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Carrying Capacity Using Emergy Evaluation and Ecological Footprint

Elisa Sayoko Nakajima and Enrique Ortega

ABSTRACT

The ecosystem depends on the preservation of environmental resources, the auto regulation of consumption and the change of production models at local and global levels. To think in change the life style in order to adjust social patterns to sustainable development, it is necessary comprises the carrying capacity of each region. In this study, the carrying capacity was evaluated using two methodologies in different approaches, with the objective of identifying critical issues related to sustainability indicators; in the methodology suggested by Brown and Ulgiati (2001) the obtained indicator is terms of area, which has the same didactic characteristic as the one provided by the Ecological Footprint methodology. In our emergy assessment, the renewability percent of this municipality was high (52.82%). To determine the renewable support area, the emergy approach carrying capacity was applied and the support area calculated was 341.871 ha or 4.75 ha per person. This result reveals a value for the equivalent natural area needed to absorb the impacts of the fossil fuel consumed in the production of industrial inputs used in the region. To comparing the carrying capacity a new ecological footprint methodology proposed by Merkel (2007) was considered interesting to calculate the support area based on the consumption profile of population. This methodology was adapted to obtain an alternate carrying capacity for the county. The result was 249,650 ha or 3.47 ha per person. This study showed the importance of preserving natural areas and introduced the need for changes in the configuration of the county economy and in its population's lifestyle needed to improve Ibiúna's sustainability.

INTRODUCTION

In recent years, the concept of sustainability has been used to help decision makers elaborating environmental policies for regional development. A literature revealed several studies assessing the sustainability of cities and regions. Some of them used the emergy approach to evaluate sustainability. Emergy evaluation is a form of environmental accounting, in which energies of material resources and services coming from the economy, along with energy flows from nature are taken into account. Hossaini et al. (2013) applied emergy accounting to Canada and its provinces, generating emergy maps that showed resource consumption as emergy per person, and emergy density under two parameters: 1) the quantities of resources consumed and 2) the location of consumption. The characterization of the regions can be used for future planning for sustainable development and management of the land, both at the federal and provincial levels. In a case study in the Loess Hilly Region of China, the emergy assessment was applied to evaluate the sustainability of an ecological restoration program (Dang and Liu, 2012). The results of this research indicated that the program was not successful and also that not enough was being done in terms of environmental preservation and optimizing resources usage. To enhance sustainability, they indicate that further actions are necessary to conserve environmental resources, to improve the emergy input structure for agricultural production and to change lifestyles of the local people live in that region. Vassallo et al. (2009) used emergy assessment to compare the sustainable development of six districts in the coastal Italian resort region called Riviera Del Beigua. In this region, tourism is the main economic activity and the traditional production capabilities of agriculture and fishing have been neglected. In these comparisons, it was verified that a large amount of emergy is expent to support tourists. This analysis supports the idea that coastal tourism is an expensive resource and intensive endeavor. Brown and Ulgiati (2001) determined carrying capacity for economic investments based on an emergy evaluation of the environmental resources of a region in Mexico and Papua New Guinea. Using data from tourism development, the concept of carrying capacity is related to intensity of development. The result is the necessary area of the surrounding region that would be required if the economic activity were using solely renewable emergy inputs. Macao is also a tourist city and in this case Lei and Wang (2008) applied emergy evaluation to investigate and characterize urban evolution and city development. They found that the region absorbs large amounts of emergy to support not only its survival, but also its booming development (Lei and Wang, 2008). In another study about Macao, the life support systems outside the city, tourism, and waste treatment were assessed and a comparison was made with other regions. In this study, Lei et al. (2008) found that the city with its large population and scarce natural resources showed a very high environmental loading.

Ecologists define carrying capacity as the maximum size of a species population that a given area can support without reducing its ability to maintain a given species for an undefined time period (Daily and Ehrlich, 1992). The support area is defined by Brown and Ulgiati (2001) as the minimum carrying capacity needed for a human-made system. Thus, the support area is an indicator of the load on the environment, as it is the Ecological Footprint indicator. Since the late 50's with the revolution industrial, the population's consumption has increased, and also there are forces that make it grow even more; Merkel (2007) concerned with a population´s intense consumption, suggests measuring it using a simplified ecological footprint, which is a fast and accurate tool for assessing the individual's consumption; this calculus has been used in the United States and Europe. This method estimates the amount of area that is required to meet consumption and absorb the waste that consumption generates. In this present work both support area methods were used, the emergy approach and Simplified Ecological Footprint, in order to assess the relationship between economy demands and environmental capacity.

