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Emergy Analysis of a Sucessional Agroforestry System (SAF)

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ABSTRACT

This research aims to study the recovery of a degraded area through the establishment of an agroforestry system (AFS) at Catavento farm, located in Indaiatuba County, state of Sao Paulo, Brazil, to demonstrate both the economic and ecological viability of AFS for small farmers. It was studied: (a) the ecosystem's behavior using emergy (H. T. Odum, 1996); (b) a species consortium with vegetable succession and nutrients cycling. A data survey has been done on soil covering, classification of species and identification of their ecological and economic functions and their life cycles. By applying the mentioned methodologies, a prediction of the agroforestry system behavior and a diagnosis of the dynamic process of ecological restoration have been carried out, using emergy indicators calculated for a complete cycle of forest recovery (fifty years). The emergy indices obtained were: Transformity (Tr), Renewability (%R), Emergy Yield Ratio (EYR), Emergy Investment Ratio (EIR) and Emergy Exchange Ratio (EER). The following values were found: Transformity varies from 8000 and 12000 seJ/J; Renewability starts at 52% and reaches 81% in the third year, and then grows slowly up to 93% in 50 years. The initial value of EYR is 2; it reaches 6.5 in 10 years and 13 in 50years. The EIR varies from 0.17 at the start and after 40 years it decreases to 0.10, showing that the economic investment is low. The EER value is 1.0 at the beginning, it decreases rapidly (0.2 in year 4), then decreases slowly (minimum value of 0.1 in 40 years) showing a slight recovery (up to 0.2 in year 50). The annual profit has been calculated for the cases of both a farm with employees and family managed farm. In the employer-employee case, the profitability is negative in the first 4 years; in the year 5, the profit is $550/ha.year, goes up to US $ 900/ha.year in year 6 and reaches a maximum at year 40 (US$ 17.000/ha.year).

INTRODUCTION

Large-scale agricultural production systems with intensive use of agrochemicals and machinery have been questioned for not preserving biodiversity, soil and water quality. Thus, new alternatives for agricultural production need to be studied and implemented to recover agro-ecosystems quality through ecological farming techniques, among which agroforestry systems stand out.

In Albuquerque’s research of on agro-silvopastoral systems (SASPs) (2006), some questions were raised for future studies, both related to SASPs and agroforestry systems (SAFs). In order to continue this research, contacts were a made to identify an ecological farm located in Indaiatuba County near to the city of Campinas (São Paulo State) that could be useful as case study. The Catavento farm was chosen the farm owner was willing to provide information of the agroforestry system under development. The concepts of systemic interpretation of rural production units were presented to the farm owner, Mr. Fernando Ataliba, as well as the possibility of applying the emergy analysis on the area where a SAF is being implemented. The landowner already knew the emergy methodology since it had been applied by Albuquerque (2006) to the Nata da Serra Farm in Serra Negra (São Paulo State). The farmer agreed with the study of the small area (one hectare) where he is implementing an agroforestry system since 2006. The landowner had previously visited the Association of Agroforestry Farmers (COOPERA-FLORESTA) in Barra do Turvo (Sao Paulo State), and recognized the positive results of agroforestry. The main research lines of the project were traced along with the producer, who was willing to offer all the information, in order to obtain the following data along time: (a) total biomass, organic matter and soil nutrients, (b) carbon sequestered, (c) wood and fruits production. In this research, the emergy methodology was slightly modified to be able to analyze an agroforestry system, which differs from others for presenting the following characteristics: food production along tree's growth, different periods of production of all species and different species growing rates in the different steps of the agroforestry development. In the conventional emergy calculation only inputs and outputs are used, whereas in the agroforestry systems the changes in the internal stocks were accounted based on calculations of Roncon (2012).

LITERATURE REVIEW

The SAFs represent an alternative, on a sustainable and economic basis, for family farmers, considering the forest management, product diversity, and income generation (COSTA, 2008). Agroforestry Systems are defined as “land management where trees or shrubs are used in association with crops and/or animals, in the same area, simultaneously or in a temporal sequence”. The function of crop fertilizing promoted by trees and shrubs, justifies the use of SAFs (LUNDGREN, 1887; OLIVEIRA e SCHREINER 1987; DUBOIS et al., 1996; MANUAL AGROFLORESTAL, 2008). According to Oliveira (2009), Agroforestry Systems emerge as an alternative for environmental and socio-economic development, which seeks to benefit the production system through the enrichment of species within the same area, increasing both the life of cultures and income for the producer. Figure 1 shows agroforestry species (herbaceous plants, shrubs, and trees) in successional cyclic stages, improving the soil organic content (PENEIREIRO, 2008, VIVAN, 1998, GOTSCH, 1995).

MATERIALS AND METHODS

Species Considered in this Research

In this research, the following types of species are considered: (I) short cycle, species with cycles up to six months (corn, beans, pumpkins); (II) intermediate cycle, species that produce between six months and three years (castor beans, cassava, papaya); (III) secondary: species that produce between three and fifty five years (mostly fruits), that show two peaks, the first at thirteen years and the second at twenty six years; (IV) climax: species that produce between ten and fifty years (wood useful for fencing, small constructions and farm tools; (V) species that produce after fifty years (noble wood). The species found in Catavento SAF area are presented in figures 2, 3, and 4. The fruit trees in SAF are: bananas, citrus fruits, jackfruits, mango, tamarind, peach palm, cacao, açaí, cupuaçu, amongst others.

