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Environmental impact assessment of land use systems using emergy in Teresópolis-Brazil

Torrico J C * [a], Janssens M [b]

[a] University of Applied Sciences Cologne - Institute for Technology and Resources Management in the Tropics and Subtropics, Betzdorferstr 2, 50679, Köln-Germany.

[b] University of Bonn, Unit of Tropical Crops. Sechtemer Straße 29, D-50389-Wesseling-Germany.

* Corresponding author : juan.torrico@fh-koeln.de

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Abstract

This paper provides a set of indices based on emergy analysis for the Côrrego Sujo basin, Teresópolis-Brazil. Encompassing natural and agricultural systems, the Côrrego Sujo basin has been affected by destruction and fragmentation of natural habitats and unsustainable land use practices. The main objective is to evaluate the environmental impact of the land use systems, the load capacity and the use of natural and economic resources. The studied land use systems were: i) agriculture, ii) grassland and cattle, iii) rainforest and iv) forest in regeneration stage (fallow: 1, 2 and 3 years old). Emergy analysis integrates all flows within a system of coupled economic and environmental work in common biophysical units (solar emjoules – seJ). The main conclusions of the study are: the basin does not have dependence of purchased resources and the environmental impact is moderate; the efficiency of the basin as a system is highly positive and it represents a positive contribution to the economy; the emergy exchange ratio is moderate and; the biggest contributions to the system come from natural sources showing that the ecological sustainability is moderate to good.

Introduction

After the UN Convention on Biological Diversity of Rio de Janeiro in 1992 there was increased concern and interest in internalizing environmental costs (Kumar *et al.* 2004 and Mota 2000). The intrinsic value of natural resources like soil as a contribution to national, regional and local economic productivity is not adequately recorded in financial planning and decision making. As a consequence, long-term sustainability is challenged by degrading natural resources (Cohen *et al.* 2006), and by improper functionality of ecosystems. There is also a need to develop quantitative tools that can be used to support policy makers (Bouman *et al.* 1999), to understand the functions of natural systems and to identify alternative state within agricultural systems.

The Atlantic Forest, or Mata Atlântica, is one of the worlds most outstanding and most threatened ecosystems (Myers 1990; Myers *et al.* 2000; Mittermeier *et al.* 2005). On the one hand it hosts an enormous structural, floristic and faunal diversity comprising a high degree of endemism at all levels of organism organization (Fonseca *et al.* 1999; Kinzey 1981; Morawetz and Krügel 1997; Mori *et al.* 1981; Prance 1987). On the other hand, its destruction since the beginning of the colonization of South America has led to a dramatic reduction and fragmentation of the ecosystem (Bertoni *et al.* 1988; Dean 1996; Leitão Filho 1987). Of the five South American biodiversity hotspots the Atlantic Forest is the most densely populated one and comprises the smallest portion of protected areas (Mittermeier *et al*. 2005). Today agricultural landscapes, different land use types and some of the biggest Brazilian urban agglomerations are embedded in the area once almost continuously covered by the Mata Atlântica.

The reduction and fragmentation of natural ecosystems by anthropogenic impacts have elevated the rate of species extinction by one thousand times the natural background rate (Pimm *et al*. 1995). Physical and chemical qualities of landscapes have been affected by the destruction and fragmentation of natural habitats and unsustainable land use practices. Soil erosion and landslides are natural processes but have been intensified by man made degradation (Augustin 1999; Coelho Netto 2003). Other parameters affected by anthropogenic landscape transformations are soil and air quality as well as surface and groundwater availability and quality. In turn, the negative effects of man made habitat destruction are impairing the productivity of land use systems. In spite of this, the importance of ecosystem services are not sufficiently recognized and appreciated by the society (Tonhasca Jr. 2005).Accelerating anthropogenic climate change is likely to magnify the effects of habitat destruction and fragmentation (Thomas *et al*. 2004). Its specific effects on biodiversity have yet to be assessed for most of the biodiversity hotspots (Midgley *et al*. 2002). In general, ongoing climate change is affecting the vulnerability of ecosystems and land use systems at economic, social and environmental level (Parmesan and Yohe 2003; Rahmstorf and Schellnhuber 2007). Therefore, the evaluation of related risk and resilience potential considering climate change scenarios is useful for developing concepts, strategies and instruments for sustainable natural and agricultural resource management and conservation. Trade-off and synergy analyses help to identify alternative sustainable states, as a multidisciplinary organizing principle and a basis for conceptual modelling to design and organise research and development projects in order to quantify and assess the sustainability of agricultural production systems (Crissman *et al*. 1998).

