EMERGY SYNTHESIS 6:

Theory and Applications of the Emergy Methodology

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Emergy Synthesis and Ecological Footprint: Drawing a Parallel between Methodologies for a Sub-National Case Study

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ABSTRACT

Emergy synthesis (ES) was proposed as a method for integral evaluation of environmental and economic resources to measure the quality of matter, energy and information within systems. The method takes into account every contribution from nature and human economy in order to express the relative importance of each resource. Emergy is considered a scientific measure of real wealth in terms of the potential energy previously required to make goods or services. Despite the powerful concept behind the method, it has not been able to reach decision makers and the general public with the same strength. On the other hand, the ecological footprint (EF) has been promoted as a planning tool for sustainability and widely used by many researchers and organizations, due to its didactic way to show the impact of human activities on the nature as the area needed to support consumption. In this work, procedures for a qualitative evaluation of the State of Sao Paulo in Brazil are described for both methods. Shortcomings found on the way are presented as well as some insights on how to overcome them. The aim should be to ensure that assessments are conducted and communicated in a way that is accurate and transparent. ES standards should be developed through a consensus procedure and be applicable to all emergy studies, including global, national, regional, and organizations. Lack of addressing the above points will prevent emergy from being recognized as both a suitable scientific (investigation and understanding side) and policy tool (socio-economic side), in spite of the present need for reliable assessment and evaluation methods alternative to neoclassical economics.

INTRODUCTION

As the concept of sustainable development is more accepted and incorporated by the institutions, it becomes necessary to evaluate economy's performance based on new methods and not only on economic indicators. Despite the importance of sustainability to the preservation of natural ecosystems and services, there is not a standard in the world scientific community concerning a methodology to evaluate it.

According to Zhao et al. (2005), in recent years, there has been some positive development with new valuation tools making substantial headway. Several methods have been used aiming to provide sustainability indicators, focusing on specific aspects, for instance, emergy synthesis (Odum, 1996), ecological footprint (Wackernagel et al., 2005), material flow accounting (Schmidt-Bleek, 1993), embodied energy analysis (Slesser, 1974), exergy analysis (Szargut and Morris, 1998), modified GDP's, among others. In fact, there is not only one indicator able to accomplish that work (Siche et al., 2008). Singh et al. (2009) comment that indices and rating systems are subjective, despite the relative objectivity of the methods employed in assessing the sustainability. Wilson et al. (2007) argue that different approaches reach various interpretations about the sustainability of nations, and emphasize the lack of clear direction at the global level on how to approach sustainable development. Ulgiati et al. (2006) have suggested using different methods with different indicators to assess the sustainability in a proper way, in which each methodology is used in accordance with its specific rules.

We deal in this paper with two scientific tools that have been used worldwide to measure the human impact on nature: ecological footprint (EF) and emergy synthesis (ES). Papers trying to combine them, and obtain more accurate results have appeared in scientific literature (Zhao et al., 2005; Chen and Chen, 2006; Siche et al., 2009, Pereira and Ortega, 2011). Because of the current discussion among emergy enthusiasts and practitioners on the need for standards and good quality intensity factors, ecological footprint could serve as a good example of a methodology with such characteristics that could help improve emergy methodology and make it more attractive to decision makers.

Emergy synthesis (ES) was proposed by Howard T. Odum (Odum, 1996) as a new method for integral evaluation of environmental and economic resources to measure the quality of matter, energy and information within systems. The method takes into account every contribution from nature and human economy in order to express the relative importance of each resource. Since real wealth can be measured by the work previously done to produce something, emergy is considered a scientific measure of real wealth in terms of the potential energy previously required to make goods or services. Despite the powerful concept behind the method, ES has not been able to reach decision makers and the general public with the same strength.

Ecological footprint, created by Wackernagel and Rees (1996), has been promoted as a planning tool for sustainability and widely used by many countries and organizations, due to its didactic way to show the impact of human activities on the nature as the area needed to support consumption. Despite becoming very well known, the method has received many criticisms.

Although both approaches differ, both try to solve the same issue, which is to estimate the gap between human demand of resources and nature's offer. The aim of this paper is to discuss their methodologies, presenting similarities, shortcomings and strong points while applying them for a qualitative sub-national sustainability evaluation of the state of Sao Paulo in Brazil.

