PRODUCTION OF ETHANOL IN MICRO AND MINI-DISTILLERIES.

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Summary

A careful and complete evaluation able to value environmental inputs, losses of local environmental services and negative externalidades of ethanol production projects can reveal a very different reality that is not shown at media. It is possible to discover that scale economy disappears and to notice that ecological agricultural systems integrated with small distilleries of alcohol can have a great environmental and economical performance. In order to arrive to that conclusion it is necessary an ecosystemic approach and also to include social parameters. Beyond that, the choice of the modality of alcohol production demands an analysis of the global conjuncture, both political and biophysical, because the sustainable development depends as much on local potentialities as on regional or international political arrangements and at this crucial times also on climatic and social global issues.

1. INTRODUCTION:

The production of ethanol as fuel can be made of several manners. Lamentably, until now, the choice of technological option happens in function of the economical and political interests only, not considering environmental and social objectives of land use.

In the decade of 70's, at the time of implantation of Pró-alcohol in Brazil the big plants option (120 000 liters/day or more) was chose even other possibilities exist at that time [Bueno, 1980]. As result, a great destruction of natural and human resources (rural exodus, native forests and diversified farm land occupied by sugar cane plantations) happened in three decades. The preference for great scale resulted in a harmful monoculture (land ownership concentration), pollution, loss of soil fertility, loss of interaction within livestock and agriculture and biodiversity loss [Paschoal, 1983; San Martin, 1985]. Today we know that the choice also affected the quality of global atmosphere (due to CO_2 emissions by direct and indirect use of fossil fuels).

In the present decade the situation lived in the 70's is repeated, however affecting still larger rural areas, because the investments choice is made taking into account only the economical aspects of benefit/cost ratio that neglect negative externalities, the loss of environmental services and the scientific evidence of the aggravation of environmental and social problems. The critical reflections of social movements on the unfair economic model an also the implications of chemical agriculture on climatic of changes are not considered.

Neither planners nor the investors consider the loss of environmental services and also the additional costs that are transferred to local communities. The order of magnitude of lost environmental services and negative externalidades value is around 300 to 500 dollars/ha/year. It is a hidden subsidy to the great land owners that also explains the so called "scale economy".

Hypothesis:

> If those values were counted in the alcohol enterprises, it would be possible to discover that economic profit disappears and to notice that ecological agriculture systems integrated with micro-distilleries can be economically viable in facilities of small (100, 1000 liters/day) and medium size (5000, 20000 l/d), that in this study we will denominate "micro" and "mini-distillery", respectively.

2. JUSTIFICATIVE AND ANTECEDENTS

Humanity is able to self-organize in order to use available exergy resources. The exergy resources can be of two kinds: stocks and renewable flows. Usually, after a time of adaptation based on renewable resources the human societies try to use all the available stocks and, after that, they fit again to use renewable flows. Growth occurs during adaptation to use of limited flows and limited stocks. Decay and adjustment occurs when stocks decrease, it is as natural as growth. The symptoms of a global decline of energy resources and biodiversity are evident, as well as an increase of pollution, social and climate problems. Humanity should change its trends and adapt again to use renewable energy sources, in that process biomass and biodiversity will fit a fundamental role. Renewable resources are less intensive than oil and they will not be able to substitute petroleum, but they may support a society with lower consumption demands [Odum and Odum, 1976; 2001]. Biomass fuels are of several types (solids, gaseous and liquids); ethyl alcohol is a liquid easy to transport and not poisonous therefore it is a good substitute to gasoline.

Brazil was always deficient in petroleum and today it has a temporary surplus. The country is still susceptible to offer variations. According to forecasts, the reserves will be exhausted in three decades and price will keep growing up to the levels reached during the crises of 1972 and 1983 or even larger. The use of biomass fuels can constitute a planned alternative to collaborate in the solution of "greenhouse effect" [Cerqueira Leite, 1988, 2006] and new economic model [Vasconcelos and Vidal, 2002]. In all the countries, it is necessary the elaboration of plans to obtain self-sufficiency in energy, considering the short, medium and long range. However, to be really viable for the long run, the planning should consider the ecological and social aspects of energy supply [Wiesner, 1984; Minc, 1987; Ortega, 1987; Bacic, *et al*. 1988].

The study of the production of alcohol in small scale was topic of scientific interest for several researchers of many Brazilian research institutions (ESALQ; USP/São Carlos, IAA, Embrapa) and also of private enterprises. Many small autonomous distilleries were installed in several places of the State of São Paulo [Folha de São Paulo, 1985]. Special prominences deserve some more integrated projects or ideas, as that of Jundiaí [Solnik, 1984] and São Carlos [Corsini, 1981]. A new concept of alcohol production as an integrated system with production of food, forage for bovine cattle, biogás, biofertilizers, with utilization of residues as vinasse and spare pulp in other industrial activities that could increase the profitability of the enterprise [La Rovere and Tolmasquim, 1984].

