Carrying Capacity Using Emergy Evaluation and Ecological Footprint

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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. Vassalillo 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
expended to support tourists. This analysis supports the idea that coastal tourism is an expensive resource
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, 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
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.

\[ \text{SA}(r) = \frac{(F + N)}{\text{DE}(r)} \]  

Equation (1)

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

The renewable support area (\( \text{SA}(r) \)) 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 equations listed in Table 1. These equations and each factor were adapted by Merkel (2007) based on 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 into family incomes range, according to the number of minimum wages in a family’s 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)

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

<table>
<thead>
<tr>
<th>Segmentation</th>
<th>Families</th>
<th>Sample</th>
<th>Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>More than 20 minimum salaries</td>
<td>151</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>10 to 20 minimum salaries</td>
<td>590</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>5 to 10 minimum salaries</td>
<td>2443</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>2 to 5 minimum salaries</td>
<td>8103</td>
<td>38</td>
<td>57</td>
</tr>
<tr>
<td>1 to 2 minimum salaries</td>
<td>5857</td>
<td>28</td>
<td>27</td>
</tr>
<tr>
<td>1/2 to 1 minimum salaries</td>
<td>3228</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>below 1/2 minimum salaries</td>
<td>294</td>
<td>2</td>
<td>*</td>
</tr>
<tr>
<td>No salaries</td>
<td>762</td>
<td>4</td>
<td>*</td>
</tr>
</tbody>
</table>

* survey of social assistant

Figure 2. System diagram of the Ibiúna County.
Table 3. Emergy table of Ibiúna County.

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


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:

\[ \text{SA}(r) = \frac{(4.09E+21 + 2.52E+21)}{1.94E+16} \]

\[ \text{SA}(r) = 341,871 \text{ ha or 4.75 ha person}^{-1} \]

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.

<table>
<thead>
<tr>
<th>Expression</th>
<th>Unit</th>
<th>Ibiúna</th>
<th>Preserved Area</th>
<th>Rural Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>ha</td>
<td>105,800.00</td>
<td>31,929.50</td>
<td>8,641.90</td>
</tr>
<tr>
<td>Population</td>
<td>POP people</td>
<td>72,029</td>
<td>44,802</td>
<td></td>
</tr>
<tr>
<td>Total Emergy</td>
<td>U seJ</td>
<td>3.93E+21</td>
<td>5.20E+19</td>
<td>7.54E+20</td>
</tr>
<tr>
<td>Renewable Emergy</td>
<td>N seJ</td>
<td>2.52E+21</td>
<td>5.80E+19</td>
<td></td>
</tr>
<tr>
<td>Non Renewable Emergy</td>
<td>F seJ</td>
<td>4.09E+21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergy per person</td>
<td>U/POP seJ/person</td>
<td>5.46E+16</td>
<td>1.68E+16</td>
<td></td>
</tr>
<tr>
<td>Emergy density</td>
<td>U/Area  seJ/ha</td>
<td>3.72E+16</td>
<td>1.63E+15</td>
<td>1.68E+16</td>
</tr>
<tr>
<td>Renewable Emergy density</td>
<td>DE (r) seJ/ha</td>
<td>1.94E+16</td>
<td>6.71E+15</td>
<td></td>
</tr>
<tr>
<td>ELR</td>
<td>(F+Imp)/N</td>
<td>9.96</td>
<td>53.7</td>
<td></td>
</tr>
<tr>
<td>Renewability</td>
<td>N/U</td>
<td>52.82%</td>
<td>98.07%</td>
<td>1.83%</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Segmentation</th>
<th>Families</th>
<th>Footprint 1 Obtained</th>
<th>Footprint 1 Estimated</th>
<th>Footprint 2 Obtained</th>
<th>Footprint 2 Estimated</th>
</tr>
</thead>
<tbody>
<tr>
<td>More than 20 minimum wages</td>
<td>151</td>
<td>8.99</td>
<td>1357</td>
<td>56.50</td>
<td>8,531</td>
</tr>
<tr>
<td>10 to 20 minimum wages</td>
<td>590</td>
<td>10.05</td>
<td>5,930</td>
<td>17.67</td>
<td>10,427</td>
</tr>
<tr>
<td>5 to 10 minimum wages</td>
<td>2443</td>
<td>7.81</td>
<td>19,075</td>
<td>17.70</td>
<td>43,251</td>
</tr>
<tr>
<td>2 to 5 minimum wages</td>
<td>8103</td>
<td>7.23</td>
<td>58,617</td>
<td>12.93</td>
<td>10,4756</td>
</tr>
<tr>
<td>1 to 2 minimum wages</td>
<td>5857</td>
<td>5.74</td>
<td>33,605</td>
<td>12.12</td>
<td>70,987</td>
</tr>
<tr>
<td>1/2 to 1 minimum wages</td>
<td>3228</td>
<td>3.31</td>
<td>10,685</td>
<td>3.31</td>
<td>10,685</td>
</tr>
<tr>
<td>bellow 1/2 minimum wages</td>
<td>294</td>
<td>0.96</td>
<td>282</td>
<td>0.96</td>
<td>282</td>
</tr>
<tr>
<td>No incomes</td>
<td>762</td>
<td>0.96</td>
<td>732</td>
<td>0.96</td>
<td>732</td>
</tr>
<tr>
<td>Ibiúna Support Area (ha)</td>
<td></td>
<td>130,282</td>
<td>249,650</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 3. Support area for Ibiúna County with and without fuel consume.

