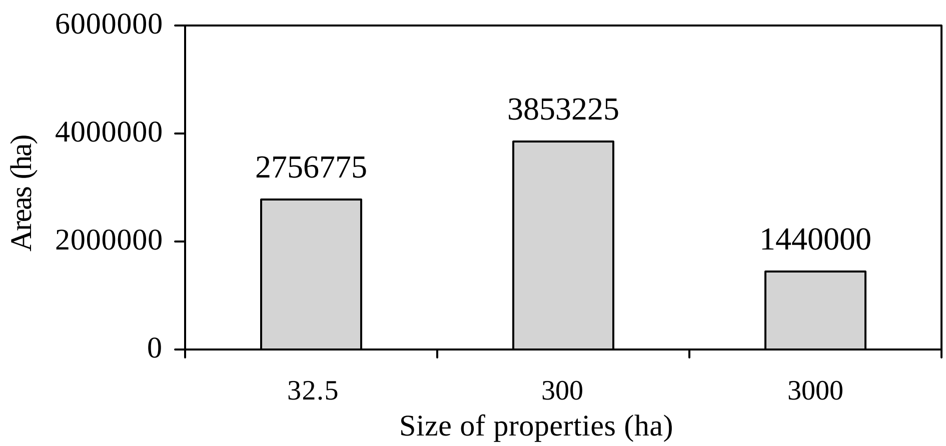

Figura 5. Hectares of soybean cultivted in RS, PR and MT.

Figure 5 shows the soybean area cultivated in Paraná, Rio Grande do Sul and Mato Grosso, responsible for the main part of national production (Man Yu, 1993; Farias, 1996; Roessing, 1996). The distribution of area according to the type of farm make evident that the small family farms are responsible for almost a third part of production.

CONCLUSIONS

The best option for Brazil is an agricultural system based on small family properties that use ecological-organic cultivation. It allows the farmer an acceptable life quality and a proper use of natural resources, moderate use of economy resources and recycling of many materials. According to recent studies (Veiga, 2002) the Brazilian counties with small ecological farms have the highest human development index (HDI) and can produce for internal and external markets with productivity equivalent to conventional chemical systems. Just as a remark, Altieri (1998) says that conventional systems show a decrease of productivity with time due to destruction of soil organic matter stocks and biological activity; this loss can be so intensive that the productivity becomes lower than that of ecological- organic production systems.

The suggested public policies are:

(a) Not allow use of the herbicide/direct planting option in soybean production due to its social, environmental and political negative impacts.
(b) Implement agrarian land ownership reform and agriculture restructuring programs with enough investments in public infrastructure to give support to organic family operated systems.
(c) Establish incentives to promote preservation of nature and recycling;
(d) Impose taxes on producers that damage the environment or destroy jobs to induce changes to organic or ecological farming, agrarian reform and natural area preservation enforcement.
(e) Establish certification of soybean producers to induce proper prices for each kind of production systems

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ANNEXED TABLES:

Table 8. Agronomical techniques:

	Ecological	Organic	Conventional	No tillage
Seedbed preparation	Plowing and harrowing	Plowing and harrowing	Plowing and harrowing	No seedbed preparation, use of herbicides to clear fields from weeds.
Application of fertilizers	Only those permitted for organic production	Only those permitted for organic production	Highly soluble chemical products	Highly soluble chemical products
Weeds control	Hand clearing	Mechanized and manual weeding.	Utilization of pre-seedling herbicides	Utilization of pre-seedling herbicides
Plague control (bugs)	Utilization of natural products (biological control) and chemical control on the borders of planted area.	Utilization of natural products (biological control), traps and chemical control on the borders of planted area	Utilization of insecticides	Utilization of insecticides
Harvest	Made with help of manual threshers	Mechanized	Mechanized	Mechanized

Additional explanations of agricultural processes used in soybean cultivation:

Plowing	Digging furrows in the soil, before seeds are planted
Harrowing	Breaking lumps of earth up
Border of planted area	Area not harvested for organic production; generally planted with shrubs to prevent from contamination by chemical products utilized in neighboring areas
Pre-seedling herbicides	Herbicides applied before seedling of crops and weeds
Post-seedling herbicides	Herbicides used after seedling of crops (transgenic) and weeds
Second weed cutting (manual)	Weeding done in order to clear furrows from weeds left by mechanized weeding
Thresher	Machine used to separate the grains from other parts of the plant (pod and stems)

Calculations

According to Brazilian law part of farm area must be destined to preserve nature with economic use (in Amazon: forested areas 80%; savannas 35%; in all other areas 20%). We multiply the inputs by a factor (put beside the value of flow) because each input affects in different proportion the area of farm. For emergy and monetary calculations the quantity considered is the product of input times area factor.