After the oil embargo crisis the price felt down and those micro-distilleries were disassembled, because they could not compete with a fuel of high quality with a price maintained low to subsidize the global industry. But as petroleum shows to be a finite resource that causes a great impact on nature, society and atmosphere, research on integrated mini-systems is now retaken in many countries.

3. TECHNOLOGY:

When an ethanol distillery is planned it is determined the future of a region, we could think about a relationship between production scale and social organization. See Table 1.

Scales from 4000 up to 40 000 hectares allow to produce concentrated alcohol (99%) and efficient electricity production with high pressure steam. Scales from 4 up to 400 hectares present limitations in relation with production of absolute ethanol, nowadays they allow to produce alcohol of 94% without co-generation of electricity, but part of ethanol can be used to produce electric power if needed.

Table 1. Scales and social-political models.

Modality of organization social meeting	Farming area (ha). Tons of cane per day (TCD)	Liters of ethanol/day MegaWatts of electricity / year
Highly concentrating model	40 000 ha 5000 TC	5 000 000 l / day ~730 000 MW / year
Capitalism or socialism with environmental adjustments	4 000 ha 500 TC	500 000 l / day 73 000 MW / year
Big rural establishments	400 ha 50 TC	50 000 l / day -
Medium rural establishments	40 ha. 5 TC	5 000 l / day -
Small rural establishments	4 ha be. 0,.5 TC	5 00 l / day -

Table 2. Scales and technological models.

Organization modality	**Farming**	**Other characteristics**
Highly concentrating model	Extensive monoculture and chemical agriculture.	Plain land, mechanization.
Environmentally adjusted model	Organic monoculture and cattle production	Plain land, mechanization.
Small, medium or big farms (community model)	Mixed crops ecological farming	High declivity land, without mechanization.

If all the social and environmental benefits and costs were included in calculations of the profitability of rural enterprises, the higher profitability will favor the systems with ecological best social characteristics.

Until now, the inclusion of these additional benefits and costs has not been made, probably by lack of knowledge of the real values of environmental services and negative externalities. The study and diffusion of these values may allow society to self-organize to support the truly economical systems.

Table 3. Estimate the value of the sober benefits and partner-environmental costs.

Measured of Effect	Ecological model US$/ha/year	Chemical model US$/ha/year
Maintenance of rural jobs, one in 10 ha (one minimum wage) against one in 300 ha (two minimum wages) [14].	180,00	12,00
Social problems in cities periphery: infrastructure and services for migrants, drugs traffic, criminality, etc. [00].	0	-30,00
Soil formation [17].	0	-13,60
Accumulation of sand in rivers [20].	0	-83,00
Maintenance of the covering and of the vegetable biodiversity [17].	0	-4,00
Generation of climatic of changes: carbon dioxide, nitrous of oxide methane [03][17].	-10	-60,00
Percolation of water in preserved forest and water biological filtration in swamps Rivers water quality preservation [01].	180,00	22,50
Water pollution problems [17].	0	-39,70
Rural life quality and landscape esthetics preservation [20].	3,7	0
Ecosystem destruction (forest, savannah): soil and biodiversity replacement costs [14].	0	-98,38
Health problems provoked by pesticides [17].	0	-0,20
Total	353,70	-303,38
Difference	657,00	

Table 3b. Estimative of the value of social, military and ideological forces.

Preservation of the national sovereignty	?	0
Destruction of national social structure [15]	0	300,00
Toatl difference	957,00	

Table 4. Estimative of social-environmental services and externalities for each model.

Social organization modality	Environmental services (US$/ha/year)	Negatives Externalities (US$/ha/year)	Balance (US$/ha/year)
Highly concentrator model	+25	-360	**-335**
Capitalism or socialism with environmental adjustments	+50	-180	**-130**
Small rural establishments	+100	-50	**+50**
Big rural establishments	+200	-10	**+190**

A network of small integrated ecological distilleries could generate a profitable self-sufficiency energy program, if there were training of rural labor, self-sufficiency of foods and support for the better use of natural resources, rational use of techniques (agricultural, forestry, livestock husbandry), the decrease of pollution in rural areas, etc. In this case, technology can be applied with technical viability, social commitment, economical profitability and ecological sustentation [Sachs, 1988].

At the end of the 80's, several universities, research centers and entrepreneurs developed efforts to study, build and operate micro-distilleries. Due to the international petroleum crisis in 1979, a group of researchers considered the possibility of autonomous of small size distilleries that would use sugarcane and saccharine sorghum with a production capacity of 1000 to 40000 liters of ethyl alcohol of 94ºGL per day. Today, thanks to the continuity of that effort on the part of several private entrepreneurs, alcohol micro-distilleries can be considered technique and economically feasible; but however not unviable from a political point of view because this option is ignored by social forces. In Figure 1 it is shown a diagram of an ideal system for integrated production of food and energy.