Description of the Study Area

The farmer, Fernando Ataliba, is a registered member of the organic agriculture society of Brazil and currently owns the Catavento property, where organic farming has been used since 1979.in an area previously over farmed with coffee crops and incorrectly used for animal pastures since the 19th century. The introduction of the agroforestry system at the Catavento farm began in 2006. The farm is located in Indaituba County, Sao Paulo, presents the following coordinates 23° 05’21.83’’S and 47° 05’ 11.20’’W, with an elevation of 774 m above sea level according to the Google Earth, in August, 11^{th}, 2010.

Figure 1. *Drawing of SAF from Catavento Farm: Species I, II, II, IV e V (See Annex 1).*

Figure 2. *Short cycle species (three months to three years) cropped in Catavento Farm. (Species I and II) Annex 2e.*

Figure 3. *Intermediate cycle species (three to ten years) cropped in Catavento Farm, mostly fruit trees. (Species III).*

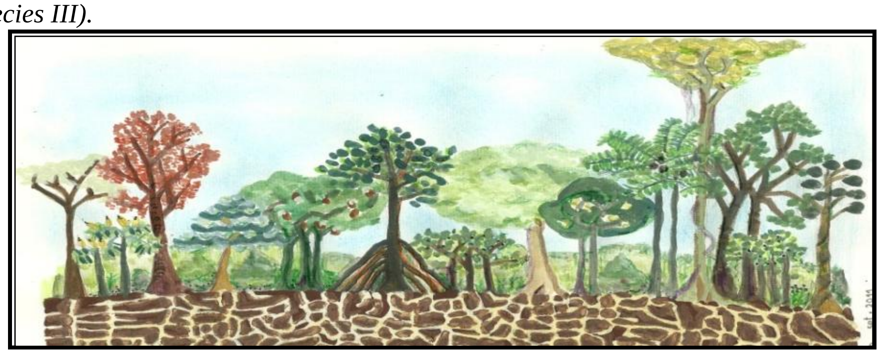

Figure 4. *Intermediate and climax species in Catavento Farm, mostly timber trees (Species IV and V) (Annex 1).*

Emergy Methodology for SAFs Analysis

Emergy analysis

Emergy is all the available energy of one kind that is used up, directly and indirectly, in the transformation processes needed to make a product or a service. Sunlight, fuel, electricity, and human service can be converted on a common basis by expressing them in the *emjoules* of solar energy required in their production. The value is of a unit of emergy is expressed in solar *emjoules* (abbreviated seJ). Although other units have been used, such as coal *emjoules* or oil *emjoules*, this research expresses all its emergy data in solar *emjoules*. Emergy accompanying a flow of something (energy, matter, information, etc.) is easily calculated if the emergy per unit value is known. The flow expressed in its usual units is multiplied by the emergy per unit of that flow. For example, the flow of fuels in Joules per time can be multiplied by the transformity of that fuel (solar emjoules/Joule). A flow of emergy per unit of time is named *empower* (Odum, 2000).

Conventional, productive and agroecological agriculture models

According to Ortega (2002), chemical agriculture is usually perceived as a black box, meaning a closed system in which interactions with the environment are not taken into account and a linear response in production is expected, it is not the case of emergy analysis of complex agricultural systems. Diagrams are prepared in order to show the organization of the farm under study showing inflows, outflows and internal stocks of the agroforestry systems (Figure 5). There are also the negative externalities such as: erosion that increases the need for chemical fertilization, agrochemicals impact farmer's health, pollute of water, soil, and air, and endanger flora and fauna.

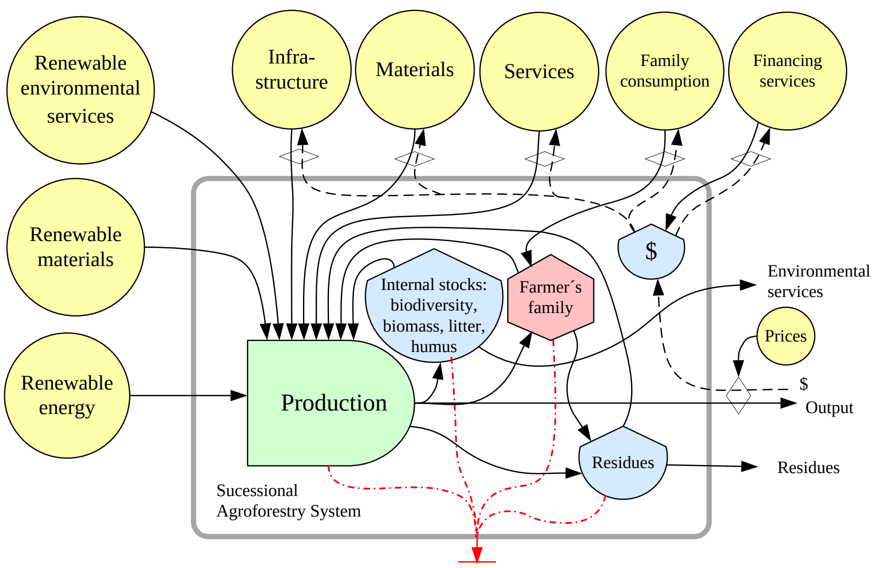

Figure 5. *Diagram of Sucessional Agroforestry model, adapted from Ortega et al (2002).*