Ibiúna as case study

Ibiúna County is located in the physiographic basin of Paranapiacaba, with the following coordinates: Latitude: 23° 39 '20" S and Longitude:.47 °13' 31" W. and 72 km distant from the state capital of São Paulo, Brazil (Figure 1). Ibiúna holds approximately 70,000 inhabitants of whom 67% live in rural area. The municipality is located in a mountainous region and possesses a large green area, almost 45% of its total area. The green area is composed of native forests, savannas and reforested area. There is a large water basin with three rivers that flow to the Itupararanga dam that provides water to 6 cities. The dam is located within a state preservation area (26,000 ha) called "Jurupará State Park" that is considered by the United Nations as a biodiversity reserve and Ibiúna holds 95% of its area (Ibiúna County Government, 2010).

The economy of many municipalities in the state of São Paulo is based on agriculture that provides products for the metropolitan areas. In a study of typology according to the state Gross Domestic Product (GDP) (SEADE, 2009), Ibiúna is among the segment of 63 counties that represent 4.6% of São Paulo state's GDP and account for 35.3% of added value of the state's agriculture. Ibiúna is located near the São Paulo metropolitan region, and for this reason it has become an important supplier of horticulture and vegetable products to the city. In the past, this proximity to São Paulo induced many families to adopt Ibiúna as a summer resort.

The region's farms used to be successful as small monocultures, but higher costs for fertilizers and pesticides combined with a drop in the selling price of the region's agricultural products made the traditional farming methods no longer viable. Horticulture was tried as a solution, but not too long after being implemented it revealed a behavior similar to the small monoculture farms – the difficulty in obtaining profit from this activity. As a result, many families who lived on agriculture began to sell their lands. Many of these lands were located near the highway leading to the city of São Paulo and they were

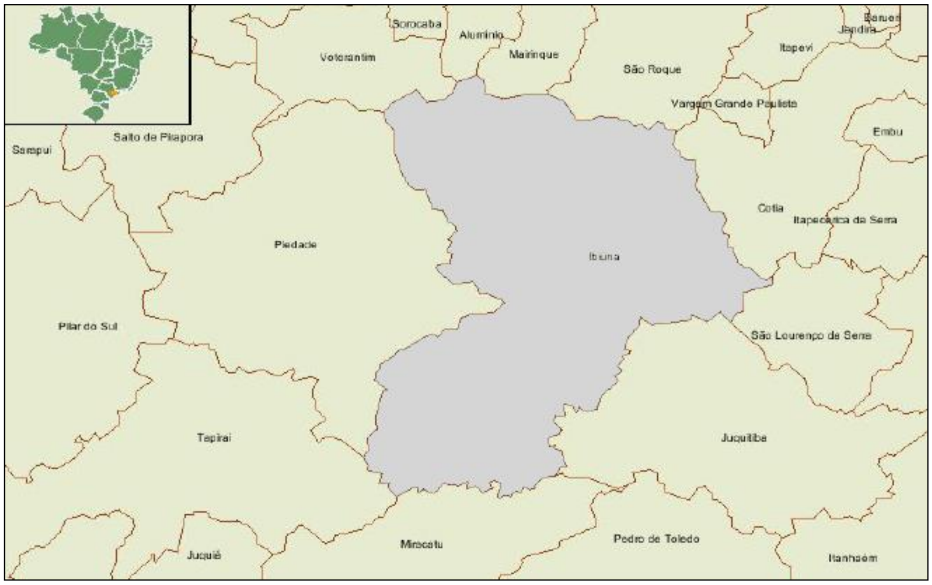

Figure 1. *Location of Ibiúna County in Brazil.*

sold at very low prices. Later on, these areas were rapidly occupied by allotments ("condominiums" and rural neighborhoods) that were in high demand by São Paulo inhabitants, who wanted a second house or recreational farm in the vicinity of the city and near the dams, which were an attractive feature for leisure activities. The county's potential as a tourism area (Gomes, 1997) is illustrated by this transition. Nowadays, Ibiúna has become a dormitory town for people who work in São Paulo.

The objective of this study is to evaluate the carrying capacity of Ibiúna County using two methods for characterizing support area: the Emergy approach and the Simplified Ecological Footprint, in order to assess the relationship between economic demands and environmental support capacity.

METHODOLOGY

Emergy evaluation was carried out in Ibiúna County for diagnosis of sustainability issues of the municipality. In order to improve these diagnoses the carrying capacity was evaluated. It was choice the support area developed by Brown and Ulgiati (2001) to comparing with the simplified ecological footprint developed by Merkel (2007), because in the quoted authors methodology firstly, the obtained indicators, are in terms of area, and are the same characteristics of ecological footprint, thus, become in an easy-to- understand indicators for decisions maker to elaborate public policies.

Emergy Evaluation

Emergy evaluation of Ibiúna County was performed as follows: a) development of a energy system diagram b) Construction of the emergy table for the region, using input data in the year 2008, from the Municipality and some data input from Brazil converted by a factor that relates the Brazil Gross Domestic Product with the municipality GDP, the adopted emergy baseline was 15.83E+24 seJ. $year^{-1.}$; c) Emergy indicators calculation.