The objective of this paper is therefore to evaluate the environmental impact of land use systems; including the load capacity[1] and use of natural and economic resources, using the emergy methodology in Teresópolis, Rio de Janeiro.

Comparing agro-ecological systems

When comparing agricultural and natural systems, or mixed systems combining the latter two components it is difficult to find appropriate yardsticks. When using monetary methods in farming systems analyses one is left with a double difficulty, viz.; (i) only the saleable output of agricultural systems will be taken into account, leaving some of the production side effects unaccounted for like e.g. soil improvement or degradation, erosion control, biomass residues left in situ, rotation effects etc; and (ii) most of the ecosystem services are difficult to monetize.

[1] The load capacity is an indicator of the load on the environmental and might be considered a measure o stress due to economic activity

When adopting biomass as a yard stick some comparisons are possible to do although the reduction of crops or vegetation to dry weight is somewhat clumsy as there is not such a thing as dry biomass to be observed on a farmer's field or in natural vegetation, not to speak about the irrelevant reduction of animals or even human beings into dry weight "items". However, biomass appraisals give us important information as to the photosynthetic potential of agro-ecological systems as e.g. litter fall, net primary production (NPP), carbon sequestration etc. Some comparisons are easier to do by using spatial parameters. Foresters like to use basal area of a forest stand as an indicator of growth and biomass capital. Other spatial parameters have been proposed like eco-volume, bio-volume contending that living plants and animals are acting as visible volume units. The bio-volume of plants and animals is closely related with their fresh weight. West *et al*. (1997, 2001) proposed the universal law of biology stating that there exists a universal relation, valid for all living organisms, between metabolic energy rate, E and fresh biomass, M as follows (West *et al*. 1997, 2001, also referred as the WBE model):

$$E = kM^{3/4}$$

Where E = metabolic energy of a living organism
M = fresh weight of a living organism
k = specific coefficient for each species

After log transformation, all organisms, plants or animals, line up linearly. However, this approach cannot consider inert components or physical attributes of the surrounding environment. This leads us into parameters of energy for comparing different agro-ecological systems. Energy is a relevant parameter to study the sustainability of systems. It is also, essential to most human activities, including agriculture. Too much energy means wastage, global warming and other environmental pressures (Simoes 2001). Energy might be more sensitive and a concrete indicator in guiding us for better resource allocation (Wilson 1974, Chou 1993). Resources of agricultural production can also be discussed in terms of land energy and labour (Doyle 1990). Agriculture can also be defined as an alternate process of concentration and dilution of energy and resources (Janssens *et al*. 2011). The increased productivity by hectare leads to a decline of energy use efficiency. Intensive production brought a high dependence on inputs from non-renewable resources. Systems analysis of agricultural production is the first step to study this situation (Hill 1976). Since life is basically, an energy transforming process, energy issues are central to sustainability. "Everything is based on energy. Energy is the source and control of all things, all values, and all actions of human beings and nature", according to Odum & Odum (1976). While social and economic sustainability certainly are essential and highly desirable, energy processes and limitations set definite bottom lines (Jansen 2000). Energetic output to input ratios are widely used (Pimentel 1989). Many cropping systems have ratios being lower than one. However, it is difficult to incorporate values for eco-system services.