Calculation of the biomass values for fruit and timber species in fifty years

Equation 1 describes biomass growth; it corresponds to a logistic model:

$$B(t) = \frac{K \cdot C}{(1+A \cdot e^{kt})} \qquad \text{(Equation 1)}$$

Where: $A = \frac{(K-Bf)}{Bf}$ and $k = \frac{\ln(\frac{K}{Bf})}{T}$

T is the time within production period, K is the plant biomass when it is completely developed, B_f is the biomass at harvest, after which production is no longer economically viable. It was used a coefficient (C) to represent the effect of competition for light, water and nutrients, deaths, and pruning (caused by natural and cultural practices that reduce biomass). This coefficient was estimated considering an adult natural forest in the region (CAIRNS, M.A., et al, 1997). The value obtained by Roncon (2012) is 2.2 times lower, we used this value. K corresponds to the biomass production per hectare for monoculture system when this data is found on the literature. However, if the value is not found, a mean value is considered among those found in the literature, in kg of product per hectare of cropped area. The period of a SAF development in order to recover the soil's organic matter, mobilize nutrients, and provide nutritional conditions for the plants that compose the next stage of evolution vary from 0 to 10 years. Each species has a specific tolerance to the reduction of luminosity that determines the time it will stay on the system, whether it is pioneer or any other sucessional type. The method differs in the biomass calculation for non-fruit trees, because the value of K is considered as: $k = \ln(P/T)$, where P is the fraction of the initial production which is viable to maintain a pioneer species on the system, and T is the time in years from the implementation of the system until the degrowth of the pioneer species; B represents the amount of biomass produced in a given year (productivity). Figure 6 shows the behavior of system's production and the amount of stocks that are produced during the SAF development. It is observed that the largest production is related to the non-fruit trees, followed by fruit trees. The pioneers, they are only important at the beginning (first 10 years).

RESULTS

Table 1 shows inputs and outputs. Output is presented in APPENDICES (Tables 2, 3 and 4). Figure 7 presents the values for the Emergy aggregated flows during the development of the SAF. It may be observed that the values of renewable resources are higher than the non-renewable ones, once SAF uses the minimum amount of non-renewable resources.

Hereafter, the emergy indices are presented.

Transformity assesses the quality of the energy flow and it allows comparisons with other systems: $Tr = Y / Ep$. For the case studied, transformity decreases and grow until year 15, is constant through 25 years, and increases after 40 (Figure 8).

The Emergy Yield Ratio is the ratio of emergy invested (Y) to economic investment (F): $EYR = Y/F$, in other words: $EYR = ((R+N)/F) + 1$. It provides a measure of the incorporation of nature's resources per unit of economic contribution. In chemical agriculture it varies from 1.05 to 1.35. The value for agroforestry varied from 1.2 (first year) to 13 (47^{th} year). In the third year it already achieved 5, a very high value. The SAF shows a high emergy yield that increases along the growing period. This means that the SAF transfers net emergy to the surrounding region, an important fact for public policies that consider oil supply reduction as well as carbon sequestration (Figure 9).

The Emergy Investment Ratio (EIR) measures society's investment to produce a given good in relation to the nature's contribution. It may be interpreted as an index of competitiveness that shows the quantity of economic resources (F) that is needed to obtain resources from nature (I): $EIR=F/I$ (Figure 10). The EIR value for conventional chemical agriculture varies from 5 and 8. In this case. the lower the better. The estimated value of EIR drops rapidly from 5.65 in the first year to 0.87 in the second and keeps falling until it reaches 0.08 in 48^{th} year. The SAF demands a substantial initial investment to provide self-sufficiency and independence from industrial economic resources.

Income curves were obtained considering sales and costs of SAF along time. (Figure 11). The production cost is high during the first three years. when investment is made. From the economic point of view. the SAF showed to provide a mean income of US$ 654/month for the patronal system and US$ 849/month for the family managed farm. a much better values than the conventional agriculture systems but the SAF farmer should be prepared for an initial stage of low income that can take several years.

The cost is high only during the first three years. because this is the period of implementation of the system (when fixed investment is made).

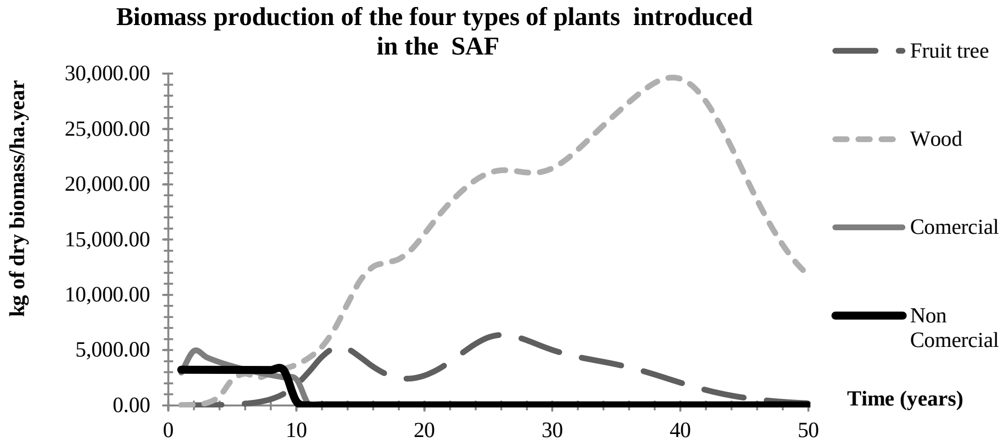

Figure 6. *Biomass for all species in the SAF area in Catavento farm.*

Table 1. Emergy Flows, Outputs, Emergy Indices, Economics and Social.

