Systemic behavior of a Brazilian municipality whose economy is based on agricultural commodities

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Abstract

The municipality evaluated is São Gabriel do Oeste, located in the state of Mato Grosso do Sul, Brazil. In the 1960's the region was occupied by migrants from southern Brazil who have converted native vegetation (savanna) into extensive cattle and monocrops (coffee, cotton, soybeans and corn, successively), and more recently intensive swine was introduced. The following emergy indicators were calculated for the current municipal situation: Renewability (%R): 8%; Emergy yield ratio (EYR): 14; Emergy investment ratio (EIR): 0.08; Environmental loading ratio (ELR): 11; Emergy exchange ratio (EER): 13 and Transformity of the commodities: $8x10^5 seJ.J^{-1}$. The very low %R and high environmental pressure (ELR) signalize that the municipality's economy is highly dependent on external inputs. Above all, there is a high loss of system internal stocks (soil) and the high EYR obtained is directly related to this predatory land use. The emergy value of the soil loss is 83% of the total emergy, which is an environmental imbalanced situation. The main land use in São Gabriel do Oeste, accounting for 39% of the territory, is extensive cattle farming that demands few agricultural inputs, what explains the very low EIR. The EER shows that the rural area is subsidizing urban economies that import products from the study area. The real value of the agricultural products should be 13 times the market value of such commodities to be considered as a fair trade. The inclusion of soil loss as a negative externality shows that (in economic terms) the amount of soil lost by erosion and leaching ($4,149x10^6$ $emUSD.year^{-1}$) corresponds to 46% of the total production monetary value ($9,018x10^6$ $emUSD.year^{-1}$). The emergy diagnosis shows that the business model established for commodities producers is highly dependent on the external market, which does not remunerate the imported resources accordingly to its real value. To settle this situation, a dialogue between farmers, consumers and authorities should be established. The latter two should involve not only local representatives as well as players of the importing countries.

1. Introduction

Brazil is a leading global producer of agricultural commodities at the expense of vast areas of forests and savannas converted into farmland, a phenomena that was intensified during the 1990's when cropland area and cattle herd increase coincided with the greatest deforestation of Amazonia and Cerrado (Lapola et al., 2014). Although the agroindustry accounts for 25% of the country's gross domestic product (GDP) this commoditized economy generates environmental and social inequalities in terms of soil and water resources degradation (Bergier, 2013, D'Odorico et al., 2010), unfair income distribution and land concentration in the hands of a few large landowners (Abbey et al., 2006). Historically, Brazilian agricultural activities were concentrated in the South and Southeast regions. However, due to this economic concentration, uneven demographic densification and the need to increase productivity, the Brazilian government has promoted several programs of agricultural expansion in the country's Midwest region (WWF, 2000). In the last three decades, this expansion contributed to the depletion of local natural resources accelerating the degradation of the Cerrado (WWF and CI, 2009). Currently, 50% of this biome is occupied by agriculture and in the last two decades it has been observed a pronounced conversion of Cerrado to soybean monoculture (Lapola et al., 2014). From 2000 to 2014 soybean harvested area throughout Brazil expanded in 116%[1]. In addition, the Cerrado biome has inherent characteristics of rainfall, soil and relief that represent high potential for laminar erosion, and the areas covered by Lithosols and Quartz Sands offer higher sediment yield risks (Galdino et al., 2006). The land use for agriculture should be done in such a way to minimize erosion and this requires crops management (pastures, soybeans, etc.) to provide a good vegetation cover in the soil surface, especially in the rainy season associated with soil conservation practices to reduce runoff and to favor water infiltration. Crop-livestock-forest integration systems has

[1] AMIS Statistics- Agricultural Market Information System, www.statistics.amis-outlook.org/data/index.html

been implemented and researched in the region aiming to reincorporate tree-element in the agroecosystem, to recycle energy, to reduce soil losses and to mitigate other undesired agricultural side-effects in Cerrado (Buller et al., 2014).