AN OVERVIEW OF THE ECOLOGICAL FOOTPRINT

Since this work is to be presented and published in the Sixth Biennial Emergy Research Conference, a brief explanation of the concepts within the EF seems relevant.

Wackernagel and Rees (1996) proposed the EF as an indicator of the carrying capacity of regions, nations and the globe, and extended it as an indicator of sustainability. The basic idea is that every individual, process, activity, and region has an impact on Earth, via resource use, generation of waste and the use of services provided by nature. These impacts can be converted to biologically productive area (land able to perform photosynthesis and produce biomass).

There are two main reasons why ecological footprint has become mainstream. First, it has created a mathematical formula that can estimate the consumption of the society (footprint[1]) in its natural environment (biocapacity[2]). Second, final results are expressed in a very simple and intuitive way, which is 'land area'. Basically, it measures the impact of human activities on nature in a way that anyone can understand.

In the EF, six main categories of productive area are distinguished: cropland, grazing, forest, fishing area, built-up and energy land. As the various ecological categories have differences in biological productivity, Wackernagel et al. (1999) uses 'biological productive areas with world average productivity' as a common measurement unit for footprint and biocapacity. Using world average yield, consumption and waste absorption are translated into biologically productive areas.

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[1] Impact of human activities and consumption translated into area units (global hectares) (Wackernagel and Rees, 1996).

[2] Biological production capacity of a space with photosynthetic activity and biomass accumulation presented in global hectares (Wackernagel and Rees, 1996).

Some countries or regions are better endowed with ecological productivity by having either more space available and/or ecosystems and agroecosystems of higher productivity per unit area. Therefore, to document the ecological production available within a country or region, the number of physical hectares of biologically productive area that exist in each ecological category is multiplied by the factor by which the country's or region's ecosystem differ in productivity from the world average. This factor is the "yield factor". After the concept of EF was developed, some analyses include detailed descriptions of the EF method (Wackernagel et al., 1999; Haberl et al., 2001; Senbel et al., 2003; van Vuuren and Bouwman, 2005).

AT GLOBAL LEVEL

Global Emergy Baseline

Three main emergy inputs are considered for the calculation of the global emergy base: solar energy, tidal energy and deep Earth heat. In order to evaluate the transformities of global tidal energy and global deep heat, two emergy equations were written for the joint contributions of the main emergy inputs to crustal heat and to the geopotential energy of ocean water. Although, explicit calculations can be found on Folio #2 (Odum, 2000), procedure is somehow complicated and references used may be obsolete. The energy flow from tide to oceanic geopotential is 0.52 10^{22} J yr^{-1} (Miller, 1966) and the main processes contribution to Earth's heat is 13.21 10^{22} J yr^{-1} (Sclater et al., 1980). The oceanic geopotential energy is 2.14 10^{20} J yr^{-1}, which considers the inflow from tide (0.52 10^{22} J yr^{-1}) and a non-referenced value of 1.62 10^{22} J yr^{-1} that seems to come from the geobiosphere.

In Folio #2, one can also find that the global emergy base to be used as reference should be 15.83 10^{24} seJ yr^{-1}. That value is an increase from the 1996 solar empower base of 9.44 10^{24} seJ yr^{-1}. This modification changes all the unit emergy values, which directly and indirectly are derived from the value of global annual, empower. Therefore, two alternatives are suggested when using emergy values: either increase older values multiplying them by a factor of 1.68 or decrease the new values multiplying by 0.60 to keep them on the 1996 base.

Despite this clarification, there seems to be a lack of standard in this case, especially when 'non-experts' apply the ES. Firstly, there is no clear rule saying which is the proper global emergy baseline (15.83 10^{24} seJ yr^{-1} or 9.44 10^{24} seJ yr^{-1}) and explaining the reasons for that. We believe that there is no consensus in this case yet, since both values can be found in the literature and publications. Moreover, as the main source of transformities is Odum (1996), values taken from that reference should be updated by the 1.68 factor. Some authors simply do not explain if the modification was made or even which baseline was used. A factor of 1.68 represents an increase of 68% in the transformity values, what may lead to inaccurate results, if the factor is not applied.

Therefore, the definition of a clear explained and standardized emergy baseline should be the first step towards a transparent and accurate methodology.

Global Ecological Footprint

EF uses economic and biophysical data published primarily by international statistical and scientific agencies. According to Wackernagel et al. (2005), data gaps in these statistics are filled with research from governmental, non-profit, academic, and private sector sources.