Emergy Flows	**Expression**	**Description**	**10 years**	**20 years**	**30 years**	**40 years**	**50 years**
I	Natural Contribution	R+N	3,50E+15	4,09E+15	4.82E+15	5.93E+15	7.62E+15
R	Renewable Resources	R	3.50E+15	4.09E+15	4.82E+15	5.93E+15	7.62E+15
N	Non Renewable Resources	N	4.00E+07	1.90E+06	1.06E+05	6.95E+03	5.06E+02
F	Feedback from Economy	M+S	6.10E+14	6.11E+14	6.11E+14	6.11E+14	6.11E+14
M	Materials	M	1.60E+14	1.56E+14	1.56E+14	1.56E+14	1.56E+14
S	Services	S	4.60E+14	4.55E+14	4.55E+14	4.55E+14	4.55E+14
Y	Total Emergy:	I+F	4.10E+15	4.70E+15	5.43E+15	6.54E+15	8.23E+15
Outputs	**Expression**	**Description**	**10 years**	**20 years**	**30 years**	**40years**	**50 years**
Ep	Energy of Products	Ep	3.20E+09	2.13E+09	2.31E+09	2.16E+09	1.93E+09
	Internal Stocks	Stk	2.00E+11	4.23E+11	6.43E+11	6.99E+11	2.84E+11
Es	Internal Stocks Changes	ΔStk	1.20E+17	1.80E+17	2.73E+17	4.12E+17	6.13E+17
E	Total Energy	Ep+Es	2.10E+11	4.25E+11	6.45E+11	7.02E+11	2.86E+11
Emergy Indices	**Expression**	**Description**	**10 years**	**20 years**	**30 years**	**40years**	**50 years**
Tr	Solar Transformity	Y/E	2.00E+04	1.11E+04	8.41E+03	9.32E+03	2.88E+04
EYR	Emergy Yield Ratio	Y/F	6.70E+00	7.69E+00	8.88E+00	1.07E+01	1.35E+01
EIR	Emergy Investment Ratio	F/I	1.70E-01	1.50E-01	1.27E-01	1.03E-01	8.02E-02
%R	Renewability	R/Y*100	8.50E+01	8.70E+01	8.87E+01	9.07E+01	9.26E+01
EER	Emergy Exchange Ratio	Y/In*emdollar	2.50E-01	2.06E-01	1.26E-01	8.44E-02	1.86E-01
Economics and Social	**Expression**	**Description**	**10 years**	**20 years**	**30 years**	**40years**	**50 years**
In	Income		4.50E+03	6.16E+03	1.17E+04	2.09E+04	1.19E+04
C	Costs		7.80E+03	7.83E+03	7.83E+03	7.83E+03	7.83E+03
P	Profits	In-C	-3.40E+03	-1.67E+03	3.82E+03	1.31E+04	4.10E+03
Y	Yield	P/C	-4.30E-01	-2.13E-01	4.88E-01	1.67E+00	5.24E-01
Employees		workers/ha	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00