Carrying Capacity

According to Brown and Ulgiati (2001) the carrying capacity can be calculated as the preservation area needed to support economic activity. The support area can be obtained by dividing the total nonrenewable emergy inputs from nature and the economy by the renewable regional emergy density. Emergy density acts as a factor for transforming emergy into area.

$$SA(r) = (F + N) / DE(r) \quad \text{Equation (1)}$$

Where:
SA(r) = Renewable support area (m2)
F = Economy´s nonrenewable materials and services (seJ/year)
N = Nature´s nonrenewable resources (seJ/year)
DE(r) = Renewable emergy density (seJ/m2.year)

The renewable support area (SA(r)) measures the area that could be necessary to produce the fuel consumed by the economic activity by means of production of biomass through renewable emergy production. This value reveals the natural equivalent area required to replace the imported nonrenewable resources used in productive processes.

Support Area by Simplified Ecological Footprint

It is possible to estimate the population consumption profile by adopting the method proposed by Merkel (2007) that allows determining the equivalent factors for consumption area in terms of hectares per person. For these calculations, it was necessary to apply a questionnaire where each question corresponds to a footprint factor.

The questionnaire consists of four types of consumption and each type was calculated, respectively, with the equation s listed in Table 1. These equations and each factor were adapted by Merkel (2007) based in footprint equivalence factor. The sum of this value is the results of ecological footprint in hectares (ha) per person.

To evaluate the total area of the county, the population was split in to family incomes range, according to the number of minimum wages in a families' income using the data of the IBGE (Brazilian Institute of Geography and Statistics). The quantification of research has been performed to calculate an error of 10% assumption. Table 2 shows the sampling of necessary population to apply the questionnaires. A field survey with 109 people who answered the survey was conducted. Due to the difficulty of access to low-income populations an interview with the social assistant of the government of the city was conducted, who describe the consumption profile of this people.

Table 1. Simplified calculation of the ecological footprint (Merkel, 2007)

Ecological Footprint	**Equation**
Food Consumption (A)	
Animal source food consumption (AOA)	A= 2.21 x AOA X AR
Regional source food consumption (AR)	
Housing (M)	
Number of inhabitants (H)	
Housing area (AM)	M = 2.1 x (2.6/H) x AM x DM x CE
Housing description (DM)	
Energy conservation (CE)	
Transportation (Tt)	Tt = T1 + T2 + T3
Public transportation (TP)	T1=0.026XTP
Individual transportation (TI)	
Fuel consumption (TC)	T2= 1.65xTIxTCxTR
Accompanied transportation use (TR)	
Air transportation (TA)	T3 = 0.12 x TA
Goods consumption use (BC)	BC
Food consumption + housing (PAM)	PAM = A + M
Goods and Service consumption use(PBS)	PBS = BC x PAM x 0.9
Total Ecological Footprint (PET)	**PET= A+M+Tt+PBS**

RESULTS AND DISCUSSIONS

Emergy evaluation of the county of Ibiúna considers both, the rural and urban areas. Figure 2 is the system diagram represents all the input flows to the county as well as the internal flows.

Table 3 presents the emergy calculations for the county of Ibiúna. Indicators of the preservation area and agricultural one were also calculated as shown in Table 4. According to the estimated data it was verified that the rates of sustainability in terms of renewability of this municipality is high (52,82%). Regarding the emergy density, the results of this indicator shows that the Municipality of Ibiúna have a form of land use that similar to a more characteristic model for rural area and farms.

The analysis of emergy indicators shown that the environmental load, ELR, in the Ibiúna County is moderate. This indicator is different in the agricultural areas, where the environmental load has a high pressure. This result indicates the needs to start thinking about changing the systems of chemical agriculture to less intensive systems such as organic ones. The emergy per person used in the rural area is less intensive, although the rural people have been adopting urban habits.

Table 2. Segmentation of the social Class and sampling for research.

Segmentation	Families	Sample	Applied
More than 20 minimum salaries	151	1	2
10 to 20 minimum salaries	590	3	5
5 to 10 minimum salaries	2443	12	17
2 to 5 minimum salaries	8103	38	57
1 to 2 minimum salaries	5857	28	27
1/2 to 1 minimum salaries	3228	16	1
bellow 1/2 minimum salaries	294	2	*
No salaries	762	4	*