The continuous change of Brazilian agricultural scenarios associated with the need for land use change and soil loss diagnoses for a variety of purposes such as monitoring, damage prevention and policy formulation, requires a new approach related to system internal stocks role for a sustainable agriculture. In this work, we propose the inclusion of soil loss as an additional system's externality in the Emergy methodology (which was applied for the entire municipality assessment) in order to understand and measure its magnitude in the Cerrado's agriculture.

2. Methodology

2.1 Study area description

The study area, São Gabriel do Oeste (SGO) municipality (Mato Grosso do Sul state, latitude 18º40'00 "S and 19º35'00"; longitude 54º10'00"W and 54º50'00"), is a typical case of the grain-cattle based economy in the Brazilian Cerrado that suffered massive deforestation (Figure 1). This location is a representative case of land use changes over the past decades. Initially, the municipality economy was based on extensive cattle ranching and subsistence farming. From the 1970's, coffee was introduced by São Paulo (Southeast) and North of Paraná (South) farmers. In the 1990's, a new migratory movement from Santa Catarina and Rio Grande do Sul (South), started with rice, beans, wheat, oats and later large-scale soybeans and corn monocrops, and, at last, intensive swine (Assis et al., 2003).

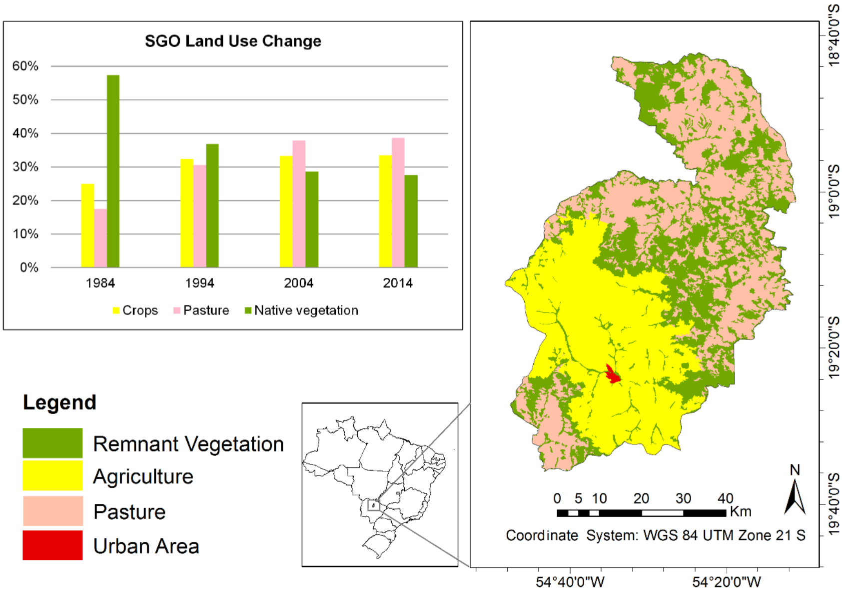

Fig. 1: SGO location map and land use change graph

2.2 Emergy assessment

The Emergy methodology converts all forms of energy, materials and human services into equivalents of solar emergy allowing the establishment of a common basis to compare nature work in natural or human-dominated processes (Odum, 1996). Emergy is an economic-environmental accounting method that considers the biophysical value of renewable and non-renewable resources necessary for the operation of a system. In general, conventional economic assessments disregard the energy used for biosphere's resources formation and the costs of negative externalities associated to human interferences in the environment. In the present study, the emergy analysis accounts for those externalities as additional services (Ortega et al., 2005) and considers the soil loss flow among them (normally this flow is considered as a non-renewable one). SGO economy data (year 2012) were collected from the Mato Grosso do Sul State Agency of Environment, Cities, Planning, Science and Technology (SEMAC). SEMAC supplied a full report including SGO's production and GDP per economy segments namely: urban, agricultural, livestock, commerce and industry sectors. The report also included City Hall revenue and taxes and fees collection.