Table 6. Comparison of the obtained support area.

<table>
<thead>
<tr>
<th></th>
<th>Support area</th>
<th>Per person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown and Ulgiati (2001)</td>
<td>341,871 ha</td>
<td>4.75 ha</td>
</tr>
<tr>
<td>Merkel (2007) Footprint 2</td>
<td>249,650 ha</td>
<td>3.47 ha</td>
</tr>
</tbody>
</table>

CONCLUSION

Comparing the results of the carrying capacity using emery evaluation and new ecological footprint, it is possible to see that the necessary support area in the emery approach is bigger. This difference can be explained, because while in the emery 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 emery approach evaluates non-renewable resource use in relation to the renewable emery 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.
REFERENCES


SEADE (State System of Data Analysis). Available in:
   Accessed: 2010/08/07


APPENDICES

Renewable Inputs

1 Insolation
   Solar energy received = (avg. Insolation)(area, m2) = 5.92E+00 kWh/m2/d ; 1kWh = 3600000 J
   Time frame = 8.23E+18 J/year
   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)(area, m2)(sec/year)=
   Air density = 1.3 kg/m3
   Drag coeff. = 3.00E-03.
   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&grid_id=grid_id&sitelev=&veg=17&hgt=+100
   Geostrophic wind = 5.2 m/s
   Time frame = 3.15E+07
   Wind energy on land = 1.83E+16 J/year
3 Rain (Chemical Potential)
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/m$^2$/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 kgCO2
  - 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 kgCO2
  - Price = 1.37E+00 US$/L
  - Price = 1.03E+05 US$/year

9 Natural Gas

- Consume = 2.13E+03 kg/ano; MME, 2008
  - 1m³
  - 4.19E+10 J IEA/OECD
  - Consume = 3.26E+10 J/year
  - Price = 0.93 RS/m³
  - Energy content = 8.51E+02 m³
  - Price = 7.95E+02 US$/year

10 Coal

- Consume = 6.06E+02 to/ear 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 to/year MME, 2008
  - 1 l= 1.01E+05 J IEA/OECD
  - Consume = 6.91E+11 J/year
  - 1 L ethanol = 1.58 kgCO2
  - 2.11E+07 J
  - Consume = 3.28E+04 L
Emission = 5.16E+04 kgCO₂
Price = 0.53 US$/L
Price = 1.75E+04 US$/year

12 Electricity
Consume = 1.19E+08 Kwh/year
1 toe = 4.19E+10 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 Food
13a Fish
Consume = 3.56E+08 g/year
Energy content = 4.64E+03 J/g
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
energy content = 5.71E+03 J/g
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
Energy content = 5.36E+03 J/g
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
Price = 4.57E-04 US$/g
Price = 2.40E+06 US$/year

13e Cereals
Consume = 7.23E+09 g/ano
Price = 2.35E-05 US$/g
Price = 1.69E+05 US$/ano

13f Sugar
Consume = 7.02E+09 g/year
Energy content = 1.62E+04 J/g
Consumo = 1.14E+14 J/year
Price = 5.72E-04 US$/g
Price = 4.01E+06 US$/year

14 Meat for Industrial Process
Consume = 6.00E+07 kg/ano
Energy content = 5.71E+03 J/g
5.71E+06 J/kg
Consumo = 3.43E+14 J/year
Price = 3.11E+06 US$/ton
Price = 1.87E+14 US$/year
15  **Flour for Industrial Process**
Consume = 5.01E+07 kg/year
Energy content = 1.51E+01 J/g
Consumes = 7.55E+11 J/year
Price = 2.35E-01 RS/kg
Price = 1.17E+07 RS/year

16  **Iron and steel**
Consumes = 2.94E+11 g/year
Price = 9.30E-05 US$/g
Price = 2.74E+07 US$/year

17  **Paper**
Consumes = 2.35E+09 g/year
Price = 5.00E-05 US$/g
Price = 1.18E+05 US$/year

18  **Fertilizers**
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/year
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  **Agrochemicals**
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-
Price = 4.62E+06 US$/year

20  **Cement**
permanent crops consume = 1.51E+10 g/year
Price = 1.88E-04 US$/g
Price = 2.83E+06 US$/year
Negative Externalities (Add services)

permanent crops
= 1851.1 ha

temporary crops
= 4640.1 ha

Rural negative externalities = 250 USD/year

Jules Pretty

Rural negative externalities = 1.62E+06 USD/year

Effluent treatment Rosarial (depreciation) = 291.67 USD
wastewater treatment plant pric 13 m³

Effluent treatment Nissin (depreciation) = 291.67 USD
wastewater treatment plant pric 13 m³

Effluent treatment Rosarial (operation) = 3600 USD

Effluent treatment Nissin (operation) = 3600 USD

Industrial negative externalities = 7.78E+03 USD

Total added Services = 1.63E+06 USD