Table 9. Economic inputs and services; proportion factor according with area affected.

Note	Flows	Units	Ecol.		Org.		Chem.		Herb.	
Materials (Economy resources)										
M1	Farmer seeds	kg/ha/y	**10**	0.8	**10**	0.8	**0**	0.8	**0**	0.8
M2	Certified seeds	kg/ha/y	**70**	0.8	**70**	0.8	**70**	0.8	**85**	0.8
M3	Transgenic seeds	kg/ha/y	**0**	0.8	**0**	0.8	**0**	0.8	**0**	0.8
M4	Limestone	kg/ha/y	**0**	0.8	**0**	0.8	**1000**	0.8	**1000**	0.8
M5	Nitrogen fertilizer	kg/ha/y	**0**	0.8	**0**	0.8	**0**	0.8	**0**	0.8
M6	Phosphate fertilizer	kg/ha/y	**150**	0.8	**150**	0.8	**150**	0.8	**250**	0.8
M7	Potassium fertilizer	kg/ha/y	**50**	0.8	**50**	0.8	**150**	0.8	**100**	0.8
M8	Inoculating agent	kg/ha/y	**1**	0.8	**1**	0.8	**1.7**	0.8	**1.7**	0.8
M9	Herbicides	kg/ha/y	**0**	0.8	**0**	0.8	**4.3**	0.8	**8.3**	0.8
M10	Insecticides	kg/ha/y	**1**	0.8	**1**	0.8	**1.8**	0.8	**1.8**	0.8
M11	Formicides	kg/ha/y	**0**	0.8	**0**	0.8	**1**	0.8	**1**	0.8
M12	Fungicides	kg/ha/y	**0**	0.8	**0**	0.8	**0.2**	0.8	**0.2**	0.8
M13	Petroleum fuels	kg/ha/y	**30**	0.8	**40**	0.8	**80**	0.8	**40**	0.8
M14	Steel (depreciation)	kg/ha/y	**1.3**	0.8	**2.7**	0.8	**2.7**	0.8	**2.7**	0.8
M15	Manure (20% humidity)	kg/ha/y	**2667**	0.8	**2667**	0.8	**0**	0.8	**0**	0.8
Services (Economy resources)										
S1	Hard worker manpower	hours/ha/y	**145**	0.8	**100**	0.8	**3.2**	0.8	**0.5**	0.8
S2	Operator manpower	hours/ha/y	**2**	0.8	**3.2**	0.8	**71.9**	0.8	**40**	0.8
S3	Administrative labor	US$/ha/y	**4.3**	0.8	**4.3**	0.8	**4.3**	0.8	**4.3**	0.8
S4	Technical assistance	US$/ha/y	**10**	0.8	**10**	0.8	**2**	0.8	**2.9**	0.8
S5	Accounting labor	US$/ha/y	**0.8**	0.8	**0.8**	0.8	**0.8**	0.8	**0.8**	0.8
S6	Trips costs	US$/ha/y	**0.4**	0.8	**0.4**	0.8	**0.4**	0.8	**0.4**	0.8
S7	Governmental taxes	US$/ha/y	**9.5**	0.8	**9.5**	0.8	**13.6**	0.8	**13.6**	0.8
S8	Circulating capital costs	US$/ha/y	**2.95**	0.8	**2.95**	0.8	**2.95**	0.8	**2.95**	0.8
S9	Insurance costs	US$/ha/y	**1**	0.8	**1**	0.8	**0.59**	0.8	**1.0**	0.8
S10	Transport to storage cost	US$/ha/y	**6.8**	0.8	**6.8**	0.8	**6.8**	0.8	**6.8**	0.8
S11	Drying & storage cost	US$/ha/y	**14.31**	0.8	**14.31**	0.8	**14.31**	0.8	**14.31**	0.8
S12	Social security taxes	US$/ha/y	**12.8**	0.8	**12.8**	0.8	**13.6**	0.8	**13.6**	0.8
S13	Land leasing	US$/ha/y	**0**	0.8	**0**	0.8	**0**	0.8	**0**	0.8

Sources:
Chemical and Herbicide options: FNP, 1999. Organic: Agrorgânica, 2000 and FNP, 1999.
* Value estimated by authors (weight of tractors and area of use).