Globally, EF identifies 11.2 billion hectares of distinct productive areas - cropland, forest, pasture, fisheries, and built-up land – that performs photosynthesis and provide economically useful concentrations of resources. These 11.2 billion hectares cover a little less than one quarter of the planet and include 2.3 billion hectares of marine and inland fisheries and 8.8 billion hectares of land. The land area is comprised of 1.5 billion hectares of cropland, 3.5 billion hectares of grazing land, 3.6 billion hectares of forest, and an additional 0.2 billion hectares of built-up land assumed to occupy potential cropland (EEA, 2000; FAO, 2000; SEI, 1998; WRI, 2000). According to Wackernagel et al. (2005), these areas concentrate the bulk of the biosphere's regenerative capacity.

Remaining areas of the planet are also biologically active, but the authors affirm that renewable resources are not enough concentrated in those areas to be a significant addition to the overall biocapacity. The conventional methodology of the EF arbitrarily excludes from the calculations areas considered as low productivity ones. Venetoulis and Talberth (2008) criticize this assumption, saying that the whole Earth is relevant, because most of its surface participates of the carbon cycle. These areas include deserts, oceans and ice caps. It seems incoherent not to consider those areas, because they are very important to geochemical cycles. The method fails, as it does not recognize the role of the ocean on the sequestration of CO_2. According to IPCC (2004), oceans are responsible for two thirds of the total CO_2 absorption. Therefore, despite being regions with low production of useful biomass, these areas perform essential functions to the planet. Many ecosystems that are not directly used may have indirect benefits to human beings like providing biodiversity or environmental services (van den Bergh and Verbruggen, 1999).

CONVERSION FACTORS

Emergy Intensity Factors

In general, emergy intensity factors may be viewed as the conversion factors of the ES. Their use allows us to convert usual units into emergy flows. Emergy intensity is divided in: transformity (seJ J^{-1}); specific emergy (seJ g^{-1}); and emergy per monetary unity (seJ $\$^{-1}$), usually expressed as seJ USD^{-1}. Brown and Ulgiati (2004) have defined the three main types of unit emergy values.

We consider that these factors are the 'heart' of the ES, because they carry the concept of 'considering all the previously used energy to produce something' and they are essential to obtain the flows in the emergy unit, which is seJ yr^{-1}.

Considering the importance of the emergy intensity factors for the calculation, some suggestions are presented below:

(a) clearly define the procedures for the calculation of the emergy intensity factors (Should the factors be specific for every product, country, year? In the case of transformity, should labor and services be considered? Or should the value be presented with and without labor and services?);
(b) create solid updated databases of emergy intensity factors;
(c) make databases available online for free and for everyone.

Ecological Footprint Factors

EF expresses the use of built-up areas, and the consumption of energy and resources (crops, animal products, timber, and fish) in standardized units of biologically productive area, termed global hectares (gha). Each global hectare represents an equal amount of biological productivity. Productivity does not refer to a rate of biomass production, such as net primary production (NPP). Rather, productivity is the potential to achieve maximum agricultural production at a specific level of inputs. Thus, one hectare of highly productive land is equal to more global hectares than one hectare of less productive land.

Global hectares allow for the meaningful comparison of footprint and biocapacity of different countries, which use and have different qualities and mixes of cropland, grazing land, and forest. Two conversion factors - equivalence factors (constant for all countries for a given year) and yield factors (specific for each country and each year) - translate each of the productive areas from hectares into global hectares.

<u>Equivalence Factors</u>

Equivalence factors represent the world's average potential productivity of a given area relative to the world average potential productivity of all areas. Cropland, for example, is more productive than pasture, and so has a larger equivalence factor.

The equivalence factors for cropland, forest, pasture, and built-up area are derived from the suitability index of Global Agro-Ecological Zones (GAEZ) 2000, a spatial model of potential agricultural yields. GAEZ maps the suitability of agricultural production by optimizing crop varieties with data on soil type, growing season, slope, temperature, and precipitation to a global grid. The GAEZ model assigns a 'suitability index', or measure of potential agricultural productivity, to each grid cell. The National Accounts model calculates an area weighted average suitability index (SI) for primary and marginal cropland, pasture, and forest. The equivalence factor is the ratio of the specific land use SI to the average SI. Normalizing with the area weighted SI sets the number of global hectares equal to the number of physical hectares of bioproductive space.