The area of native vegetation necessary to mitigate or absorb environmental impact (carbon sequestration) of agricultural occupation was calculated by means of the equation:

$A = F/(NPP*E_b*Tr_b)$, (AGOSTINHO et al., 2007). Where: *F* is the economy emergy flow, *NPP* (Net Primary Production) for the Brazilian Cerrado is 3,700 kg.ha^{-1}.year^{-1} (Meirelles and Henriques, 1992), E_b is the biomass energy estimated as 16,736 kJ.kg^{-1}, and Tr_b is the transformity of a typical savanna considered as 4.55E+04 seJ.J^{-1} (Prado-Jatar and Brown, 1997).

3. Results and discussion

Figure 2 shows the systems diagram for the current SGO municipality economy.

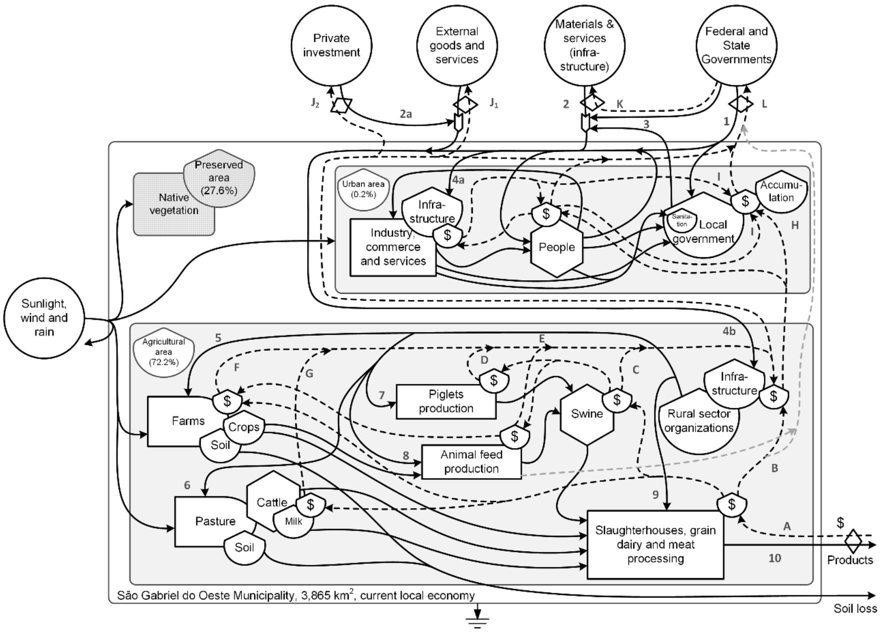

Fig. 2: SGO current economy systems diagram

Flows description is given below:

1- Federal/state governments are "sponsors" of the infrastructure to economic processes used by states and/or municipalities that, in turn, are home to agriculture, industry, trade and services.

2- The production of public infrastructure above mentioned requires materials and services that are distributed in accordance with the needs of each sector.

2.a- In addition, the operation of the several subsystems usually demands other materials and services from the external economy, such as steel and cement for construction, chemicals,

fertilizers, seeds, swine matrices, calves, machinery, electricity (not locally generated), fossil fuels etc. The purchase of these items often requires external economy investments.
3- The local government also contributes to the flow of materials for local infrastructure.
4.a/4.b- Materials and public services are used for the infrastructure for production, transformation and consumption in urban areas (industry, commerce and urban services).
5/6- In the countryside, rural organizations (cooperatives and associations) intermediate materials, goods and services with farmers through their structures or organizations.
7- Rural organizations also work with the piglets' production units interacting with pig farmers who fatten and mostly work in integrated systems (grain and pig farming).
8- Grains flows to market and to animal feed mill (also coordinated by rural organizations).
9- Local organizations also make the intermediation of the sales of agricultural commodities for processing industries (grains and meat processing, dairy, slaughterhouses).
10- The local agroindustry exports the most part of the processed products to regional, national and international markets.

Money circulation- the money from sales firstly goes to the agroindustry (A) who pay suppliers or intermediary organizations (B), local taxes (H) and state/federal taxes and fees (L). Rural organizations pay materials producers (C, D, E, F and G). Payments for the rural products flow to the population (I), both people working in the field and in the city. People consume local industrial goods, trade and services, also external resources and services (J_1 and J_2) and pay for them and for the local and federal governments' taxes and fees. Local governments receive taxes for the maintenance of the public infrastructure (L).