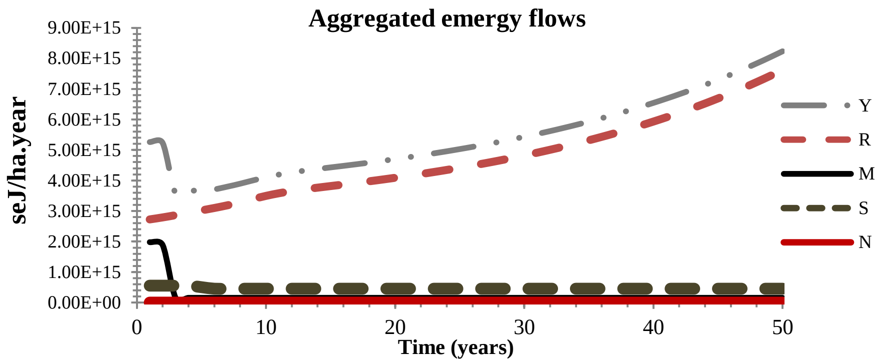

Figure 7. *Graph of the aggregated flows in the SAF*

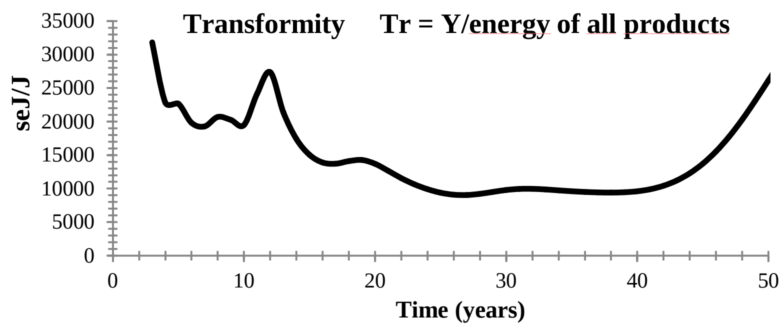

Figure 8. *Transformity value during the 50 years.*

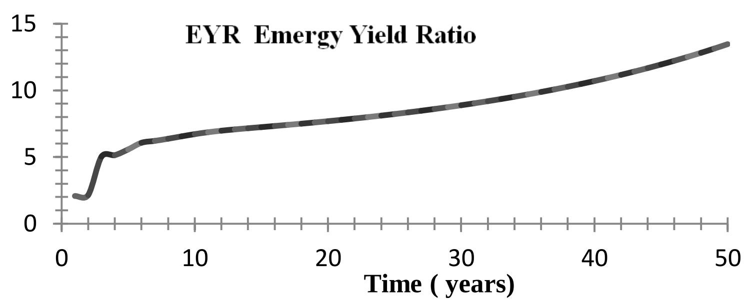

Figure 9. *Graph of the EYR value during the 50 years.*

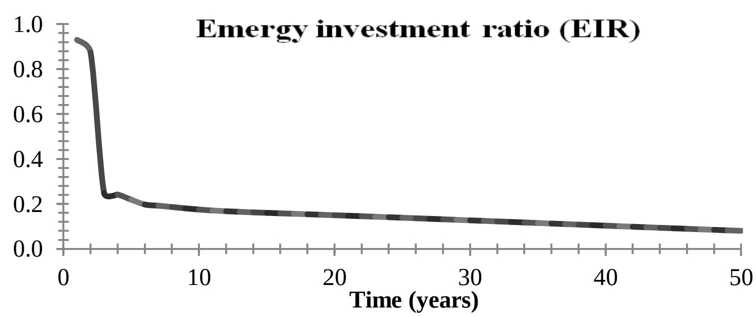

Figure 10. *Graph of the EIR values during the 50 years span.*

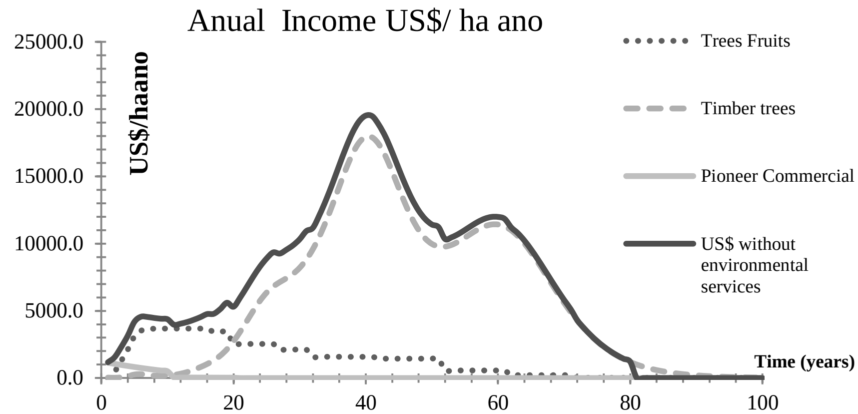

Figure 11. *Simulated annual income for the SAF in Catavento farm in 100 years*.

Besides the emergy indices. the economic index yield was calculated. Usually the economic profitability is calculated as the ratio between sales divided by the production costs (Equation 1); According to Ortega (2004). if public policies consider environmental services as a valuable product and negative externalities as additional cost then the methodology for calculating the profitability could be improved (Equation 2). The equations (1) and (2) consider the studies of Pretty et al. (2000, 2001).

$$R = \frac{Sales - Costs}{Costs} = \frac{\sum(Products\ sales) - \sum(Inflows\ costs + fixed\ \ costs)}{\sum Costs} \quad \text{(Equation 2)}$$

$$R = \frac{Sales - Costs}{Costs} = \frac{\left(\sum Sales + \sum Environmental\ services\right) - \left(\sum Costs + \sum Externalities\right)}{\sum Costs + \sum Externalities} \quad \text{(Equation 3)}$$

CONCLUSIONS

Emergy analysis proved to be useful to study agroforestry systems. Agroforestry is a suitable alternative for the transition to sustainable development in a world where non-renewable resources can no longer be used due to climate change. The agroforestry system demands a provident farmer willing to make a big investment during a life-span (50 years). All emergy indices present values considered better for SAFs when compared to conventional systems. therefore an agroforestry system may be a good social and ecological investment.

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APPENDICES

Table 1. Inputs.

Inputs/Time (years)	Units	1	2	3	4	5	6	7	8	9	10	20	30	40	50
Sun	kWh/m²/day	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Wind	m/s	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Rain	m3/m2.year	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fixed nitrogen atmosphere	kg/ ha.year	16	17	19	20	22	23	25	27	28	30	53	87	136	205
Nitrogen available soil	kg/ ha.year	27	28	29	30	31	32	33	34	36	37	55	83	126	190
Available phosphorus through the soil	kg/ ha.year	34	35	37	39	41	43	45	47	50	52	85	139	226	368
Potassium released from soil	kg/ ha.year	18	44	74	103	130	151	167	178	186	190	331	341	351	361
Other nutrients available soil	kg/ ha.year	18	44	74	103	130	151	167	178	186	190	199	199	199	199
Nitrogen available through the litter	kg/ ha.year	1	2	3	4	4	5	6	6	6	6	7	7	7	7
Phosphorus available through the litter	kg/ ha.year	2	4	7	10	13	15	16	18	18	19	20	20	20	20
Potassium released by the litter	kg/ ha.year	18	44	74	103	130	151	167	178	186	190	199	199	199	199
Other nutrients released by the litter	kg/ ha.year	18	44	74	103	130	151	167	178	186	190	199	199	199	199
Soil loss	kg/ ha.year	20000	15577	12133	9450	7360	5733	4465	3478	2709	2110	173	14	1	0
Inventory of soil	kg/ ha.year	27	28	29	30	31	32	33	34	36	37	55	83	126	190
Accumulation of organic matter in litter	kg/ ha.year	64	74	114	155	202	251	297	345	397	439	477	527	590	663
Accumulation of biomass of trees	kg/ ha.year	6219	8227	7798	7992	9172	9462	8981	9411	10053	8252	18202	26462	31596	11928
Calculation of carbon (Biomass /2)	kg/ ha.year	263	348	330	338	388	401	380	399	426	349	771	1121	1338	505
Diesel tractor	L/ha.year	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Thermo-phosphate (organic input)	US$/ ha/year	286	286	0	0	0	0	0	0	0	0	0	0	0	0
Seedlings and seeds	US$/ ha/year	238	238	0	0	0	0	0	0	0	0	0	0	0	0
Conservation and depreciation	US$/ ha/year	27	27	27	27	27	27	27	27	27	27	27	27	27	27
Temporary labor	US$/ ha/year	150	150	150	150	135	120	120	120	120	120	120	120	120	120
Administrator	US$/ ha/year	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Taxes and Fees	US$/ ha/year	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Workers (permanent)	US$/ ha/year	7800	7800	7800	7800	7800	7800	7800	7800	7800	7800	7800	7800	7800	7800
Income	US$/ ha/year	1411	1812	2528	3385	4468	4872	4847	4808	4795	4387	6050	11443	20861	11926
Costs	US$/ ha/year	8509	7833	7833	7833	7833	7833	7833	7833	7833	7833	7833	7833	7833	7833