* survey of social assistant

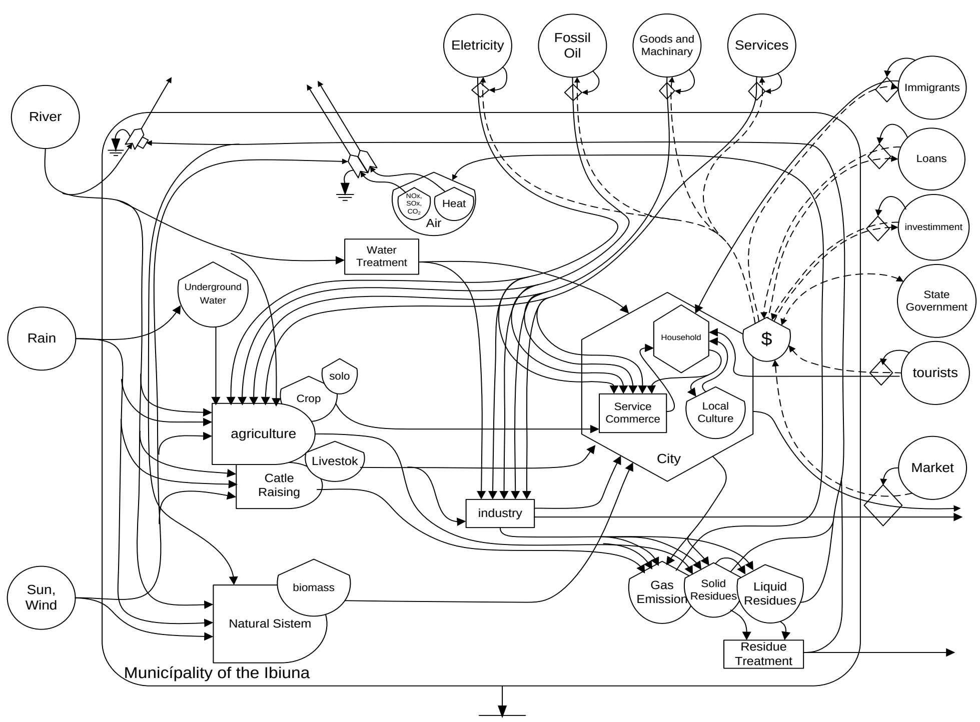

***Figure 2**. System diagram of the Ibiúna County.*

Table 3. Emergy table of Ibiúna County.

	Item	Unit	Value	UEV (seJ/Unit)	Ref.	Emergy (seJ/ano)
Renewable Input (locally avaible)						
1	Sun	J/year	6.58E+18	1	[a]	6.58E+18
2	Wind	J/year	1.83E+16	2.51E+03	[b]	4.59E+19
3	Rain	J/year	3.08E+15	3.05E+04	[b]	9.39E+19
5	River	J/year	2.02E+15	5.80E+05	[m]	1.17E+21
6	Rivers Geopotential	J/year	4.00E+15	4.66E+04	[b]	1.86E+20
Non-renewable input (locally available)						
7	Soil erosion	J/year	1.41E+14	1.24E+05	[g]	1.75E+19
Imported input						
8	Gas oil	J/year	8.80E+14	1.48E+05	[l]	1.30E+20
9	Natural Gas	J/year	3.26E+10	1.70E+05	[l]	5.54E+15
10	Coal	J/year	2.54E+13	6.71E+04	[l]	1.70E+18
11	Ethanol	J/year	6.91E+11	4.87E+04	[k]	3.37E+16
12	Electricity	J/year	4.27E+14	2.52E+05	[d]	1.08E+20
13	Food					
13ª	Fish	J/year	1.65E+12	5.88E+06	[e]	9.71E+18
13b	Meat	J/year	2.97E+13	2.87E+06	[j]	8.53E+19
13c	Fruit	J/year	2.53E+13	4.82E+05	[f]	1.22E+19
13d	Dairy products	g/year	5.25E+09	3.37E+10	[g]	1.77E+20
13e	Cereal	g/year	5.25E+09	1.63E+09	[h]	8.55E+18
13f	Sugar	J/year	1.14E+14	2.80E+04	[k]	3.18E+18
14	Meat - Industrial Process	J/year	3.43E+14	2.50E+06	[j]	8.57E+20
15	Floor - Industrial Process	J/year	7.55E+11	1.63E+09	[h]	1.23E+21
16	Iron and Steel	g/year	2.94E+11	2.99E+09	[b]	8.80E+20
17	Paper	g/year	2.35E+09	6.55E+09	[c]	1.54E+19
18	Fertilizers	g/year	4.18E+10	1.85E+09	[b]	7.73E+19
19	Agrochemical	g/year	2.60E+08	1.38E+12	[b]	3.58E+18
20	Cement	g/year	1.51E+10	3.48E+09	[d]	5.24E+19
Services						
21	Brazil government services	US$/year	2.60E+07	4.12E+12	[i]	1.07E+20
22	Negative externalities	US$/year	1.63E+06	4.12E+12	[i]	6.72E+18

References: [a] by definition; [b] Odum, 1996 (updated after Odum et al., 2000; [c] Brown & Arding,1991 (updated after Odum et al., 2000); [d] Brown & Ulgiati, 2004; [e] Hammer, 1991 (updated after Odum et al., 2000); [f] Ulgiati et al., 1993 (updated after Odum et al., 2000); [g] Brandt-Williams, 2002; [h] Brown & McClanahan, 1996 (updated after Odum et al., 2000) e [i] Pereira, 2012 ; [j] Agostinho e Ortega, 2012; [k] Pereira e Ortega 2010; [l] Brown et al., 2011; [m] Pulselli et al.,2011 and [n] Ortega et al., 2000.