The emergy analysis method

The emergy analysis method was selected as a method to study the different agricultural systems in Teresópolis because it provides a general category i.e. emergy, for measurement of heterogeneous flows within the ecosystem, as well as an instrument to account for interactions between physical flows in nature and the economy and monetary flows within internal and external markets of natural resources and goods (Odum 1986, Odum 1996, Odum 1998). Emergy can be considered as the "embodied or embedded energy" for each component of a system i.e. the total sum of energy of a given kind required to achieve this component. For the sake of easy comparison, energy of solar origin is used as yard stick and expressed as seJ (solar embodied joule). Hence, the solar constant amounting to 1350 W m^{-2} i.e. the energy/time/area/wavelength vs. wavelength received at the top of the Earth's atmosphere from the sun is equivalent to 1350 seJ and will release 1350 Joule of available sun light energy. This situation is for a portion of the Earth where the sun's rays are straight overhead. Note that by far most of the energy occurs in visible wavelengths. Above solar transformation ratio between 1350 seJ and 1350 J has been called solar "transformity" (in seJ/J). Solar energy has a solar transformity of 1. Other examples of solar transformities are given by Vito *et al.* (2004). Emergy evaluation is an environmental accounting method that addresses the issue of environmental and economic sustainability by quantifying the total amount of natural resources that nature spends (i.e. dissipates) and the total amount of economic resources are consumed to produce a product or operate a service (Tilley 2010, Vito *et al*. 2004) . A history and review of applications of the emergy method was given by Brown and Ulgiati (2004).

Due to emergy's ability to compare environmental and economic resources used in agricultural production, emergy analysis can assess a system's sustainability based on indices that relate the free work of nature based on renewable inputs to non-renewable resource consumption, agricultural yield and economic investment. A fundamental assumption of emergy analysis is that the worth of a contributed resource to agricultural production is proportional to its solar emergy, i.e., the total amount of solar energy dissipated directly and indirectly (Brown and Herendeen 1996).

The emergy theory also has been criticized and observed by several authors like Spreng 1988, Mansson 1993, Ayres 1998, Cleveland et al. 2000 the most criticized points are (i) that emergy theory of value ignores human preference and demand. (ii) There seems to be much confusion about the relationship between emergy and other thermodynamic properties. (iii) It is difficult to know the inputs and processes over a long period of time like from the prehistoric period onwards. (iv) Problems of quantifying transformation units. (v) Tenuous physical and biological foundations to assign monetary values to ecological products and services.

The same critics have been refuted by (Patten 1993, Odum 1995a, 1995b), who says that emergy method provides a bridge that connects economic and ecological systems. The economic and ecological aspects can be compared on an objective basis that is independent of their monetary perception. Emergy analysis provides an ecocentric evaluation method.

It is scientifically sound and shares the rigor of thermodynamic methods. Emergy analysis recognizes the different qualities of energy or abilities to do work. Emergy analysis provides a more holistic alternative to many existing methods for environmentally conscious decision making. Emergy analysis can quantify the contribution of natural capital for sustaining economic activity.

There are not many methods to analyze agro-ecologically the farming systems and compare each other in a holistic form, some of the alternatives to emergy methods could be thermodynamic variation as energy and exergy analysis, discussed in Nilson (1997) and Bastianoni & Marchettini (1997), biomass balance (Janssens *et al.* 2009). Multivariable analysis combined with systems analysis, this method implies a lot of input data including some social, physical, economical, environmental, etc. (Grace 2006), information that are not available in the study region. Another common used method is the economical analysis, alone this method doesn't say too much about the environmental behavior of the system. Other fast assessment method could be agroclimax evaluation, discussed in Janssens 2009.

Material and Methods

This study was carried out in the Côrrego Sujo basin, Rio de Janeiro, from April 2003 to December 2005. Emergy analysis was used to compare the main land use and natural systems in the municipality of Teresópolis within the mountain region of the Atlantic Forest. The studied systems were: i) agriculture, ii) grassland and cattle, iii) rainforest, iv)forest in regeneration stage (fallow: 1, 2 and 3 years old). The results of those analyses in the Côrrego Sujo Basin were extrapolated to the whole municipality of Teresópolis.