EF accounts value fisheries according to their capacity to supply animal protein relative to that of grassland (75%). The equivalence factor describes the potential crop yields attainable in an area with an assumed level of inputs such as water and fertilizer, regardless of current management practices or rates of biomass production. Once again, potential productivity differs from measures of ecosystem productivity such as net primary productivity (NPP) in that it describes the land's inherent ability to support agricultural production, and therefore human populations. According to Wackernagel et al. (2005), building the accounts on potentially usable productivity is an advantage, since the methodology has a human-biased focus (consumption and useful natural resources). Using the land's 'potential' productivity at a specified level of technical inputs makes equivalence factors more robust over time, whereas equivalence factors based on actual productivity shift markedly with changes in the intensiveness of agriculture over time, making the interpretation of time series difficult.

Venetoulis and Talberth (2008) criticized the use of the GAEZ model and proposed the use of the net primary productivity (NPP) to estimate equivalence factors. According to them, the factors, which influence biocapacity estimates, fail to take into account substantive ecological and bioregional disparities. Besides that, according to the conventional footprint method as proposed by Wackernagel et al. (2005), one could assume that one hectare of cropland is more 'important' to human society than one hectare of preserved natural forest, since the equivalence factor for croplands is higher than for forests.

<u>Yield Factors</u>

Yield factors describe the extent to which a productive area in a given country/region is more (or less) productive than the average of the same area. Each country/region has its own set of yield factors, one for each type of productive area. Specifically, the yield factor is the ratio between the area a country/region uses in the production of all goods in a given category - i.e. timber from forests, forage from pastures, etc - calculated with national/local yields, and the area that would be required to produce the same goods with world/national average yields. The yield factor reflects prevailing technology and management practices, in addition to the inherent resource productivity of a country/region. In other words, a country's/region's agricultural output per hectare is dependent upon soil fertility as well as harvest methods.

PROCEDURES FOR A SUB-NATIONAL CASE STUDY

As previously mentioned, although both methodologies differ in terms of concepts and procedures, they both try to solve the same issue, which is to estimate the gap between human demand of resources and nature's load capacity.

For a sub-national case study, it is important that global and national levels are well understood and defined, since base values used in local and regional analysis come from broader scale studies. In this item, we will present procedures for the case study of Sao Paulo state in Brazil, using both methods.

Sao Paulo is the most important state of Brazil responsible for almost 40% of the Brazilian GDP and with 40 million inhabitants in 645 municipalities. The State Environmental Agency has been gathering 17 different indicators for an environmental report to be published at the end of 2010, among which ecological footprint is required. Thus, there is an increasing demand and interest on the calculation of that indicator. We also found relevant applying the ES for that case study, in order to compare results, since the raw data necessary for the calculation is basically the same for both methods.

Emergy Synthesis

Full procedures for the emergy synthesis can be found on Brown and Ulgiati (2004). The aim of this paper is to describe the steps for the evaluation, pointing out possible difficulties to be found on the way of the analysis.

(a) *system diagrams* are used to show the inputs that are evaluated and summed to obtain the emergy of resulting flow or storage. According to Brown and Ulgiati (2004), the purpose of the system diagram is to conduct a critical inventory of processes, storages and flows that are important to the system under consideration and are therefore necessary to evaluate. The great idea behind the construction of the diagram can also be a point of controversy. User is given freedom to create the diagram, but this freedom may lead to inaccurate analysis. The construction of the diagram will depend on the user's interpretation of the functioning of the system. It may be valid for a single evaluation, but when dealing with sustainability, comparison between different systems is almost mandatory. In the case of a sub-national case study, the limits of the system under analysis are already defined by geopolitical boundaries. Besides that, it's important to define which inputs (renewable and non-renewable), processes, storages, and outputs are relevant to the system. We believe that there should be 'models' in different scales (national, state, regional, local, etc) to be followed. That would make the diagram's construction and comparison of results easier.

The diagram (Figure 2) shows physical components and economic sectors as well as their interactions (pathways of matter and energy flows exchanged), providing a preliminary picture of internal complexity and dynamics. The pictorial representation of input flows is used to identify and list items to be used in calculation tables. Input resource flows support the development and dynamics of the system as a whole, as well as its component sectors. Resources drive the system and build a network of interaction between the production and consumption parts:

(1) physical components: built-up land, natural parks and public gardens, agricultural areas, resources storages (water reservoirs, biomass, non-renewable, air).
(2) functional components: primary production, manufacture and service sectors.
(3) population: demographic aspects, social status (householders, immigrants), income and other economic aspects.
(4) matter, energy and information flows: energy infrastructure, information networks, economic flows.