Services (Econ. resources)			Ecol.		Org.		Chem.		Herb.	
S20	Government subsidy	US$/ha/y	0	0.8	**0**	0.8	**0**	0.8	**0**	0.8
S21	Effluent treatment	US$/ha/y	**0**	0.8	**0**	0.8	**20**	0.8	**10**	0.8
S22	Risk & health treatment	US$/ha/y	**10**	0.8	**10**	0.8	**20**	0.8	**50**	0.8

Source: value of externality estimated by authors (to be confirmed in future studies).

Table 10. Environmental inputs, services and output, proportion factor according with area affected.

Note	Flows	Units	Ecol.		Org.		Chem.		Herb.	
Renewable Natural Resources										
R1	Rain	10^6 kg/ha/y	**1.5**	1.0	**1.5**	1.0	**1.5**	1.0	**1.5**	1.0
R2	Nutrients from rocks	kg/ha/y	**10**	1.0	**10**	1.0	**1**	1.0	**3**	1.0
R3	Nitrogen (atmosphere)	kg/ha/y	**181**	0.8	**181**	0.8	**181**	0.8	**181**	0.8
R4	Sediments (rivers)	kg/ha/y	**0.5**	0.2	**0.5**	0.2	**0.5**	0.2	**0.5**	0.2
R5a	Forest products: seeds	kg/ha/y	**10**	0.2	**5**	0.2	**0**	0.2	**0**	0.2
R5b	Forest products: food	kg/ha/y	**100**	0.2	**50**	0.2	**0**	0.2	**0**	0.2
R5c	Forest products: biomass	kg/ha/y	**2000**	0.2	**1000**	0.2	**0**	0.2	**0**	0.2
R6a	Forest services: water	kg/ha/y	**12**	1.0	**6**	1.0	**0**	1.0	**0**	1.0
R6b	Forest services: leisure	US$/ha/y	**3.3**	1.0	**1.65**	1.0	**0**	1.0	**0**	1.0
R6c	Forest biological control	US$/ha/y	**50**	1.0	**25**	1.0	**0**	0.8	**0**	0.8

Sources:
R1: IBGE, 2001.
R2: value estimated by authors based on Buckmann (1983) and IPT (1986).
R3: value estimated by authors based on Dobereiner (1999).
R4: general value estimated by authors.
R5a: value estimated by authors based on Silva (1997) and Ahrens (1997).
R5b, R5c: values estimated by authors.
R6a, R6b: values estimated by authors.
R6c: value estimated by authors based on annual cost of pesticides per hectare of other options.

The farmers that adopted chemical and herbicide options generally do not obey legislation that demand to preserve 20% of area as forest. Organic producers need the benefits of forest and usually preserve it .

Note	Flows	Units	Ecol.		Org.		Chem.		Herb.	
Non Renewable Natural Resources										
N1	Soil loss	kg/ha/y	**1000**	0.8	**1000**	0.8	**12500**	0.8	**1500**	0.8
N2	Biodiversity loss	kg/ha/y	**0**	0.8	**0**	0.8	**100**	0.8	**19**	0.8

Sources:
N1: Correia, L. http://www.cnps.embrapa.br/search/planets/coluna14/coluna14.html (23/10/2001).
N2: value estimated by authors.

Production data		**Units**	**Ecologic**	**Organic**	**Chemical**	**Herbicide**
P1	**Soybean production**	**kg/ha/y**	**1920**	**1920**	**2240**	**2240**
P2	**Price**	**US$/kg**	**0.250**	**0.235**	**0.170**	**0.170**
P3	**Sales**	**US$/ha/y**	**480**	**451.2**	**380.8**	**380.8**
P4	Humidity (water/soybean)	kg/kg	0.18	0.18	0.18	0.18
P5	Conversion factor	kcal/kg	4428	4428	4428	4428
P6	Conversion factor	J/kcal	4186	4186	4186	4186
P7	Energy of Product	J/ha/y	2.9E+10	2.9E+10	3.4E+10	3.4E+10
P8	Emergy of Sales	sej/ha/y	1.78E+15	1.7E+15	1.4E+15	1.4E+15

Sources: Chemical and Herbicide options: FNP, 1999. Organic: Agrorgânica, 2000 and FNP, 1999.