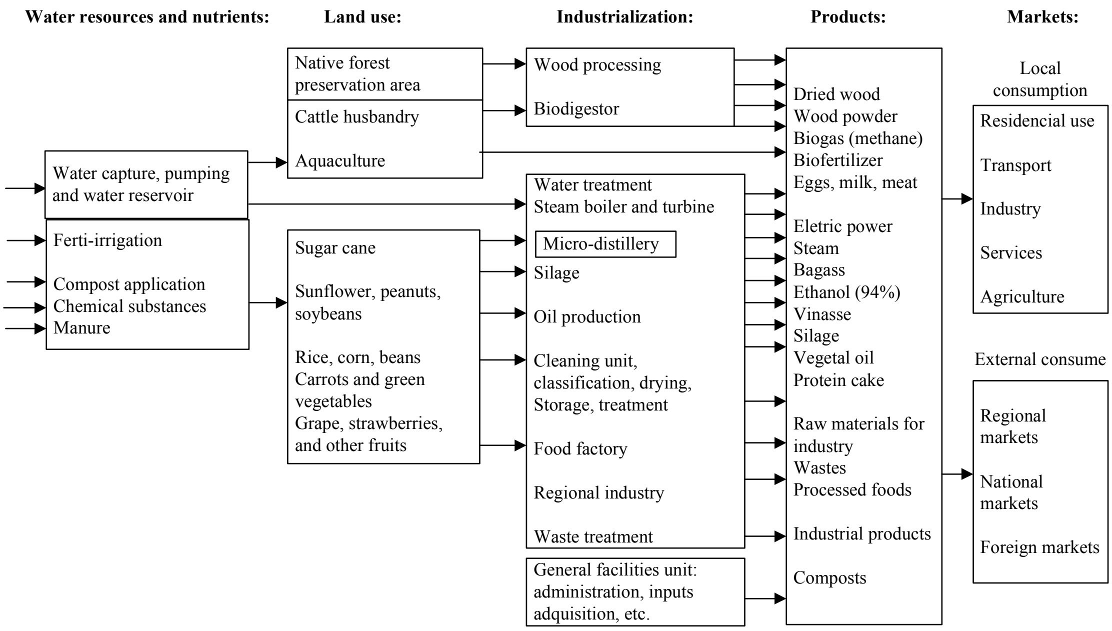

Figure 1. Integrated system for production of food and energy (SIPAE)

4. CASE STUDY

The farm "Fazenda Jardim" of Marcello Mello, in Mateus Leme, Minas Gerais, has a micro-distillery developed by his proprietor (Marcello Mello) working since 2002. The farm has 300 ha; however the alcohol micro-distillery system occupies only 20 ha. From those 20 ha, sugarcane occupies only 3 ha, a native forest area 10 ha, a diversified plantation (banana, eucalypt and orchard) occupy 1 ha and grazing land for cattle 6 ha. It maintains an ecological occupation of the geographical space that contributes for a good value of sustainability, for the preservation of quality of atmosphere and existence of water springs. Figure 2 and the following pictures show details of the alcohol micro-distillery.