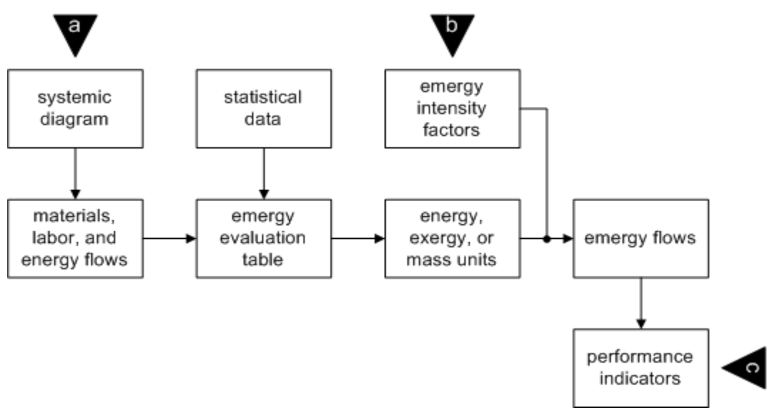

Figure 1. *Procedures for the Emergy Analysis (a, b and c indicate points where a user could find difficulties applying the methodology).*

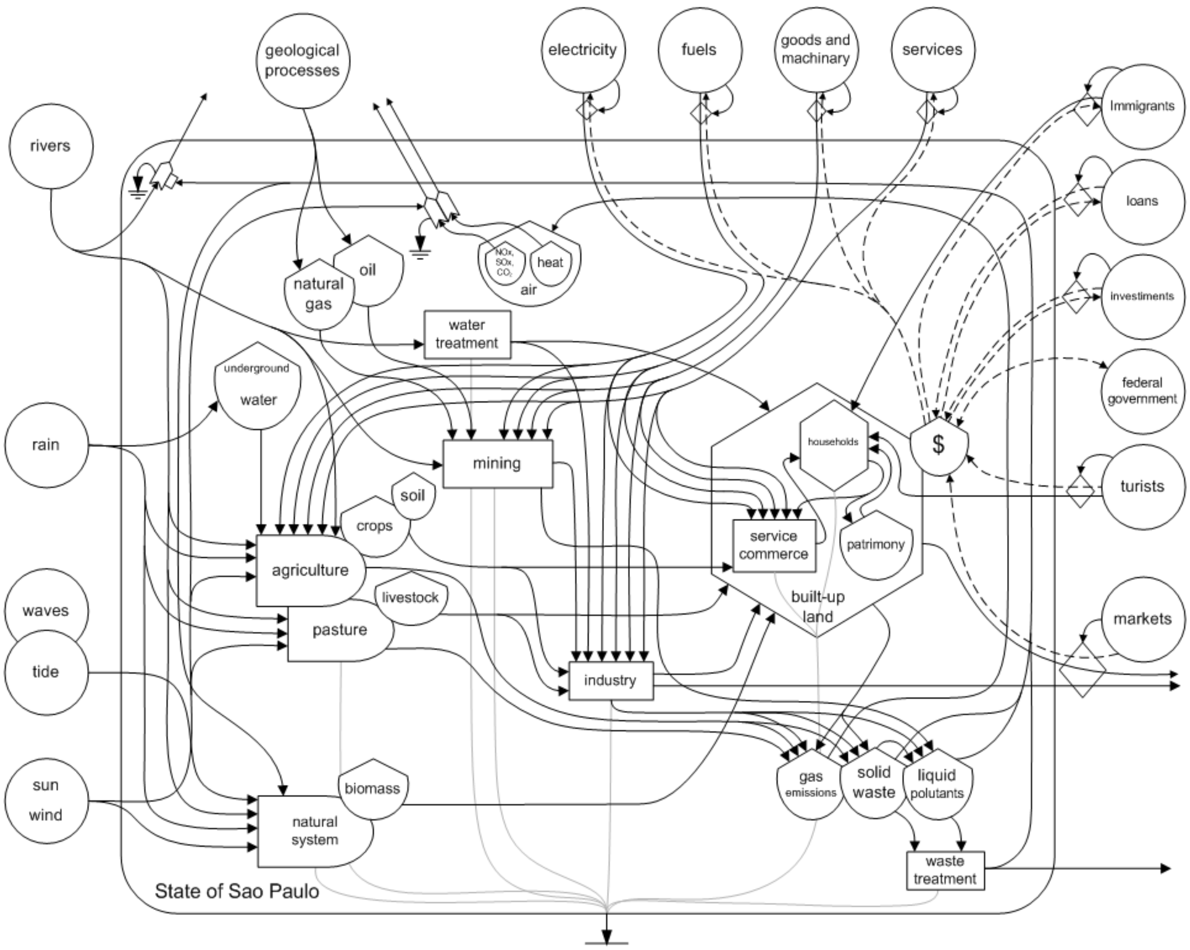

Figure 2. *Systemic diagram for the State of Sao Paulo, Brazil.*

(b) as mentioned before, *emergy intensity factors* are essential to convert all the considered flows of the system into emergy flows. Despite the importance, there is a lack of reliable database for Brazil and Sao Paulo State. Some specific studies are already available for some products: soy (Cavalett, 2008), sugarcane and orange (Pereira, 2008), and sugarcane, peanut, coffee, pasture, eucalyptus, and fruits (Agostinho, 2009). Those studies may be used as reference, since those evaluations were made inside the State of Sao Paulo. In order to be considered and recognizes as a relevant policy tool, ES needs to have an accurate database for emergy intensity factors. If one transformity value is inaccurate, it may completely change the performance indicators, and therefore the final result.

(c) *performance indicators* provide the final results for the ES. There are essential for the understanding of the relations between non-renewable environmental contributions (N), renewable environmental inputs (R), and inputs from the economy purchased as good and services (F). Although they represent the final step of the evaluation, there is still no consensus on how to make them easier and more appealing to decision makers and non-experts. Ortega (2010) proposes the use of renewable and non-renewable fractions in transformity, materials, and services. He also proposes the recognition of the roll of biodiversity, environmental services, and externalities. We believe that more current indicators should be developed in order to relate ES with other methodologies. These new indicators could provide the results in terms of CO_2 emissions, support (impact) area, and valuation of environmental services.

Ecological Footprint

Full procedures for the calculation of the EF of nations can be found on Wakernagel et al. (2005). When applying to a state or region case study, some scale adaptations must be made. As mentioned before, the aim here is not to provide the full procedures, but to discuss and point out possible difficulties to be found on the way of the calculation.