Procedure of emergy evaluation

The procedure for emergy evaluation is described and summarized by Haden (2003) in three steps: the first consists of drawing the energy system diagram (Figure 1).

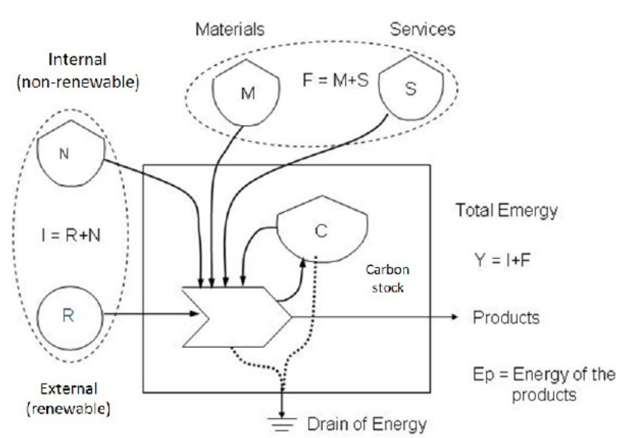

Figure 1. Aggregated emergy input and outputs from the economy (service and materials). and renewable and not renewable resources from natural systems.

The second elaborates the emergy evaluation table and the third is calculating the emergy indicators and the summary diagrams. The summary diagrams show all aggregated emergy inputs from the economy as service or materials and from natural systems in the form of renewable or non renewable resources.

In Figure 1, R is the sum of the renewable emergy flows supporting the economy (i.e. rain, waves, tide); N is the sum of non-renewable resources from within the system (national) boundary; M is the sum of all materials used by or paid for in the system; S is the sum of all services used by or paid for in the system; Y is the total consumed emergy; Ep is the total energy produced from the system and C is the natural capital of the system (biomass, biodiversity, water, soil fertility, etc). After tabulating the material and energy flow data for the system in question and calculating their emergy contributions using transformities, a number of emergy ratios and indices can be calculated. The indices are used as expressions of the sustainability of the "Côrrego sujo" are described in Table 1.

Table 1. Summary of the emergy indices used in this study

Indices	Form	Description
Emergy Yield Ratio	EYR = Y/F	Evaluates the efficiency of a production unit or process. If the relationship is smaller than 1 the system consumes more than it produces
Environmental Load Ratio	ELR = (N+F)/R	A measure of environmental impact. A high value indicates heavy dependency on non renewable energy sources
Emergetic Investment Ratio	EIR = F/I	Measures the dependence of the system on purchases material and services, and indirectly measures the environmental loads
Emergy Exchange Ratio	EER=Y/income*3,18E12	Measures the capital loss of the system. If the value is lower than 1, it means that the system transfers positively to the urban economy
Transformity	Tr = Y/Ep (sej/J)	Is the amount of energy (expressed in sej/J or sej/g), which has been used to create a flow or resource
Renewability	%R = R/Y*100 (%)	Indicates the percentage of renewable emergy in relation to the total emergy used from the system

Source: Adapted from Odum (1996)
sej= Solar energy expressed in Joul
3,18E12 = Setting value regression of Brazilian GDP

Results and Discussion

Description of land cover and land use in the Côrrego Sujo basin

Land cover: Forest occupies largest area with 36.2%, followed by the grassland (31.1 %), bushland (18.8 %), bare rocks, open areas, settlements (11.4%), with 2.6 % of the latter been crop area (Figure 2). In general the mountainous area is dominated by three vegetation types, the first being fragments of the Atlantic forest found in the higher parts or on steep slopes; the second being composed hillside pastures where *Brachiaria decumbens* dominates, and in some cases completely covers the hills; and the third being agriculture in the river-valleys. Much of the grassland features active regeneration and eventually ends up as schrubland (Capoeiras). The dominant land cover types are described in Table 2.