Table 2. Productivity of pioneer species (kg/ha.year) x Time (years)

Time (years)		1	2	3	4	5	6	7	8	9	10	20	30	40	50
Pineapple	*Ananas comosus*	0.89	0.01	0	0	0	0	0	0	0	5.20E-17	0	0	0	0
Pumpkin	*Corcubita sp.*	27.98	24.52	21.49	18.84	16.51	14.47	12.68	11.12	9.74	8.50E+00	0	0	0	0
Saffron	*Curcuma longa*	0.88	0.01	0	0	0	0	0	0	0	3.80E-17	0	0	0	0
Sweet potato	*Ipomoea batatas*	3.5	1.22	0.42	0.15	0.05	0.02	0.01	0	0	2.60E-04	0	0	0	0
Sugar cane	*Saccharum officinarum*	11.66	8.5	6.19	4.51	3.29	2.4	1.75	1.27	0.93	6.80E-01	0	0	0	0
Cará	*Dioscorea trifida*	4.08	1.65	0.67	0.27	0.11	0.04	0.02	0.01	0	1.20E-03	0	0	0	0
Beans – rice	*Vigna angularis*	0.96	0.02	0	0	0	0	0	0	0	9.80E-16	0	0	0	0
Azuki beans	*Vigna angularis*	0.96	0.02	0	0	0	0	0	0	0	9.80E-16	0	0	0	0
Carioquinha beans	*Phaseolus vulgaris*	57.7	54.13	50.78	47.63	44.68	41.92	39.32	36.89	34.6	3.20E+01	0	0	0	0
Feijão de Corda	*Phaseolus vulgaris*	57.7	54.13	50.78	47.63	44.68	41.92	39.32	36.89	34.6	3.20E+01	0	0	0	0
Yam	*Dioscorea villosa*	2.48	0.42	0.07	0.01	0	0	0	0	0	0	0	0	0	0
Cassava	*Manihot sculenta*	11.54	8.38	6.09	4.42	3.21	2.33	1.7	1.23	0.89	6.50E-01	0	0	0	0
Creole Corn	*Zea mays*	4.79	2.21	1.02	0.47	0.22	0.1	0.05	0.02	0.01	4.60E-03	0	0	0	0
Taioba	*Xanthosoma sagittifolium*	3.5	1	0.29	0.08	0.02	0.01	0	0	0	4.40E-05	0	0	0	0

Table 3. Productivity of timber trees

time(years)		1	2	3	4	5	6	7	8	9	10	20	30	40	50
Amora	*Morus nigra*	2.E-04	1.E-04	2.E-04	4.E-04	7.E-04	1.E-03	2.E-03	4.E-03	7.E-03	1.E-02	2.E-02	1.E-04	0.E+00	0.E+00
Anda assu	*Joannesia princeps*	1.E-04	0.E+00	0.E+00	0.E+00	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	2.E-04	2.E-03	1.E-02	7.E-02	8.E-02
Araribá	*Centrolobium microchaete*	1.E-04	0.E+00	0.E+00	1.E-04	1.E-04	1.E-04	1.E-04	2.E-04	2.E-04	3.E-04	3.E-03	3.E-02	1.E-01	4.E-02
Araticum	*Annona crassiflora*	1.E-04	1.E-04	1.E-04	1.E-04	2.E-04	2.E-04	3.E-04	4.E-04	6.E-04	8.E-04	2.E-02	2.E-02	1.E-03	0.E+00
Aroeira	*Schinus terebinthifolius*	1.E-04	0.E+00	0.E+00	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	2.E-04	2.E-04	2.E-03	2.E-02	5.E-02	2.E-02
Árvore do Pinguço	*Vernonia condensata*	1.E-04	0.E+00	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	0.E+00	0.E+00	0.E+00	0.E+00
Babosa branca	*Cordia superba*	1.E-04	0.E+00	1.E-04	1.E-04	1.E-04	2.E-04	2.E-04	3.E-04	4.E-04	6.E-04	1.E-02	1.E-02	8.E-04	0.E+00
Canafistula	*Peltophorum dubium*	1.E-04	0.E+00	0.E+00	1.E-04	1.E-04	1.E-04	1.E-04	2.E-04	2.E-04	3.E-04	3.E-03	3.E-02	1.E-01	4.E-02
Capixingui	*Croton floribunbus*	1.E-04	1.E-04	1.E-04	2.E-04	2.E-04	3.E-04	5.E-04	7.E-04	1.E-03	2.E-03	2.E-02	2.E-03	0.E+00	0.E+00
Chichá	*Sterculia chicha*	1.E-04	1.E-04	1.E-04	2.E-04	2.E-04	3.E-04	5.E-04	8.E-04	1.E-03	2.E-03	7.E-02	9.E-02	3.E-03	0.E+00
Copaiba	*Copaifera landesdorffi*	1.E-04	0.E+00	0.E+00	0.E+00	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	1.E-03	8.E-03	5.E-02	1.E-01
Embauba	*Cecropia hololeuca*	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	2.E-04	3.E-04	3.E-04	5.E-04	6.E-04	1.E-02	1.E-02	9.E-04	0.E+00