A simplified diagram of the emergy cash flow for economy sectors is presented in Figure 3.

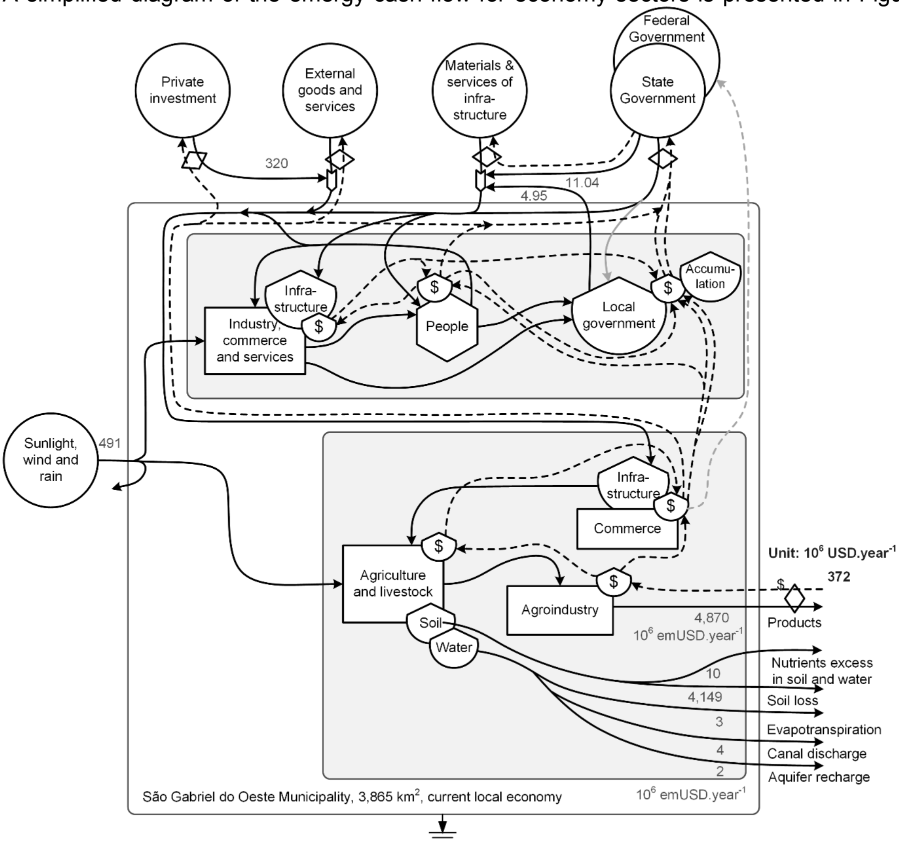

Fig. 3: SGO current economy cash flow systems diagram

The biophysical values of economy materials were replaced by their correspondent values in currency accordingly to the available data provided by SEMAC for this work. The biophysical values are desirable in the emergy method in order to place items in the energy hierarchy and properly consider its role in the system. Anyway, the material unit emergy value (UEV) should consider the economy's services to its production what it is already accounted for in the calculation done through the GDP net of taxes and fees and City hall revenues.

The emergy table (Table 3.1) shows values of renewable flows, materials, services and externalities. The externalities values were based on: a previous valuation of nutrients excess in soil and water for European agriculture (Pretty et al., 2000), evapotranspiration, canal discharge and aquifer recharge for the surrounding region (Watanabe and Ortega, 2014) and soil loss for the study region (Buller et al., 2014). The aggregated emergy indicators calculated (Table 3.2) for the current municipal situation signalize that SGO's economy is highly dependent on external inputs.