Table 2. Dominant land cover types in the municipality of Teresópolis

Land cover	Description
Mature vegetation type	Presence of species older than 30 years, high presence of epiphytes and lianas, with closed canopy. This corresponds to most of the PARNASO National Park and some fragments
Immature forest	Prevail emergent species, little presence of epiphytes. Most occurrence in small fragments

Table 2 continuation.

Land cover	Description
Early stage forest vegetation	Lacking epiphytes, grasses prevail with bushes and herbaceous plants up to 4 meters high. Many abandoned pastures more than 5 years unburnt
Grassland and shrubland	Presence of clean areas with grassland used for grassing in some cases with shrub layer
Agricultural	Horticulture predominance, dominated by leaf vegetables and some citrus
Waterlogged	*Typha domingensis* dominates; characteristic waterlogged land. In addition to conservation areas and the National Park, around 212 fragments which have an area average of 12.8 ha are observed in the region

Land use description: The watershed that is the focus of this study, "Côrrego Sujo" has a surface of 5,323 ha, divided in 8 river basins to facilitate the data collection. The land use illustrated in Figure 2 was derived from digitalized satellite "Iconos" images.

Agriculture in the region is characterized by intensive, small (less than one ha) but often irrigated horticultural production systems. This horticultural system has little or no interaction with the grazing (cattle) or forest subsystems. Inputs such as organic and inorganic fertilizers are used in both grazing and horticulture systems. Most of the seedlings are produced locally in specialized nurseries. Products are marketed through different channels, primarily via agents who take the production to the surrounding markets. Most producers units generally diversify the production as a market strategy, because the prices on the markets are very fluctuant.

The average stocking rate is 11 cows per 10 ha. This was found in a range from 2 to 67 cows per 10 ha. In the humid season the average milk production is 7.5 l day^{-1}, and in the dry season of 4.5 l day^{-1}. After 40 months of fattening, livestock production is approximately 165 kg of clean meat/head that are marketed through agents and sold in local markets. The remaining 24% is occupied mainly by horticultural systems. The intensive horticultural system is the most important economic activity and occupies circa 403 ha. Mainly five types of horticultural systems exist in the region and are summarized in Table 3.

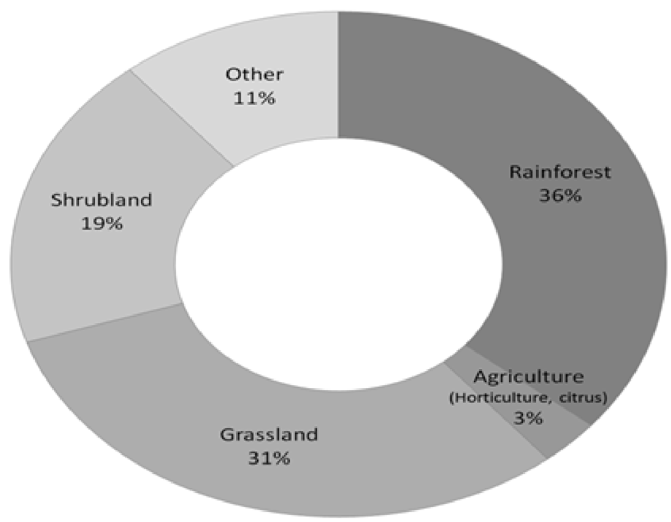

Figure 2. Land use types in Côrrego Sujo basin

Table 3. Summary of the main types of horticultural systems in the Corrego Sujo basin

	Organic farm	Fruit vegetables	Leaf vegetables	Mixed vegetables	Citrus
Proportion of horticultural area	2	20	58	15	5
Quality of seed stock	high	high	very high	very high	high
Fertilizer use	none	high	high	high	low
Pesticide use	none	high	high	high	none
Herbicide use	none	moderate	moderate	moderate	none
Irrigation	low	high	high	high	none
Principal product	diversified	*Sechium edule,* tomato	salad, cabbage	*Sechium edule,* salad	mandarin

The organic system combines a variety of crops and forest species, annual crops such as cassava and sweet corn with vegetable crops such as lettuce, green onion and cauliflower.