Support Area by Emergy Evaluation

Results of the emergy evaluation shown in the table 4 were applied to equation (1). Thus, Ibiúna support area was calculated as follows:

$$SA(r) = (4.09E+21 + 2.52E+21) / 1.94E+16$$

$$\mathbf{SA(r) = 341{,}871\ ha \quad or \quad 4.75\ ha\ person^{-1}}$$

This result reveals the value for the equivalent natural area needed to absorb the impact of the fossil fuel consumed in the production of industrial inputs used in the region.

Table 4. Emergy index – Urban , natural and rural area.

	Expression	Unit	Ibiúna	Preserved Area	Rural Area
Area		ha	105,800.00	31,929.50	8,641.90
Population	POP	people	72,029		44,802
Total Emergy	U	seJ	3.93E+21	5.20E+19	7.54E+20
Renewable Emergy	N	seJ	2.52E+21		5.80E+19
Non Renewable Emergy	F	seJ	4.09E+21		
Emergy per person	U/POP	seJ/person	5.46E+16		1.68E+16
Emergy density	U /Area	seJ/ha	3.72E+16	1.63E+15	1.68E+16
Renewable Emergy density	DE (r)	seJ/ha	1.94E+16		6,71E+15
ELR	(F+Imp)/N		9.96		53.7
Renewability	N/U		52.82%	98.07%	1.83%

Support Area by Ecological Footprint

In the Table 5, the column called as **Footprint 1** mean the results obtained without considering the fuel consumption. In the column **Footprint 2** it was summed the fuel consumption. Figure 3 shows the difference behavior of the consumption profile when consider segmentation per social classes, it is possible to see that than more higher is the salary level, the support area needs is big like as previewed and in the same order, how increases these area when the fuel consume is considered.

The obtained values were estimated to respective number of families in each social class segment, it was possible to determine the support area to Ibiúna County. Verifying theses values, it is possible to see that the area of the Ibiúna it's not enough to carrying the population consume profile, it is necessary three times of the county area. Even calculate without fuel consumption, the support area is not sufficient.

Comparing the results of support area, it is possible observe that both emergy evaluation as the new ecological footprint are similar in this case study. These two methodologies can be adopted to calculate the carrying capacity of regions. Although the results are similar, it is important to characterize the conceptual difference among them. While in emergy evaluation all the inputs of the energy flows entering in the county were considered, for the new ecological footprint, the calculation are related to the life style profile of consumption. Nevertheless, the last one, in sampler methodology, considered error was 10%, these results could be more accurate if larger number of people were considered to survey.

Table 5. Support Area by Ecological footprint.

		Footprint 1		Footprint 2	
Segmentation	**Families**	**Obtained**	**Estimated**	**Obtained**	**Estimated**
More than 20 minimum wages	151	8.99	1,357	56.50	8,531
10 to 20 minimum wages	590	10.05	5,930	17.67	10,427
5 to 10 minimum wages	2443	7.81	19,075	17.70	43,251
2 to 5 minimum wages	8103	7.23	58,617	12.93	10,4756
1 to 2 minimum wages	5857	5.74	33,605	12.12	70,987
1/2 to 1 minimum wages	3228	3.31	10,685	3.31	10,685
bellow 1/2 minimum wages	294	0.96	282	0.96	282
No incomes	762	0.96	732	0.96	732
Ibiúna Support Area (ha)			130,282		249,650

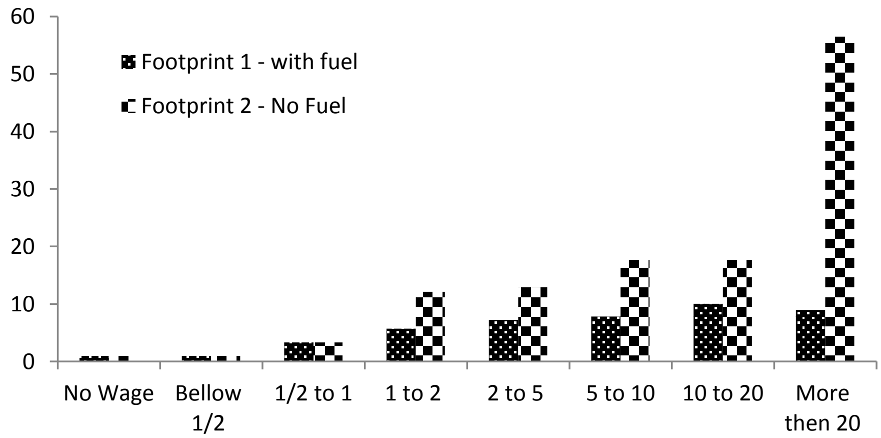

Figure 3*. Support area for Ibiúna County with and without fuel consume.*

Table 6. Comparison of the obtained support area.