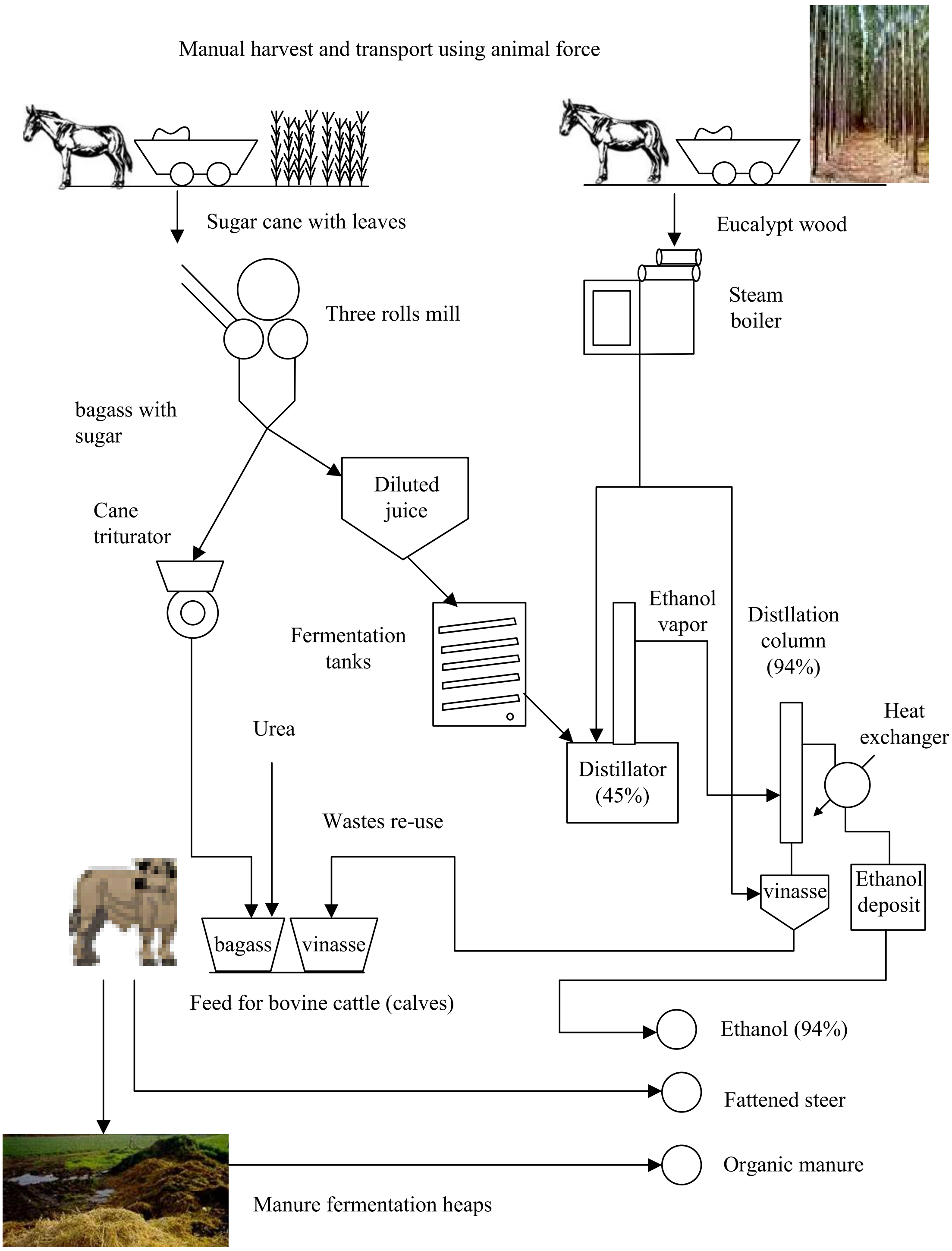

Figure 2. Flowchart of an alcohol micro-distillery as part of an Integrated System of Production of Food and Energy (SIPEA).


Fig. 2a. Farm landscape.


Fig. 2b. Micro-distillery and facilities.


Figure 2c. Extraction equipment.


Fig. 2d. Three rolls mill.


Figure 2e. Dilution tank


Figure 2f. Batch fermentation tanks.


Figure 2g. Firewood furnace.


Figure 2h. Distillation column

5. EMERGY ANALYSIS OF "FAZENDA JARDIM" ECO-UNIT:

It is used the emergy methodology according H.T. Odum (1996).