Of the 2,954 horticultural establishments in Teresópolis a little more than 2,500 have viable conditions for agricultural production. Manpower is sufficient to increase cultivation area or intensify production. On average there are three people per farm unit, totally dedicated to production. The population growth in the region has remained constant in recent years at least 1% annual growth (IBGE 2010).
Some other agricultural systems and plant communities present in the region are:

Sylvopastoral systems: It is the combination of pastures with trees. In addition to live fences, trees dispersed in pastures are the most common and most traditional silvopastoral system found in Teresópolis. The density of trees in pastures varies from zero, to approximately 30 or more per hectare. Few farmers permit greater than 25% canopy cover in their pastures fearing that greater tree cover will diminish the amount of pasture produced. The most important species are listed in Torrico (2010).
Agroforestry systems: The studied agroforestry systems correspond to horticultural crops combined with some trees. The crops are mostly horticultural crops listed in Torrico (2010).
Ecological systems: Is a type of agroforestry system, which combines intensively trees and crops, we account for this system diversity index of H=3.19, richness index R=96, dominance index 1-D=0.93. Those indices indicate that the system manages more agrobiodiversity inside the system. Species are listed in Torrico (2010).
Short rotation crop: Crops that complete their agricultural cycle in less than three months. Examples are presented in Torrico, 2010.
Perennials crops: Plants that persist for more than 2 growing seasons, in the region Citrus, banana, piper.
Shrubland: Plant community characterized by vegetation dominated by bushes, including grasses, herbs, and geophytes, shrubland species are listed in Torrico (2010).
Grassland vegetation: Dominated by grasses (*Brachiaria decumbens*) and other herbaceous plants.

Emergy evaluation

The data for the Côrrego Sujo basin shows in general that the consumption of materials and services expressed in emergy terms is very low in comparison to the total emergy used in the basin. Figure 3 shows the pathways of emergy flows in the Côrrego Sujo basin - Teresópolis. This is explained by the area, approx. 1.8% occupied by intensive horticulture dependent on inputs coming from the small economy. The largest source of emergy is from natural renewable and not renewable sources, mainly in form of water, minerals and organic matter (Table 4). The basin has a high capacity to store biomass and in emergy terms its value is $2.1x10^{18}$ seJ[2] . The loss of organic matter (3.5% average soil content) through soil erosion for the whole basin equals to $2.38x10^{19}$ seJ, which in economic terms this would represent between 1.7 and 4.9 million dollars per year.