	Support area	Per person
Brown and Ulgiati (2001)	341,871 ha	4.75 ha
Merkel (2007) Footprint 2	249,650 ha	3.47 ha

CONCLUSION

Comparing the results of the carrying capacity using emergy evaluation and new ecological footprint, it is possible to see that the necessary support area in the emergy approach is bigger. This difference can be explained, because while in the emergy evaluation the energy flow input of the county was accounted, in the ecological footprint the lifestyle consumption was considered. These two methodologies adopt totally different concepts in performing the calculation. The emergy approach evaluates non-renewable resource use in relation to the renewable emergy density of a region. It analyzes the amount of needed area that must be preserved to support the energy inputs of the system.

The new ecological footprint methodology of Merkel (2007) considered the area necessary to support the consumption of individual or families. In our study this methodology was adapted to assess the area of Ibiúna County. It's very important to note that the definition of the sample population included an error of plus or minus 10%. To obtain more accurate data, it would be necessary to perform a survey with a larger sample population of consumers. Both methods used in this study to determine the support area, shown that Ibiúna County area does not provide sufficient carrying capacity to support the energetic use of the municipality or the consumption profile of its population. These methodologies show the relevance of the energy use and fuel consumption impacts in the carrying capacity of the county.

This study presents the importance of preserving the environmental natural area and introduces the needs of changes in the configuration of the county economy and its population lifestyle in order to turn it into a more sustainable region

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APPENDICES

Renewable Inputs

1 Insolation

Solar energy received = (avg. Insolation)(area, m2) = 5.92E+00 kWh/m2/d ; 1kWh = 3600000 J
8.23E+18 J/yr
Albedo = 0.20
Received solar Energy solar recebida = **6.58E+18 J/year**

2 Wind

Wind energy = (air density, kg/m3)(drag coeff.)(geostrophic wind velocity, m/s)^3(area, m2)(sec/year)=
Air density = 1.3 kg/m3
Wind velocity (average 2005) = 4.2 m/s;
http://eosweb.larc.nasa.gov/cgi-bin/sse/grid.cgi?email=alesouza@fea.unicamp.br&step=2&lat=23&lon=47.517&num=228114&submit=Submit&p=grid_id&sitelev=&veg=17&hgt=+100
Geostrophic wind = 5.2 m/s
Drag coeff. = 3.00E-03.
Time frame = 3.15E+07
Wind energy on land = **1.83E+16 J/year**

3 Rain (Chemical Potencial)

Rain (average temperate areas) = 1.3088 m/year; http://www.cpa.unicamp.br/outras-informacoes/clima_muni_228.html
Water density = 1.00E+06 g/m^3
Mass of rainfall water = 1.38E+15 g/year water
Fraction of water that is evapotranspired = 0.45 [APAT- Gli indicatori del Clima in Italia nel 2005]
Evapotranspired rain water = 0.59 m/yr
Mass of evapotranspired water = 6.23E+14 g/year
Free energy of water=(evapotranspired water,g/ha/yr)(Gibbs free energy per gram water, J/g)=
Gibbs free energy of water = 4.94 J/g [Odum, 1996]
Energy of evapotranspired rain water = **3.08E+15 J/year**

4 Earth internal heat

Heat flow through earth crust contributing to uplift replacing erosion
Average heat flow per area = 0.00E+00 0
= 0.00E+00 J/m^2/year
Energy (J/year) = (land area, m2)(heat flow per area, J/m2/year) = **0.00E+00 J/year**

5 Chemical potential energy of river

Una = 0.00E+00 m^3/s
Sorocamirin = 0.00E+00 m^3/s
Sorocabuçu = 0.00E+00 m^3/s
Itupararanga = 1.30E+01 m^3/s
total flow= 1.30E+01 m^3/s
Chemical potential energy of water = 4.94E+03 J/kg
Water density= 1.00E+03 kg/m^3
year = 3.15E+07 second
Chemical potential energy of river = **2.02E+15 J/year**

6 Geopotential energy of rivers

total flow = 1.30E+01 m^3/s
Average altitude = 9.96E+02 m
Gravity = 9.8 m/s^2
Water density = 1000 kg/m^3
Year = 3.15E+07 second
Potential energy of river = **4.00E+15 J/year**