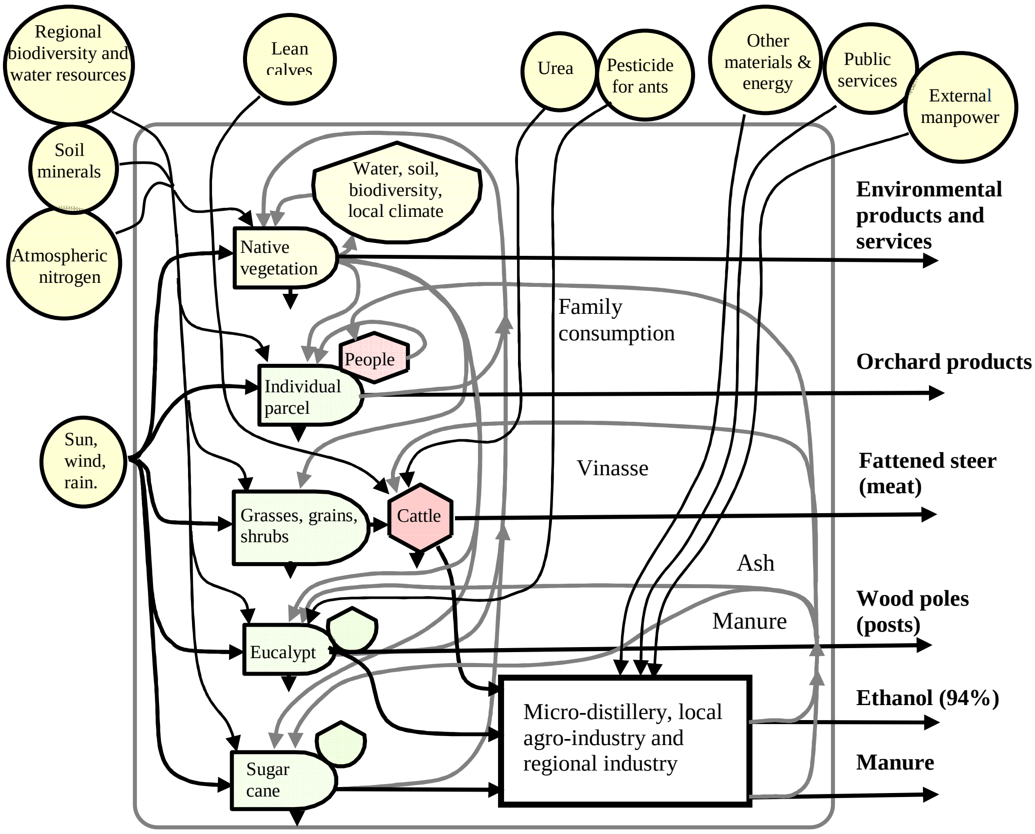

Figure 3. System diagram of Fazenda Jardim integrated micro-distillery (20 ha).

The system shown in Figure 3 has many subsystems that will be detailed in next figures, showing the input-output data necessary for the calculation of emergy flows.

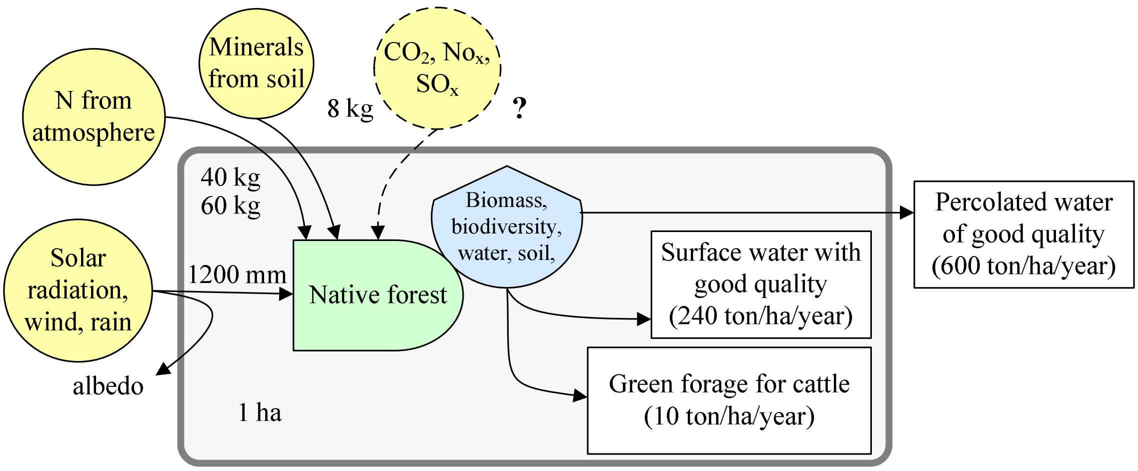

Figure 4. Diagram of native forest subsystem.

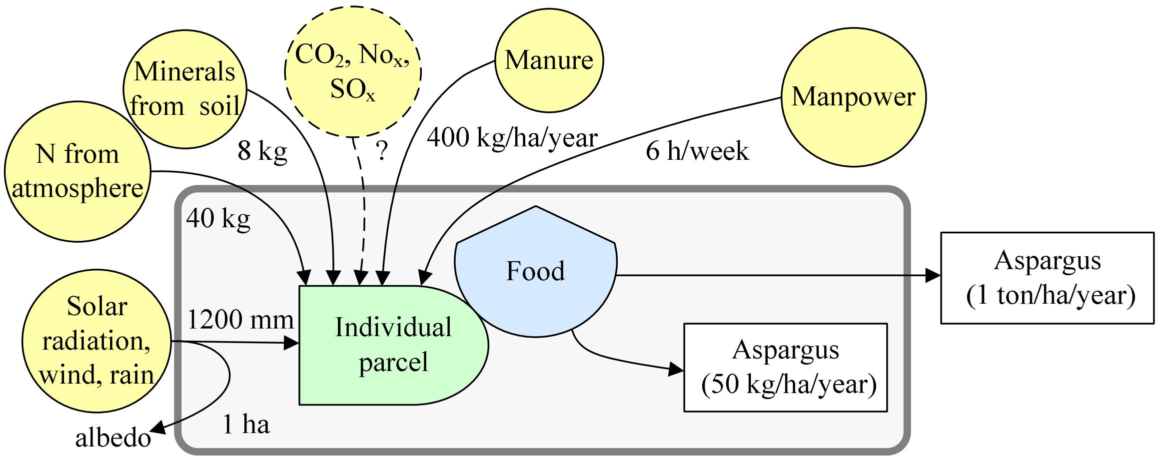

Figure 5. Diagram of orchard subsystem.