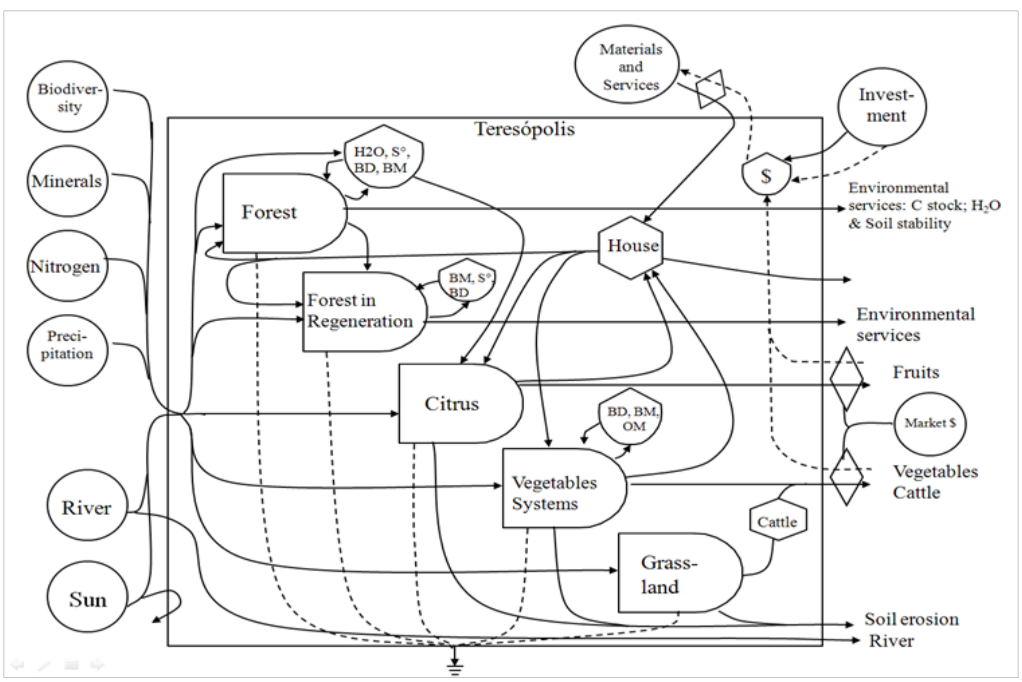

Figure 3. Overview of emergy flows in the Côrrego Sujo basin – Teresópolis, showing the coupled ecological-economic system. Depicting resource flows entering the system and the organization of major internal components that use those resources. BD: Biodiversity, BM: Biomass, OM: Organic Mater.

2 sej=Solar Energy Jouls or embodied solar equivalents (sej) and later called “emergy” with nomenclature (seJ)

Table 4. Summary of the yearly emergy flows for agriculture in Côrrego Sujo basin.

Name of flow	Quantity (x 10^{17} seJ)
Local renewable sources (R)	318
Local non-renewable sources (N)	238
Purchased resources (M)	0,41
Services and labor (S)	0,04
Emergy Yield (Y)	556
Feedback from economy (F = M + S)	0,45
Biomass saved in system	21,7

The principal renewable flows are sunlight, rainfall and minerals. Purchased goods, fertilizers, fuels, and services are also shown. Internal production systems include forests and forests in regeneration (1 to 3 years old), citrus orchards, intensive and organic farming and livestock. The aggregated data are shown in Figure 4.

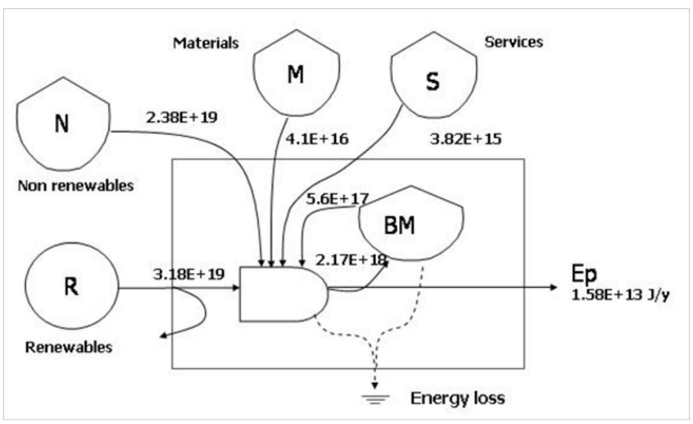

Figure 4. Overview diagram showing the main pathways of emergy flows in Côrrego Sujo agriculture. (Ep: total energy produced and BM: accumulated Biomass)

From Table 5 it can be deduced that in general the basin is not level dependent on purchased resources (EIR 0.001). The sources from the economy (material and services) increase the environmental load indirectly because great quantities of non-renewable sources are used to manufacture. The environmental impact is moderate (ELR 0.75) as the system makes high use of renewable resources. The efficiency of the basin as a system is highly positive (EYR 1234) indicating that it contributes considerably more emergy to the economic system than what it takes in form of materials and services. The EER of 3.05 indicates that there is a loss of natural capital from the system, as it exports emergy to the urban systems at a moderate to average level. In general, the basin considered as a system is characterised by a moderate renewability (% R = 57) indicating again that the biggest contributions come from natural sources, and showing that the ecological sustainability is moderate to good.

Table 5. Computed transformity and emergy indices for the Côrrego Sujo Basin.