Table 11. Table of emergy flows expressed in 10^{13} sej/ha/y

Note	Flows	Units	sej/ unit	R.	Ecologic	Organic	Chemical	Herbicide
Renewable Resources					**117.7**	**99.8**	**80.4**	**80.8**
R1	Rain	kg/ha/y	9.10E+07	1	13.7	13.7	13.7	13.7
R2	Nutrients from rocks	kg/ha/y	1.71E+12	1	1.7	1.7	0.2	0.5
R3	Nitrogen (atmosphere)	kg/ha/y	4.60E+12	1	66.6	66.6	66.6	66.6
R4	Sediments (rivers)	kg/ha/y	1.71E+12	1	0.02	0.02	0.02	0.02
R5a	Forest products: seeds	kg/ha/y	1.48E+12	1	0.3	0.1	0	0
R5b	Forest products: food	kg/ha/y	4.50E+11	1	0.9	0.5	0	0
R5c	Forest products: biomass	kg/ha/y	3.69E+11	1	14.8	7.4	0	0
R6a	Forest services: water	kg/ha/y	5.50E+08	1	0.001	0	0	0
R6b	Forest services: leisure	US$/ha/y	3.70E+12	4	1.2	0.6	0	0
R6c	Forest biological control	US$/ha/y	3.70E+12	4	18.5	9.3	0	0
Non Renewable Resources					**5.3**	**5.3**	**69.8**	**8.6**
N1	Soil loss	kg/ha/y	6.67E+10	1	5.3	5.3	66.7	8.0
N2	Biodiversity loss	kg/ha/y	3.90E+11	1	0	0	3.1	0.6
Total Natural Resources					**123.0**	**105.2**	**150.3**	**89.4**
Materials (Econ. resources)					**99.5**	**102.5**	**177.7**	**201.6**
M1	Certified seeds	kg/ha/y	1.00E+12	1	0.8	0.8	0	0
M2	Certified seeds	kg/ha/y	1.00E+12	1	5.6	5.6	5.6	7
M3	Transgenic seeds	kg/ha/y	1.00E+13	2	0	0	0	0.0
M4	Limestone	kg/ha/y	1.00E+12	1	0	0	80.0	80.0
M5	Nitrogen fertilizer	kg/ha/y	3.80E+12	1	0	0	0	0.0
M6	Phosphate fertilizer	kg/ha/y	3.90E+12	1	46.8	46.8	46.8	78.0
M7	Potassium fertilizer	kg/ha/y	1.10E+12	1	4.4	4.4	13.2	8.8
M8	Inoculating agent	kg/ha/y	3.18E+13	1	2.5	2.5	4.3	4.3
M9	Herbicides	kg/ha/y	1.48E+13	3	0	0	5.1	9.8
M10	Insecticides	kg/ha/y	1.48E+13	3	1.2	1.2	2.1	2.1
M11	Formicides	kg/ha/y	1.48E+13	3	0	0	1.2	1.2
M12	Fungicides	kg/ha/y	1.48E+13	3	0	0	0.2	0.2
M13	Petroleum fuels	kg/ha/y	2.76E+12	1	6.6	8.8	17.7	8.8
M14	Steel (depreciation) *	kg/ha/y	6.70E+12	1	0.7	1.4	1.4	1.4
M15	Manure (20% humid)	kg/ha/y	1.45E+11	2	30.9	30.9	0	0
Services (Econ. resources)					**26.2**	**24.1**	**28.6**	**24.0**
S1	Hard worker manpower	hour/ha/y	6.28E+11	1	7.3	5.0	0.2	0
S2	Manpower (operator)	hour/ha/y	1.88E+12	1	0.3	0.5	10.8	6.0
S3	Administrative labor	US$/ha/y	3.70E+12	4	1.3	1.3	1.3	1.3
S4	Technical assistance	US$/ha/y	3.70E+12	4	3.0	3.0	0.6	0.9
S5	Accounting labor	US$/ha/y	3.70E+12	4	0.2	0.2	0.2	0.2
S6	Trips costs	US$/ha/y	3.70E+12	4	0.1	0.1	0.1	0.1
S7	Governmental taxes	US$/ha/y	3.70E+12	4	2.8	2.8	4.0	4.0
S8	Circulating capital costs	US$/ha/y	3.70E+12	4	0.9	0.9	0.9	0.9
S9	Insurance costs	US$/ha/y	3.70E+12	4	0.3	0.3	0.2	0.3
S10	Transport to storage cost	US$/ha/y	3.70E+12	4	2.0	2.0	2.0	2.0
S11	Drying & storage cost	US$/ha/y	3.70E+12	4	4.2	4.2	4.2	4.2
S12	Social security taxes	US$/ha/y	3.70E+12	4	3.8	3.8	4.0	4.0
S13	Land leasing	US$/ha/y	3.70E+12	4	0	0	0	0