(a) *conversion factors* (equivalence and yield) are still a point of controversy on the methodology. As mentioned before, a lot of critics have been made by Venetoulis and Talberth (2008) and van den Bergh and Verbruggen (1999) concerning this particular issue. Equivalence factors seems to be the biggest problem in this case: the model developed to estimate these factors (GAEZ 2000) considers that land used for crop production is more important to humans than forest land for example. A studied made by Siche et al. (2010) used NPP and emergy to estimate those factors, and showed that using that approach, forests have bigger factor values than cropland. Wackernagel (2009) recognizes the need for improvements and deeper studies for some weak points of the methodology.

(b) in order to apply the methodology for a sub-national case study, *scaling factors* are essential to convert national footprint into state or region footprint on the *top-down* approach. This kind of approach considers the national accounting as the basis for the smaller scale analysis. All the national data must be compared to state data, according to defined categories. Depending on the difference among those data, scaling factors are used to increase or decrease the national factors in order to obtain the state footprint. So if a category such as food is compared for Brazil and Sao Paulo, and it's shown that people from Sao Paulo consume 10% more food than an average Brazilian, then the scaling factor for that category should be 1.10. The difficulty here is to compile all the national and state data available within the same categories, so they can be compared.

DISCUSSION

Ecological footprint and emergy synthesis are methodologies that provide a glimpse on the environmental side of the sustainability issue. Both should not be considered as definite methods. It must be realized that in no circumstance can a single method be sufficient to provide comprehensive information on environmental impact assessment, and that analyses based on only one approach invariably end up providing partial and sometimes even counterproductive indications.