Description	Value
Transformity (Tr, sej J^{-1})	1,8 x 10^5
Net emergy yiel ratio (EYR)	1234
Emergy investiment ratio (EIR)	0,001
Enviromental loading rate (ELR)	0,750
Renewability (% R)	57,00
Emergy exchange ratio (EER)	3,050

From Table 6 it is possible to appreciate that the biggest positive impact assessed using emergy indices was achieved through the replacement of the cattle production by biological farm systems. In this case, the use of non renewable energies decreased considerably at a rate of 1.17 x10^{15} seJ $ha^{-1}yr^{-1}$. This value was derived primarily from reduced soil erosion with 3.5% of organic matter. In economic terms this means 0.3 to 0.8 million dollars $year^{-1}$ are spent on non-renewable energy in the whole basin, which is considerable for such a small area, representing about 50% of the annual investment in the basin. Substituting these cattle systems for organic horticultural systems could improve many of their indices, e.g. from an economic aspect revenue is multiplied between 4 and 12 times, ecologically the negative impact decreases, and the stock of carbon and biomass increases considerably.

Table 6. Sensitivity analysis for the water-basin Côrrego Sujo: alternative systems to existing cattle production.

Alternative systems to existing cattle production	Variable Change			
	%R	EER	Economic	ELR
Ecological or organic systems	+++	+	+	+++
Intensive vegetable systems	+	- -	+++	0
Citrus	+	0	+	+
Forestry	++	++	++	+++
Fallow	++	+	-	++

(+) low positive impact; (++) middle positive impact; (+++) high positive impact; (-) low negative impact; (--) middle negative impact; (o) neutral

The ecological and organic systems increase the renewability (%R) of the whole system considerably, more than following the forestry or systems with a middle positive impact. The capital losses from the system (EER) increases when cattle production is changed to intensive vegetable systems, but remains neutral with a shift to citrus production. The use of natural resources (ELR) increases under ecological or organic systems and forestry.

In Teresópolis, annual agricultural crops and short rotation perennials (mixed systems) tend to have the greatest economic productivity per hectare per year but have marginal or even negative returns when expressed in emergy terms due to inputs for soil preparation, fertilizing and harvesting in accordance with Holgrem (2003) who studied crop rotation and its effect on emergy ratios. Long rotations and low input plantation and natural forestry (organic-farm) have lower economic productivity per hectare per year but can more easily be managed in a sustainable way and finally, can be grown on marginal land too poor for food production. These advantages show up as high emergy yield ratios Farmers that organize their operations by drawing on high yield emergy sources (vegetable systems) are able to displace their fellow farmers who continue to organize their farming systems around local renewable emergy flows

The results from analyses of the vegetable systems demonstrated the increased yield per area resulting from investments in high energy resources (e.g. fertilizers, services). However, the dependence on these inputs reduces the fraction of renewable energy and increases environmental degradation, making these systems less sustainable relative to systems more dependent on renewable energies.

Dependence on non-renewable energies for larger yields may be a good strategy when non-renewable energies are readily available. However, when non-renewable energy sources are no longer available, or environmental degradation prohibits their use, agriculture will need to be reorganized to rely on the limited flow of renewable resources.

Conclusions

a. The landscape is dominated by three components: forest including (fragments, 36.2%), grassland (31.1%) and forest regeneration (18.8%). This landscape tends to change slowly, will being replaced pastures either by horticulture or in areas with steep slop, by forest regeneration. The cropped area is only 2.6% of the total available land.

b. The emergy exchange ratio is moderate as the largest contributions to the system come from natural sources, resulting in a level of ecological sustainability that is moderate to good. The largest contributors to sustainability are the organic or ecological agricultural systems they are the only ones that have the capacity to save capital in form of biomass. These systems use fewer resources from the economy and depend more on natural renewable resources, which guarantee its sustainability. They ensure the survival of the producer throughout the time and the preservation of biodiversity.

c. The substitution of cattle systems for any other agricultural or forest system represents clear gains economic and environmental. The best options were the organic and forest systems.

d. The basin is not dependant on purchased resources and the environmental impact of production systems is moderate. The efficiency of the basin as a system is highly positive and represents a positive contribution to the economy.

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