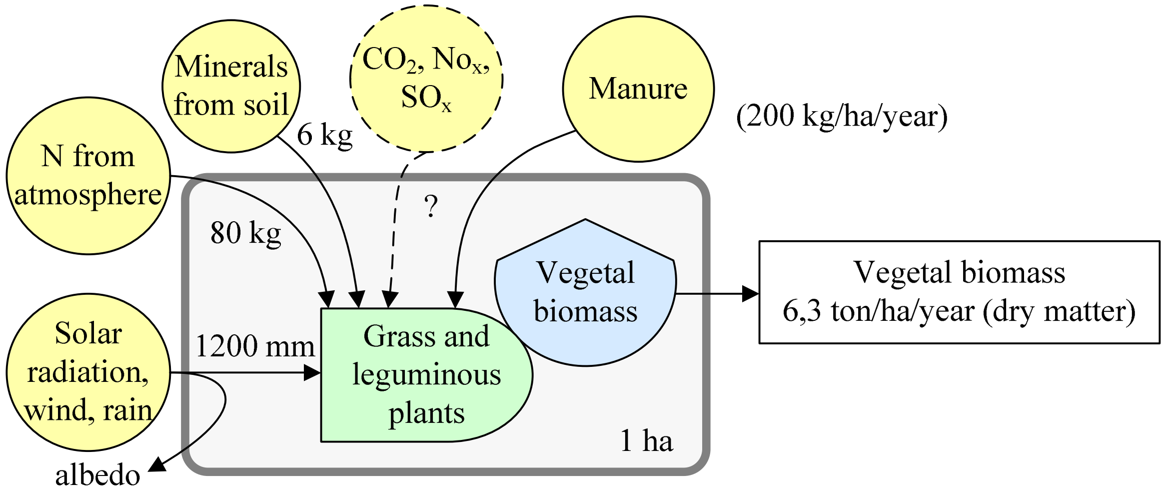

Figure 6. Diagram of grassing subsystem.

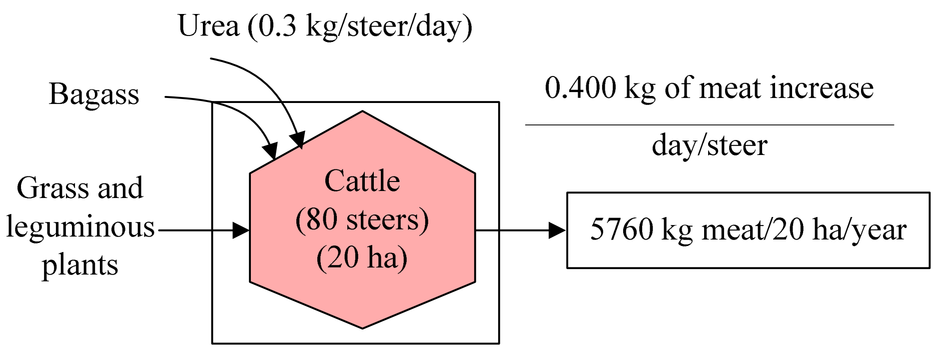

Figure 7. Diagram of calve-fattening subsystem.

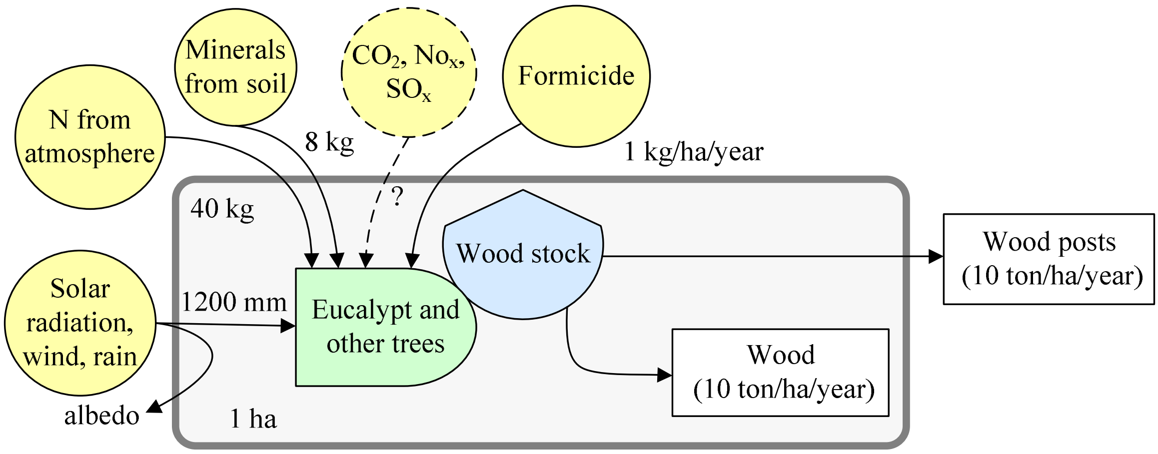

Figure 8. Diagram of eucalypt subsystem.