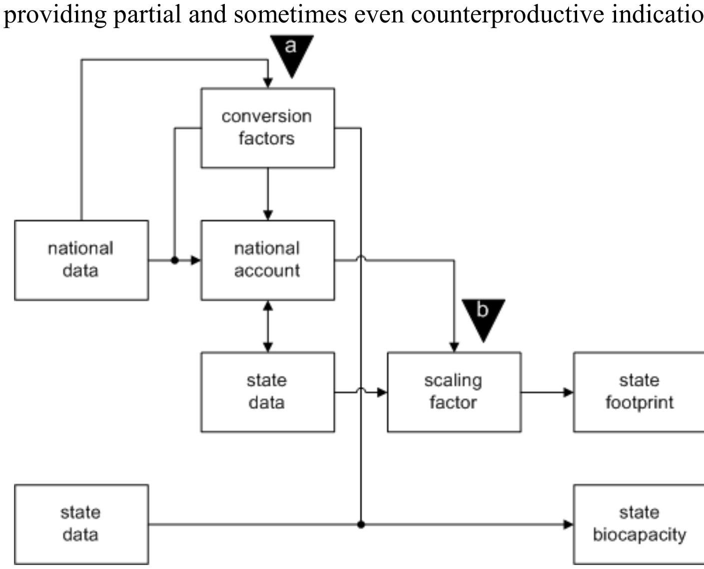

Figure 3. *Procedures for the Ecological Footprint (a and b indicate points where a user could find difficulties applying the methodology).*

Attempts have been made trying to combine the methodologies. The final goal was to arrive at some hybrid indicator, which is then expected to provide a definitive answer. In most cases, though, those indicators have carried the original methods' deficiencies.

Although both concepts and methods are used for the study of the human interface with the ecological system, they are grounded on different theoretical basis and for different purpose. Emergy synthesis may have a wider application, since it provides a series of indicators that could be also used to obtain economic and social indices. It could also include an indicator based on ecological footprint: some results may be converted into area units, using the emergy density as a factor. Some examples of work in this field are presented in Table 1.

Table 1. Strong points and shortcomings of Ecological Footprint, Emergy Synthesis and other approaches derived from both.

Methodology	Reference	Strong points	Shortcomings
Ecological Footprint	Wackernagel and Rees (1996)	(a) Widely used tool; (b) Has a didactic way of showing results; (c) Normalizes different types of productive areas; (d) Allows categories within Footprint and Biocapacity to be compared.	(a) Equivalence Factors based only on agricultural production; (b) Accounts for each type of area only once, even if the area supplies more ecosystem services; (c) Does not consider aspects such as top soil loss, water use and embodied energy; (d) Excludes areas with low biomass productivity (energy footprint is entirely based on forest carbon sequestration rates); (e) There is no difference drawn between renewable and non-renewable land use; (f) Equivalence Factors and Yield Factors are not easily available; (g) Does not incorporate the work done by nature in the production of natural and human resources.
Emergy Synthesis	Odum (1996)	(a) Allows accounting for additional flows that influence sustainability, such as waste, soil loss, human-labor, water use; (b) Takes into account every contribution from nature and human economy in order to know the relative importance of each resource; (c) All the energy memory is embodied in its Emergy Intensity Factors, and not only commercial energy; (d) Uses systemic thinking as fundamental theory base; (e) folios with several emergy intensity factors are available at www.emergysystems.org, but their quality should be assessed.	(a) Does not define a sustainability indicator (ESI, %R or both) and its sustainability boundary; (b) Lacks in available Emergy Intensity Factors with good quality (updated, standardized numeraire, etc); (c) Does not consider flows from internal natural capital storages, even if it is essential for national economy; (d) Final indicators need closer analysis to be fully understood; (e) There are no clear standards for calculation procedures, mainly those related to what is considered as external resources of the system.
Ecological Footprint 2.0	Venetoulis and Talberth (2008)	(a) Uses Net Primary Productivity as basis for the EQF's (ecologic biased approach); (b) Considers the importance of the whole planet, i.e. includes the entire surface of the Earth in the Biocapacity calculation; (c) Recognizes the importance of the preservation of biodiversity (13.4% of the total Biocapacity).	(a) Assumptions about CO_2 sequestration rates result in higher values of Footprint and Biocapacity for the energy category (other categories' values are despicable if compared to energy's in this case); (b) More precise NPP values should be used instead of averages; (c) Recognizes the importance of other impact categories as soil loss and water consumption, but it does not estimate them.

Table 1. Continued.