Table 3.1: SGO current economy emergy table (baseline: 15.83E+24 seJ.US$$^{-1}$ (Odum et al., 2000))

Item	Description	Flow	Unit	UEV (seJ.unit^{-1})	Ref	Emergy (seJ.year^{-1})	Cash flow (EM$.year^{-1})
Natural resources						8.49E+20	4.91E+08
R_1	Sunlight	2.24E+19	J.year^{-1}	1	a	2.24E+19	9.93E+06
R_2	Wind	9.33E+16	J.year^{-1}	2.51E+03	a	2.34E+20	1.04E+08
R_3	Rain	2.77E+16	J.year^{-1}	3.06E+04	a	8.49E+20	3.77E+08
N	Soil loss	2.89E+16	J.year^{-1}	3.23E+05	c	9.33E+21	4.15E+09
Imports (inputs from the system´s outside)							
Materials and Services from Economy (M)						7.19E+20	3.20E+08
M_1	For the urban sector	3.08E+07	US$.year^{-1}	2.25E+12	b	6.93E+19	3.08E+07
M_2	For agricultural (crops) sector	6.50E+07	US$.year^{-1}	2.25E+12	b	1.46E+20	6.50E+07
M_3	For livestock sector	1.29E+07	US$.year^{-2}	2.25E+12	b	2.89E+19	1.29E+07
M_4	For commerce sector	1.33E+08	US$.year^{-3}	2.25E+12	b	3.00E+20	1.33E+08
M_5	For industry sector	7.76E+07	US$.year^{-4}	2.25E+12	b	1.75E+20	7.76E+07
Services (S)						3.60E+19	1.60E+07
S_1	City Hall services	4.95E+06	US$.year^{-1}	2.25E+12	b	1.11E+19	4.95E+06
S_2	State Government services	1.10E+07	US$.year^{-1}	2.25E+12	b	2.48E+19	1.10E+07
Additional services - Negative Externalities (S_A)						9.35E+21	4.16E+09
S_{A1}	Nutrients excess in soil and water	9.98E+06	US$.year^{-1}	2.25E+12	b	2.25E+19	9.98E+06
S_{A2}	Evapotranspiration loss	2.73E+06	EM$.year^{-1}	2.25E+12	b	6.14E+18	2.73E+06
S_{A3}	Rivers discharge loss	4.04E+06	EM$.year^{-1}	2.25E+12	b	9.09E+18	4.04E+06
S_{A4}	Aquifer recharge loss	1.55E+06	EM$.year^{-1}	2.25E+12	b	3.48E+18	1.55E+06
	TOTAL EMERGY (U)					1.10E+22	4.98E+09
Exports to outside the system (O)		1.39E+16				1.10E+22	4.87E+09
O_1	Soybean	5.91E+15	J.year^{-1}	7.86E+05		4.64E+21	2.06E+09
O_2	Corn	7.22E+15	J.year^{-1}	7.86E+05		5.67E+21	2.52E+09
O_3	Processed meat	7.46E+14	J.year^{-1}	7.86E+05		5.86E+20	2.60E+08
O_4	Milk	7.18E+13	J.year^{-1}	7.86E+05		5.64E+19	2.51E+07
	Total sales	3.72E+08	US$.year^{-1}	2.25E+12		8.36E+20	3.72E+08

[a] (Odum, 1996)
[b] (Pereira, 2012)
[c] (Cohen et al., 2006)

Table 3.2: SGO's economy emergy aggregated flows and indicators

Renewable flow	$R=\Sigma R_i$	8.49E+20	seJ.year^{-1}	
Non-renewable flow	N	9.33E+21	seJ.year^{-1}	
Flow from economy	$F=\Sigma M_i+\Sigma S_i$	7.55E+20	seJ.year^{-1}	
Negative externalities	$S_A=\Sigma SA_i$	4.12E+19	seJ.year^{-1}	
Emergy Used	$U=R+N+F+S_A$	1.10E+22	seJ.year^{-1}	
System's Transformity	U/(Product energy)	7.87E+05	seJ.J^{-1}	*In the expected range*
Emergy Intensity	U/Area	2.85E+18	seJ.year^{-1}.ha^{-1}	*Very high*
Renewability (%R)	R/U	7.73%		*Very low*
Emergy Yield Ratio (EYR)	$U/(M+S+S_A)$	13.79	dimensionless	*Very high (soil erosion)*
Emergy Investment Ratio (EIR)	F/I	0.08	dimensionless	*Very low (pasture)*
Environmental Loading Ratio (ELR)	$(M+S+S_A)/R$	11.04	dimensionless	*High*
Emergy Exchange Ratio (EER)	U/[(USD*(seJ.USD-^{1})]	13.13	dimensionless	*Very high*
Lost soil Transformity	U/(Soil loss energy)	3.79E+05	seJ.J^{-1}	*Close to Cohen et al., 2006*
Area for carbon sequestration	A	2,680	km^2	*70% of the total area*