Externalities (services)					**3.0**	**3.0**	**11.8**	**17.8**
S20	Government subsidy	US$/ha/y	3.70E+12	4	0	0	0	0
S21	Effluent treatment	US$/ha/y	3.70E+12	4	0.0	0.0	5.9	3.0
S22	Risk & health treatment	US$/ha/y	3.70E+12	4	3.0	3.0	5.9	14.8
Economy Feedback					**125.7**	**126.6**	**206.3**	**225.6**
Total Economy Feedback					**128.7**	**129.6**	**218.1**	**243.4**
Total Emergy					**251.7**	**234.7**	**368.4**	**332.8**

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Table 12. Table of monetary flows in US$/ha/year

Note	Flows	Units	US$/unit	Ecologic	Organic	Chemical	Herbicide
M1	Farmer seeds	kg/ha/y	0	0.00	0.00	0.00	0.00
M2	Certified seeds	kg/ha/y	0.29	16.24	16.24	16.24	19.72
M3	Transgenic seeds	kg/ha/y	0.34	0.00	0.00	0.00	0.00
M4	Limestone	kg/ha/y	0.02	0.00	0.00	16.00	16.00
M5	Nitrogen fertilizer	kg/ha/y	0.18	0.00	0.00	0.00	0.00
M6	Phosphate fertilizer	kg/ha/y	0.40	48.00	48.00	48.00	80.00
M7	Potash fertilizer	kg/ha/y	0.18	7.20	7.20	21.60	14.40
M8	Inoculating agent	kg/ha/y	0.46	0.37	0.37	0.63	0.63
M9	Herbicides	kg/ha/y	15.00	0.00	0.00	51.60	99.60
M10	Insecticides	kg/ha/y	10.33	8.26	8.26	14.88	14.88
M11	Formicides	kg/ha/y	8.44	0.00	0.00	6.75	6.75
M12	Fungicides	kg/ha/y	11.59	0.00	0.00	1.85	1.85
M13	Petroleum fuels	kg/ha/y	0.35	8.40	11.20	22.40	11.20
M14	Steel (depreciation) *	kg/ha/y	0.45	0.47	0.97	0.97	0.97
M15	Manure (20% humidity)	kg/ha/y	0.02	42.67	42.67	0.00	0.00
	Material Inputs			**131.61**	**134.92**	**200.92**	**266.00**
S1	Hard worker manpower	hour/ha/y	0.33	38.28	26.40	0.84	0.13
S2	Manpower (operator)	hour/ha/y	0.58	0.93	1.48	33.35	18.56
S3	Administrative labor	US$/ha/y	1.00	3.44	3.44	3.44	3.44
S4	Technical assistance	US$/ha/y	1.00	8.00	8.00	1.60	2.32
S5	Accounting labor	US$/ha/y	1.00	0.64	0.64	0.64	0.64
S6	Trips costs	US$/ha/y	1.00	0.32	0.32	0.32	0.32
S7	Governmental taxes	US$/ha/y	1.00	7.60	7.60	10.88	10.88
S8	Circulating capital costs	US$/ha/y	1.00	2.36	2.36	2.36	2.36
S9	Insurance costs	US$/ha/y	1.00	0.80	0.80	0.47	0.80
S10	Transport to storage cost	US$/ha/y	1.00	5.44	5.44	5.44	5.44
S11	Drying & storage cost	US$/ha/y	1.00	11.45	11.45	11.45	11.45
S12	Social security taxes	US$/ha/y	1.00	10.24	10.24	10.88	10.88
S13	Land leasing	US$/ha/y	1.00	0.00	0.00	0.00	0.00
	Services			**89.50**	**78.17**	**81.68**	**67.22**
	Economic cost			**221.11**	**213.09**	**282.60**	**333.22**