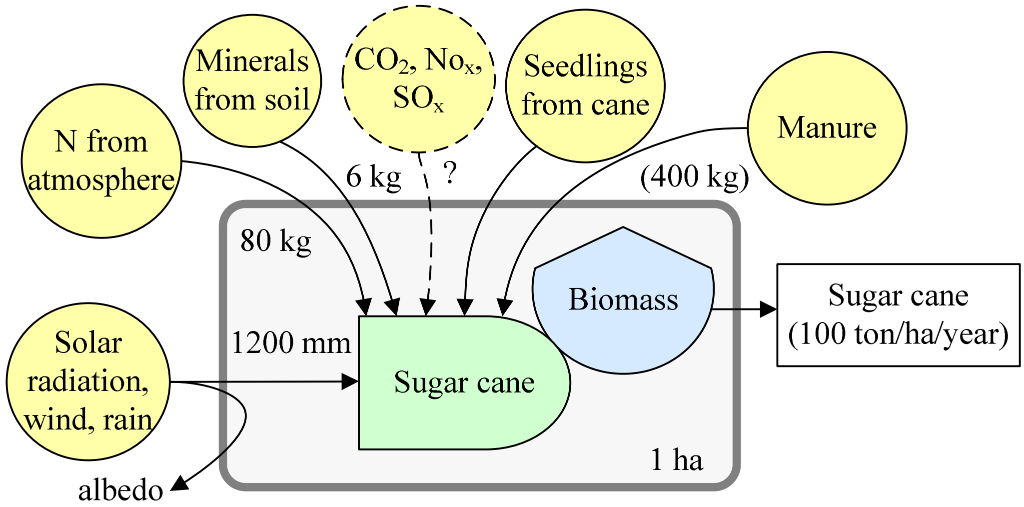

Figure 9. Diagram of sugar cane subsystem.

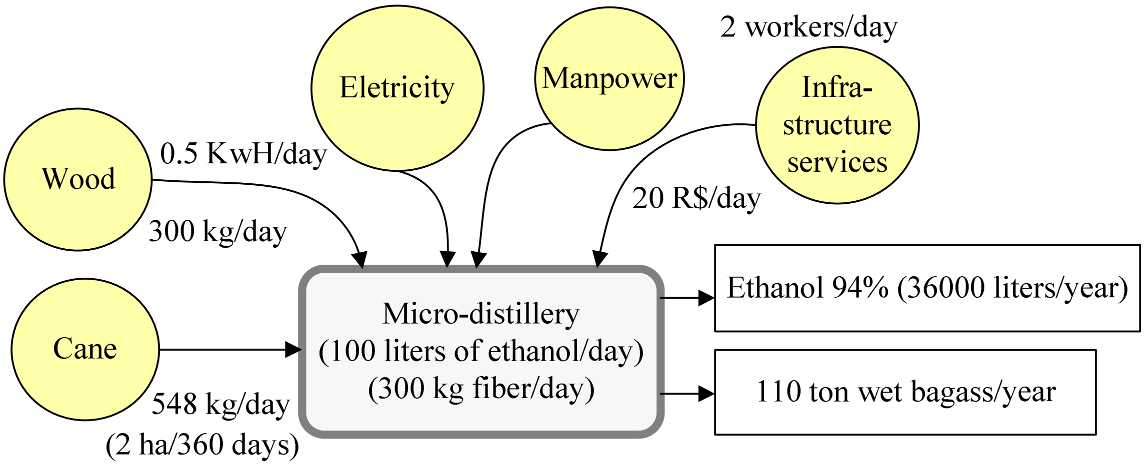

Figure 10. Diagram of micro-distillery subsystem.

As it can be observed in the subsystems diagrams there is a great capture of nature resources that are renewable and free, but it is needed some expertise to obtain them, that situation allows to obtain good energy performance indices.