SGO agriculture is mainly based on grains what corresponds to 94% of the total energy output (Table 3.1). The system's Transformity (Tr) is around the expected value, a grains production system presents Tr of $2.77x10^5$ seJ.J^{-1} while for swine system Tr is $2.09x10^6$ seJ.J^{-1} (Cavalett et al., 2006) and for cattle only it is $1.85x10^5$ seJ.J^{-1} (Teixeira, 2012). Because of the high soil loss the Emergy Intensity is 13 times higher than another tropical agricultural system (Cohen et al., 2006). The very high soil loss and EYR values are directly related to intense and destructive land use in the Brazilian Cerrado. The soil loss emergy value (N) represents 83% of the total emergy (U), a sign of the environmental imbalanced and predatory situation. The very low EIR is related to the main land use, extensive cattle farming that demands few external inputs and accounted for 39% of SGO's territory in 2014 (Figure 1). EER shows that the rural economy is subsidizing commodities for importing areas. The real value of agricultural commodities should be 13 times higher than the current market value to be a fair trade.

If soil loss is included as additional service, EYR is 1.08, i.e., there is low productivity for high soil loss and, EIR is 11.91. The latter means that the investment is very high or the cost of losing soil is elevated. Both have an opposite behavior compared to the first situation (Table 3.2), what would mean that the municipality presents a low regional development at the expense of high soil loss (if accounted as an externality). Soil loss in economic terms shows that the quantity of soil degraded by erosion and leaching ($4,149x10^6$ emUSD.$year^{-1}$) corresponds to 46% of the total SGO's production monetary value ($9,018x10^6$ emUSD.$year^{-1}$).

An important indicator is the native vegetation area to absorb environmental impacts of human activities, calculated as 2,680 km^2 or 70% of the total SGO area. For similar agricultural systems in Santa Catarina (South of Brazil) it was 65% of the total area (Teixeira, 2012). The necessary additional native vegetation area is 1615 km^2. Native forestry recovery could be achieved by means of strategies for land sharing[2] in a modified version of the integrated crop-livestock-eucalyptus systems previously evaluated for the region (Buller et al., 2014), substituting eucalyptus that causes hydric stress among other damages for native vegetation, or land sparing[2] for ecosystem services restoration and biodiversity conservation.

4. Conclusion

The large-scale expansion of soybean monocrops throughout the Brazilian Cerrado allowed local economies to prosper, as it is the case of SGO whose IDH is outstanding for Brazilian Midwest region pattern. SGO 2010 IDH was 0.73 and Brazilian IDH was 0.72 also the GDP growth was of 259% from 1999 to 2011(IBGE(a), IBGE(b)). Although the economic behavior, the future prosperity depends directly on public policies to eliminate current denying of environmental risks. As well as international beef and soybean players could reward positive incentives for producers that achieve rainforest deforestation low rates in developing countries, and some large companies has already established a zero tolerance for any level of deforestation[3]; soil loss, that directly affects the productivity and water and carbon balances, could be included in new policies for the agricultural expansion. All the agricultural involved stakeholders like international commodities buyers, local farmers, ecological groups and political leaders of developing and importing countries should align new agricultural systems for the south hemisphere countries to assure food security without environmental degradation aiming to remunerate the imported embodied natural resources of commodities products accordingly to its real value.

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[2] wle.cgiar.org/blogs/2013/09/20/land-sharing-or-sparing-considering-ecosystem-services-in-the-debate/
[3] www.eurekalert.org/pub_releases/2014-06/sc-blt053014.php#

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