Table 3. Continued.

time(years)		1	2	3	4	5	6	7	8	9	10	20	30	40	50
Escova de macaco	*Apeiba tibourbou*	1.E-04	1.E-04	1.E-04	1.E-04	2.E-04	3.E-04	5.E-04	7.E-04	1.E-03	1.E-03	5.E-02	7.E-02	2.E-03	0.E+00
Fedegoso	*Senna occidentalis*	2.E-04	1.E-04	2.E-04	3.E-04	5.E-04	8.E-04	1.E-03	2.E-03	3.E-03	5.E-03	8.E-03	1.E-04	0.E+00	0.E+00
Fumo bravo	*Solanum mauritianum*	3.E-04	5.E-04	1.E-03	3.E-03	8.E-03	2.E-02	3.E-02	4.E-02	3.E-02	2.E-02	0.E+00	0.E+00	0.E+00	0.E+00
Gliricidea	*Gliricidia sepium*	1.E-04	0.E+00	1.E-04	1.E-04	1.E-04	1.E-04	2.E-04	2.E-04	3.E-04	3.E-04	5.E-03	2.E-02	6.E-03	4.E-04
Grandiuva	*Trema micrantha*	2.E-04	1.E-04	2.E-04	4.E-04	7.E-04	1.E-03	2.E-03	4.E-03	7.E-03	1.E-02	2.E-02	1.E-04	0.E+00	0.E+00
Grumixama	*Eugenia brasiliensis*	1.E-04	0.E+00	0.E+00	1.E-04	1.E-04	1.E-04	1.E-04	2.E-04	2.E-04	3.E-04	3.E-03	3.E-02	3.E-02	4.E-03
Guapuruvu	*Schizolobium parahyba*	1.E-04	1.E-04	1.E-04	1.E-04	2.E-04	2.E-04	3.E-04	5.E-04	7.E-04	9.E-04	3.E-02	5.E-01	2.E-01	8.E-03
Ingá	*Ingá sp.*	1.E-04	0.E+00	1.E-04	1.E-04	1.E-04	2.E-04	2.E-04	3.E-04	4.E-04	6.E-04	1.E-02	1.E-02	8.E-04	0.E+00
Ipê-rosa	*Tabebuia impetiginosa*	1.E-04	0.E+00	0.E+00	1.E-04	1.E-04	1.E-04	1.E-04	2.E-04	2.E-04	3.E-04	3.E-03	3.E-02	7.E-02	1.E-02
Jacarandá	*Jacaranda cuspidifolia*	1.E-04	1.E-04	1.E-04	1.E-04	2.E-04	2.E-04	3.E-04	4.E-04	6.E-04	8.E-04	2.E-02	2.E-02	1.E-03	0.E+00
Jatobá	*Hymenaea courbaril L*	1.E-04	0.E+00	0.E+00	0.E+00	0.E+00	0.E+00	1.E-04	1.E-04	1.E-04	1.E-04	6.E-04	4.E-03	2.E-02	1.E-01
Leucena	*Leucaena leucocephala*	2.E-04	2.E-04	3.E-04	6.E-04	1.E-03	2.E-03	3.E-03	5.E-03	7.E-03	8.E-03	1.E-04	0.E+00	0.E+00	0.E+00
Louro	*Laurus nobilis*	1.E-04	0.E+00	0.E+00	0.E+00	1.E-04	1.E-04	1.E-04	1.E-04	1.E-04	2.E-04	1.E-03	4.E-03	2.E-03	2.E-04
Mutambo	*Guazuma ulmifolia*	1.E-04	1.E-04	1.E-04	1.E-04	2.E-04	3.E-04	4.E-04	6.E-04	9.E-04	1.E-03	4.E-02	5.E-02	2.E-03	0.E+00
Paineira	*Chorisia speciosa*	0.0001	0	1E-04	1E-04	1E-04	1E-04	2E-04	3E-04	3E-04	5E-04	0.008	0.142	0.817	0.184
Pau formiga	*Triplaris brasiliana*	0.0001	0.0001	1E-04	2E-04	2E-04	4E-04	5E-04	8E-04	0.001	0.002	0.06	0.018	4E-04	0
Pau Viola	*Citharexylum myrianthum*	0.0002	2.E-04	3E-04	7E-04	0.001	0.003	0.005	0.009	0.017	0.032	0.059	1E-04	0	0
Sabão de Soldado	*Sapindus saponaria*	0.0001	0.0001	1E-04	1E-04	1E-04	2E-04	3E-04	4E-04	5E-04	7E-04	0.015	0.019	0.001	0
Santa Bárbara	*Melia azedarch*	0.0001	0.0001	1E-04	1E-04	2E-04	3E-04	4E-04	6E-04	9E-04	0.001	0.04	0.052	0.002	0
Seringueira	*Hevea brasiliensis*	0.0001	0.0001	1E-04	1E-04	2E-04	2E-04	3E-04	4E-04	6E-04	9E-04	0.025	0.239	0.035	0.001
Sibipiruna	*Cesalpinia peltophoroides*	0.0001	0	0	1E-04	1E-04	1E-04	1E-04	2E-04	2E-04	3E-04	0.003	0.027	0.031	0.004
Sombreiro	*Clitoria racemosa*	0.0002	0.0001	1E-04	2E-04	4E-04	6E-04	9E-04	0.001	0.002	0.004	0.111	0.006	1E-04	0
Tefrósia	*Tephrosia candida*	0.0002	0.0001	2E-04	3E-04	5E-04	7E-04	0.001	0.002	0.003	0.004	7E-04	0	0	0
Timburí	*Enterolobium contortisiliquum*	0.0001	0.0001	1E-04	1E-04	2E-04	3E-04	4E-04	5E-04	8E-04	0.001	0.04	0.459	0.056	0.002
Urucum	*Bixa orelana*	0.0004	0.0011	0.004	0.012	0.024	0.024	0.012	0.004	0.001	3E-04	0	0	0	0