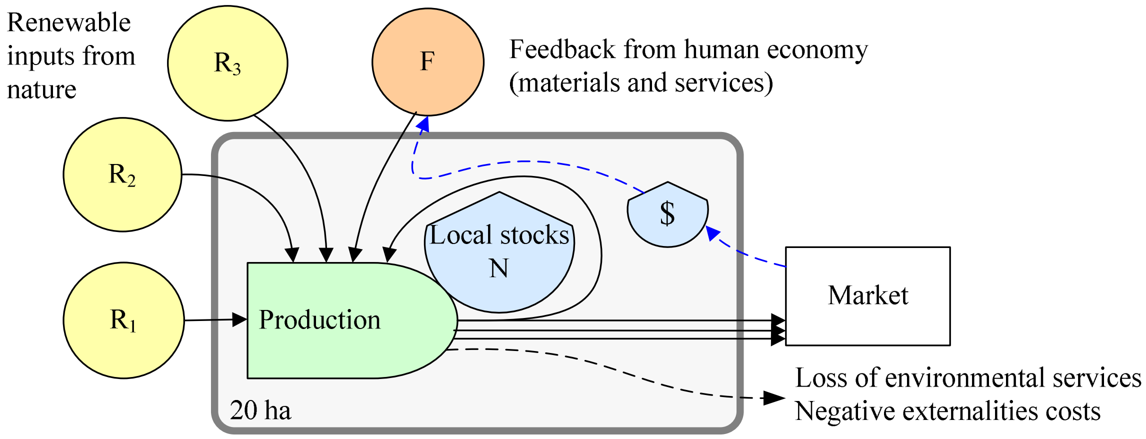

Figure 11. System's resumed diagram.

Table 5. Emergy flows calculation, considering farm mean values (per ha, per year).

Item	Renew. %.	Flow	Units	seJ/unit	Ref	Ren. emergy (seJ)	Non renew. emergy (seJ)	Total emergy (seJ)	%
Renewable									
Sun	1	5,20E+09	J	1,00E+00	1	5,20E+09	0,00E+00	5,20E+09	0,0
Rain	1	6,00E+10	J	3,06E+04	2	1,84E+15	0,00E+00	1,84E+15	18,6
Nitrogen (atm.)	1	8,60E+01	kg	4,05E+13	4	3,48E+15	0,00E+00	3,48E+15	35,2
Minerals from soil	1	8,80E+00	kg	8,72E+11	4	7,67E+12	0,00E+00	7,67E+12	0,1
Non Renewable									
Top soil loss	0	9,04E+08	J	1,24E+05	2	0,00E+00	1,12E+14	1,12E+14	1,1
Materials									
Formicide	0	5,00E-02	kg	2,48E+13	2	0,00E+00	1,24E+12	1,24E+12	0,0
Electricity	0,5	3,20E+07	J	3,36E+05	2	5,38E+12	5,38E+12	1,08E+13	0,1
Urea	0	4,38E+02	kg	3,12E+12	3	0,00E+00	1,37E+15	1,37E+15	13,8
Investment	0,3	3,65E+02	US$	3,70E+12	5.	4,05E+14	9,45E+14	1,35E+15	13,7
Services									
Manpower	0,5	4,64E+02	US$	3,70E+12	5	8,58E+14	8,58E+14	1,72E+15	17,4
Total Emergy						6,59E+15	3,29E+15	9,88E+15	100

Sources: 1. Definition; 2. Ulgiati & Brown, 2004; 3. Odum, 1996; 4. Brandt-Williams, 2002; 5. Coelho et al., 2003.

Products		
Ethyl alcohol	2,59E+10	J
Meat	4,39E+09	J
Wood (for sale)	7,10E+09	J
Asparagus	4,60E+08	J
Total energy	3,79E+10	J

Table 6. Aggregated emergy flows

Flow	Value (seJ ha^{-1} ano^{-1})
Renewable (R)	6,59E+15
Non renewable (N)	1,12E+14
Nature resources (I)	6,71E+15
Materials (M)	2,32E+15
Services (S)	8,58E+14
Economy resources (F)	3,18E+15
Total emergy (Y)	9,88E+15

Table 7. Emergy indices obtained.

Emergy indices	Calculation	Value	Units
Transformity	Tr =Y/Ep	261025	seJ/J
Emergy Yield Ratio	EYR = Y/F	3,11	Dimensionless
Emergy Investment Ratio	EIR = F/I	0,47	Dimensionless
Environment Loading Ratio	ELR = (N+F)/R	0,50	Dimensionless
Renewability	%R = 100(R/Y)	66,7	%

FINAL CONSIDERATIONS

The studied system reveals satisfactory values for all the emergy indices calculated. Renewability attains 67%, making evident its sustainability. The value of emergy captured from nature and transferred to productive chain is high (EYR=3.1). The investment from economy and pressure on environment have low values (EIR=0.47, ELR=0.5). These calculations can be improved obtaining additional data for other emergy calculations and also economic and social analysis.

Besides that, it is possible to consider a different arrangement for eco-units, as a net of milk producers. Because they have low income, they cannot afford the whole investment, therefore they could have a simple distillation process (45%) and the ethanol could be transported to a regional micro-distillery that could concentrate to 94% or more. It would be very interesting in terms of national and global public policy to prepare an emergy analysis of the ethanol macro-distillery proposed as model for a new expansion of Brazilian Ethanol Production Program (35 000 ha) (Cerqueira Leite, 2006) and compare the results of the two models, either as stand-alone distilleries as well as national networks.

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