Non renewable Inputs

7 Erosion

a permanent crops = 1.70E+01 ton/ha/year 1.70E+07. g/ha/year;
ECOAGRI: anual culture 17t/ha/year; 2E+07 g/ha/yr
b temporary crops= 9.84E+00 ton/ha/year 9.84E+06 g/ha/year ;
ECOAGRI: temporary crops (cana-de-açúcar: 9.84 ton/ha/year 1E+07 g/ha/year
c pasture = 1.00E+01 ton/ha/ano 1.00E+07 g/ha/year;
ECOAGRI: 10t/ha/yr average 1E+07 g/ha/yr
a permanent crops = 1.85E+03 ha; LUPA, 2007/2008
(Levantamento Censitário das Unidades de Produção Agropecuária do estado de São Paulo)
b temporary crops= = 4.64E+03 ha; LUPA, 2007/2008
(Levantamento Censitário das Unidades de Produção Agropecuária do estado de São Paulo)
c pasture = 2.44E+04 ha; LUPA, 2007/2008
(Levantamento Censitário das Unidades de Produção Agropecuária do estado de São Paulo)
a permanente crops = 3.15E+10 g/ano
b temporário crops= 4.57E+10 g/ano
c pasture = 2.44E+11 g/ano

Organic matter in soil is reported in the range 3-6% of total soil weigh in Italy (estimated from Medici and Martinelli 1963, Magaldi et al. 1981 and Riffaldi et al. 1994).

Other estimates report average values in the range 3 to 5 % (OTA, 1993; Follet et al., 1987; Odum, 1996) for U.S. soils. We will therefore use an intermediate figure within these ranges.

Average % organic in soil (w.m.) = 0.03 [http://eusoils.jrc.ec.europa.eu/ - 2010]

a **Organic matter in topsoil used up (total mass of topsoil)(% organic) =** 9.44E+08 g/yr w.m.
b **Organic matter in topsoil used up (total mass of topsoil)(% organic) =** 1.37E+09 g/yr w.m.
c **Organic matter in topsoil used up (total mass of topsoil)(% organic) =** 7.33E+09 g/yr w.m.
Water content in organic matter = 0.30 [Verrastro, 2009 - personal comunication avg value]
a Dry organic matter lost with erosion = 6.61E+08 g/yr d.m.
b Dry organic matter lost with erosion = 9.59E+08 g/yr d.m.
c Dry organic matter lost with erosion = 5.13E+09 g/yr d.m.
Energy content of dry organic matter = 5.00 kcal/g d.m. (avg. value for dry organic matter)
a Energy loss = (loss of dry organic matter)(5 kcal/g)(4186 J/kcal) = 1.38E+13 J/yr
b Energy loss = (loss of dry organic matter)(5 kcal/g)(4186 J/kcal) = 2.01E+13 J/yr
c Energy loss = (loss of dry organic matter)(5 kcal/g)(4186 J/kcal) = 1.07E+14 J/yr
Total energy loss = 1.41E+14 J/year

Imported Input

8 Fuel

Consume = 2.56E+07 l/year	MME, 2008
1 liter= 1.01E+05 J	IEA/OECD
Consume = **2.59E+12 J/year**	
1 L gas = 2,098 kgCO_2	6.77E+06
1 gallon = 3.79 L	8.80E+14
1 gallon = 1.30E+08 J	
Consume = 2.00E+04 gal, Consume = 7.55E+04 L	
Emission = 1.59E+08 kgCO_2	
Price = 1.37E+00 US$/L	
Price = **1.03E+05 US$/year**	

9 Natural Gas

Consume = 2.13E+03 kg/ano;				MME, 2008
1m^3	4.19E+10	J		IEA/OECD
Consume =	**3.26E+10**	**J/year**		
Price =	0.93	R$/m^3	8.51E+02 m3	
Energy content =	3.83E+07	J/m^3		
Consume =	8.51E+02	m^3		
Price =	**7.95E+02**	**US$/year**		

10 Coal

Consume =	6.06E+02	toe/year	MME, 2008
1 toe =	4.19E+10	J	IEA/OECD
Consume =	**2.54E+13**	**J/year**	
Energy content =	1.70E+04	J/g	
Consume =	1.49E+09	g/ano	
Price =	1.03E-04	US$/g	
Price =	**1.54E+05**	**US$/year**	

11 Ethanol

Consume =	6.82E+06	toe/year	MME, 2008
1 l=	1.01E+05	J	IEA/OECD
Consume =	**6.91E+11**	**J/year**	
1 L ethanol =	1.58	kgCO_2	
1 L ethanol =	2.11E+07	J	
Consume =	3.28E+04	L	