Methodology	Reference	Strong points	Shortcomings
Ecological Footprint based on Emergy	Zhao *et al.* (2005)	(a) Introduces Emergy Synthesis into the Ecological Footprint framework, trying to merge strong points from both methodologies, mainly embodied energy theory and easy-to-understand final indicators; (b) Conversion factors from emergy flows to land area are based on emergy density; (c) Consider low biomass productive areas in the calculation procedure.	(a) Does not present the systemic diagram for the case study; (b) Does not detail how the Emergy Intensity Factors were taken or modified from the source, neither if they include labor and services; (c) Categories within the Footprint and Biocapacity can't be compared; (d) Uses GED (Global Empower Density) for the Biocapacity calculations and LED (Local Empower Density) for Footprint, resulting in errors when comparisons between them are made.
Emergetic Ecological Footprint	Chen and Chen (2006)	Basically uses Zhao's et al. (2005) methodology, however, GED (Global Empower Density) is used for Biocapacity and Footprint calculations.	(a) Does not present the systemic diagram for the study case; (b) Uses the value of 9.44 10^{24} seJ yr^{-1} (Odum, 1996) for global emergy input, which is not in accordance with Zhao et al. (2005), who used an updated value of 1.583 10^{25} as proposed by Odum et al. (2000); (c) Does not detail how the Emergy Intensity Factors were taken or modified from the source, neither if they include labor and services.
Ecological Footprint based on Emergy NPP	Siche *et al.* (2010)	Basically uses Venetoulis and Talberth's (2008) approach, but (a) Equivalence factors are calculated using Emergy Net Primary Productivity, and (b) water consumption is considered as an impact category.	(a) Lack of systemic diagram for the study case; (b) There is a need of Emergy Intensity Factors with good quality; (c) Only seven Emergy Intensity Factors for NPP were considered in the equation that correlates them with NPP in mass.
Ecological Footprint using Emergy Synthesis	Pereira and Ortega (2011)	(a) A new definition for Biocapacity is introduced meaning "the natural area's capacity of receiving renewable energy", rather than "usable biomass" as proposed by the conventional Ecological Footprint methodology; (b) Instead of using an average value, uses individual renewable input values for the Biocapacity of each biome and productive system of the country; (c) Adds the "spaces not occupied by human" category in the Biocapacity; (d) considers the total area of the system analyzed; (e) Diagram is presented for better understanding of the system under analysis; (f) Emergy flows for Biocapacity and Footprint are converted into area units by the GED (Global Empower Density), which made it possible to compare them; (g) Its application is easy in global and national scales due to available data; (h) Its final indicators accounts for all the previous energy used to make the products.	(a) Footprint and Biocapacity categories cannot be compared; (b) There is a need of Emergy Intensity Factors with good quality.

Table 1 shows some strong and weak points of emergy synthesis and ecological footprint. It should be pointed out that the objective of Table 1 is not to list a complete and detailed comparison between the approaches, but only to show the main aspects that we consider important. Maybe, some points we have considered as shortcomings, other experts could assign as strong points, and vice-versa. Scientific wrks that have deeper discussed emergy synthesis' and ecological footprint's weak and strong points moay be found in Sciubba and Ulgiati (2005), Siche et al. (2009), Venetoulis and Talberth (2008), Wackernagel (2009).

In spite of this advantage, emergy still has not reached decision makers and the general public with the same strength as the ecological footprint has. In this sense, clear procedures, standards and good quality database could help emergy become a more accepted methodology.

CONCLUSION

As the concept of sustainable development is more accepted and incorporated by the institutions, it becomes necessary to evaluate economy's performance based on new methods and not only on economic indicators. There's an urgent need for reliable assessment and evaluation methods alternative to neoclassical economics.

It's possible to apply the EA for the case study of the State of Sao Paulo, but if there are no standards, accurate data and factors, the work may end up being merely academic. Standards should be developed through a consensus procedure and be applicable to all emergy studies.

On the other hand, despite the critics, EF standards are clearly defined and available. The databases for all the countries are available for sale and results are published every year. The power of the indicator is that anyone understands the concept of space, because it is simple and intuitive.

We consider that criticisms are very important to improve the methodologies and to make them more useful and widely used, but they should be made in a scientific-based and friendly way. More and more, there is a consensus that there is no super-powerful tool that could provide reliable sustainability indicators. In the case of ES, lack of addressing the shortcomings may prevent emergy from being recognized as both a suitable scientific and policy tool.

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