Table 4. Fruit productivity of dry mass (kg/ ha year) x Time (years)

time(years)		1	2	3	4	5	6	7	8	9	10	20	30	40	50
Avocado	*Persea americana*	0.0	0.3	2.0	13.7	58	103	115	116	117	117	117	117	117	117
Açai	*Euterpe oleracea*	0.0	0.4	5.4	22.1	27	27	28	28	28	28	28	28	28	0
Apple banana	*Musa paradisiaca*	0	7.53	15	15	15	15	15	15	15	15	15	0	0	0
Nanica banana	*Musa paradisiaca*	0	7.53	15	15	15	15	15	15	15	15	15	0	0	0
Golden banana	*Musa paradisiaca*	0	7.53	15	15	15	15	15	15	15	15	15	0	0	0
Bread banana	*Musa paradisiaca*	0	11.28	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	0	0	0
Silver banana	*Musa paradisiaca*	0	12.53	25	25	25	25	25	25	25	25	25	0	0	0
Coffee	*Coffea arabica*	0.08	0.13	0.19	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
khaki	*Diospyros kaki*	0.04	0.23	1.24	5.23	12.35	16.32	17.31	17.5	17.54	17.54	17.54	17.54	17.54	17.54
Coconut	*Cocos nucifera*	0.02	0.44	7.18	31.87	38.59	39	39.02	39.02	39.02	39.02	39.02	39.02	0	0
Guava	*Psidium guajava*	0.07	0.14	0.26	0.43	0.62	0.78	0.88	0.94	0.97	0.99	1	1	0	0
Guabiroba	*Campomanesia xanthocarpa*	0.07	0.14	0.26	0.43	0.62	0.78	0.88	0.94	0.97	0.99	1	1	1	1
Jabuticaba	*Myciaria cauliflora*	0.07	0.13	0.23	0.37	0.53	0.68	0.81	0.89	0.94	0.97	1	1	1	1
Jaca	*Arthocarpus heterofilus*	0.09	0.11	0.15	0.19	0.25	0.31	0.38	0.45	0.53	0.6	0.98	1	1	1
Orange	*Citrus sinensis*	0.03	0.35	4.09	27.57	51	54.73	55.05	55.08	55.08	55.08	0	0	0	0
Galego lemon	*Citrus limonia*	0.03	0.35	4.09	27.57	51	54.73	55.05	55.08	55.08	55.08	0	0	0	0
Lemon	*Citrus limon*	0.03	0.35	4.09	27.57	51	54.73	55.05	55.08	55.08	55.08	0	0	0	0
Siciliano lemon	*Citrus limon*	0.03	0.35	4.09	27.57	51	54.73	55.05	55.08	55.08	55.08	0	0	0	0
Papaya	*Carica papaya*	0	38.79	38.89	38.89	38.89	38.89	38.89	38.89	38.89	38.89	0	0	0	0
Mango grafted	*Mangifera indica*	0.04	0.28	2.1	12.67	35.44	45.98	47.8	48.04	48	48	48	48	48	48
Mango not grafted	*Mangifera indica*	0.05	0.22	0.99	4.33	15.22	32.9	43.77	47.09	48	48	48	48	48	48
Passion fruit	*Passiflora edulis*	0	5.65	11.25	11.25	11.25	11.25	11.25	11.25	11.25	11.25	0	0	0	0
Medlar	*Eriobotrya japonica*	0	2.33	56.5	58.82	58.82	58.82	58.82	58.82	58.82	58.82	58.82	58.82	0	0
Pitanga	*Eugenia uniflora*	0.04	0.24	1.26	5.35	12.69	16.76	17.77	17.96	17.99	18	18	18	18	18
Pupunha	*Bactris gasipaes*	0.05	0.18	0.56	1.43	2.62	3.47	3.83	3.95	3.98	4	4	4	4	4
Tamarind	*Tamarindus indica*	0.07	0.13	0.23	0.37	0.53	0.68	0.81	0.89	0.94	0.97	1	1	1	1
Mandarin	*Citrus reticulata*	0.03	0.36	4.37	30.66	56.91	61	61	61	61	61	61	61	61	61
Uvaia	*Eugenia uvalha*	0.04	0.24	1.26	5.35	12.69	17	18	18	18	18	18	18	18	18