	Emission =	5.16E+04	$kgCO_2$	
	Price =	0.53	US$/L	
	Price =	**1.75E+04**	**US$/year**	
12	<u>Eletricity</u>			
	Consume =	1.19E+08	Kwh/year	MME, 2008
	1 toe =	4.19E+10	J	IEA/OECD
	Consume =	**4.27E+14**	**J/year**	
	Energy content =	3.60E+06	J/kWh	
	Consume =	1.19E+08	kWh	
	Price =	0.09	US$/kWh	
	Price =	**1.06E+07**	**US$/year**	
13	<u>Food</u>			
13a	Fish			
	Consume =	3.56E+08	g/year	IBAMA, 2007
	Energy content =	4.64E+03	J/g	TACO FEA
	Consume =	**1.65E+12**	**J/year**	
	Price =	3.45E-03	US$/g	
	Price =	**1.23E+06**	**US$/year**	
13b	Meat			
	Consume =5.20E+09 g/ano		FAOSTAT, 2007	
	energy content = 5.71E+03 J/g		TACO FEA (Acem raw meat)	
	Consumo = **2.97E+13 J/year**			
	Price =	3.11E-03	US$/g	
	Price =	**1.62E+07**	**US$/year**	
13c	Fruits			
	Consume = 4.72E+09 g/year		FAOSTAT, 2007	
	Energy content = 5.36E+03 J/g		TACO FEA (Raw banana)	
	Consume = **2.53E+13 J/year**			
	Price = 5.72E-04 US$/g			
	Price = **2.70E+06 US$/year**			
13d	Milk and products			
	Consume = **5.25E+09 g/year**		FAOSTAT, 2007	
	Price = 4.57E-04 US$/g			
	Price = **2.40E+06 US$/year**			
13e	Cereais			
	Consume = **7.23E+09 g/ano**		FAOSTAT, 2007	
	Price = 2.35E-05 US$/g			
	Price = **1.69E+05 .US$/ano**			
13f	Sugar			
	Consume = 7.02E+09 g/year		FAOSTAT, 2007	
	Energy content = 1.62E+04 J/g		TACO FEA (Crystal Sugar)	
	Consume = **1.14E+14 J/year**			
	Price =	5.72E-04	US$/g	
	Price =	**4.01E+06**	**US$/year**	
14	<u>Meat for Industrial Process</u>			
	Consume = 6.00E+07 kg/ano		[2007,http://www.seade.gov.br/produtos/perfil/]	
	Energy content = 5.71E+03 J/g		TACO FEA (acem raw meat)	
		5.71E+06	J/kg	
	Consume =	**3.43E+14**	**J/year**	
	Price =	3.11E+06	US$/ton	
	Price =	**1.87E+14**	**US$/year**	

15 <u>Flour for Industrial Process</u>

Consume =	5.01E+07	kg/year	
Energy content =	1.51E+01	J/g	
	1.51E+04	J/kg	
Consume =	**7.55E+11**	**J/year**	
Price =	2.35E-01	R$/kg	
Price =	**1.17E+07**	**R$/year**	

16 <u>Iron and steel</u>

Consume =	**2.94E+11**	**g/year**	MME, 2008
Price =	9.30E-05	US$/g	
Price =	**2.74E+07**	**US$/year**	

17 <u>Paper</u>

Consume =	**2.35E+09**	**g/year**	IBGE, 2008
Price =	5.00E-05	US$/g	
Price =	**1.18E+05**	**US$/year**	

18 <u>Fertilizers</u>

permanent crops =	1851.1	ha	
temporary crops =	4640.1	ha	
permanent crops =	3000000	g/ha/year	
temporary crops =	9000000	g/ha/ year	
permanent crops consume =	**5.55E+06**	**kg/ yea**r	MDIC, 2010
temporary crops consume =	**4.18E+10**	**g**/ year	
Fertilizer consume =	4.18E+10		
Price =	6.44E-04	US$/g	
Price =	**2.69E+07**	**US$/year**	

19 <u>Agrochemicals</u>

permanent crops
= 1851.1 ha
temporary crops
= 4640.1 ha
permanent crops
= 15000 **g/ha/year**
temporary crops
= 50000 **g/ha/year**
permanent crops consume
= **2.78E+07** **g/year**
temporary crops consume
= **2.32E+08** **g/year**
Agrochemical consume
= 2.60E+08 g/year
Price = 1.78E-
02 US$/g
Price
= **4.62E+06** **US$/year**

20 <u>Cement</u>

permanent crops consume =	**1.51E+10**	**g/year**	MDIC, 2010
Price =	1.88E-04	US$/g	
Price =	**2.83E+06**	**US$/year**	

21 <u>Negative Externalities (Add services)</u>

	permanent crops		
=	1851.1	ha	
	temporary crops		
=	4640.1	ha	
	Rural negative externalitie =	250	**US$/year**Jules Pretty
	Rural negative externalitie		
=	1.62E+06	US$/year	

Effluent treatmen Rosarial(depreciation) = 291.67 US$ wastewater treatment plant pric 13 m^3
Effluent treatmen Nissin (depreciation) = 291.67 US$ wastewater treatment plant pric 13 m^3

Effluent treatmen Rosarial(operation) =	**3600 US$**
Effluent treatmen Nissin (operation) =	3600 US$
Indutrial negative externalitie =	7.78E+03 US$

Total added Services = 1.63E+06 US$