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Emergy Accounting of Brazilian States and Regions

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ABSTRACT

Brazil is a country of continental proportions that has significant economic, social and environmental heterogeneities within its territory. The country counts with a high support from renewable resources, a strengthened industrial park, and a large area used for livestock and crop production. The country has 26 states and a Federal District distributed geographically in five regions. In order to highlight and distinguish the differences among regions, an emergy evaluation of each state was performed and the emergy signatures are presented. Emergy indices of each state (ESI, EYR, and ELR) are presented in maps. The EMR of each state was calculated to assess the relationship between the environmental support and the economic development of each regional system. The total emergy of the country was composed by the sum of the emergies of each state, and the result was compared with literature.

INTRODUCTION

The economic development of countries is straightly tied to the depletion of natural resources. The environment provides the necessary resources to sustain life: fertile soil, clean water, clean air, pleasant weather and healthy ecological systems. Sustained by natural resources, population grows and prospers, and society expands increasing the use of energy derived from non-renewable resources. The economic development of regional systems was accelerated by the exploitation of cheap fossil fuels along with the environmental resources from rural areas. The consequence is the exhaustion of these resources and of the regional carrying capacity.

Regional systems depend on their natural resources for the production of goods and services. Thus, to assess regional development properly, one need to use a methodology that takes into account the work of nature that supports the generation of products and services. Results may help to develop policies to improve the use and management of natural resources leading to an economic growth that benefits society.

Brazil is a country of 8,500,000 km^2 that has significant economic, social and environmental heterogeneities within its territory. The country counts with a high support from renewable resources, a strengthened industrial park, and a large area used for livestock and crop production. However, these activities are allocated across the country in different patterns that confer distinctive features for each region.

The country has 26 states distributed geographically in five regions. The emergy evaluation of each state was carried out to highlight and appreciate the differences among regions. Thematic maps depict the ESI of each state, and EMR values determine the relationship between the environmental support and the economic development of each regional system. The total emergy of the country was composed by the sum of the emergies of each state, and the result was compared with the literature (Odum, 1983; Comar et al., 1998; Sweeney et al., 2000, Coelho et al., 2009).

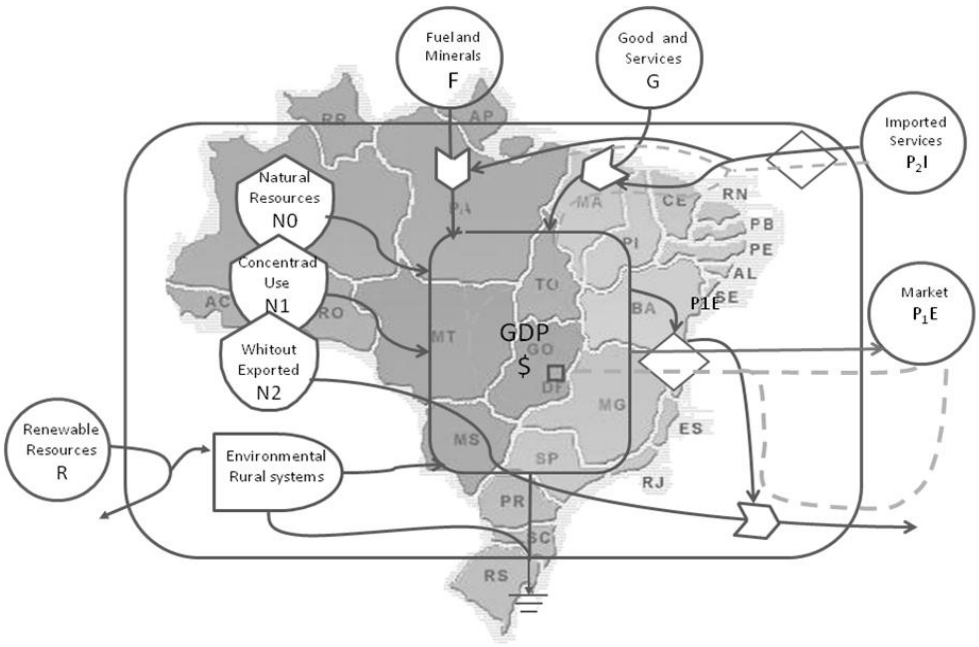

Figure 1. *Summary of national resources basis for Brazil. Symbols were identified according to NEAD.*

METHODS

The emergy accounting was performed based on the tables from National Environmental Accounting Database (NEAD); as described by Sweeney et al. (2009). Figure 1 shows the energy system diagram summarizing the main flows accounted. The energy of renewable resources and the flow of imported and exported resources were obtained from governmental institutions (IBGE 2007).

A new interpretation is carried out based on the emergy ternary diagram. More details on theoretical aspects and the use of the emergy ternary diagram can be found in the literature (Almeida et al, 2007, 2010; Giannetti et al., 2006, 2007, 2011).

RESULTS AND DISCUSSION

The main flows that supply the local economy of the five Brazilian regions were identified. The geographical division of the Brazilian territory was conceived by the Brazilian government to incorporate natural and economical aspects. This division was maintained to give support to possible suggestions for public policy for the regions, as they are recognized by the government. Figure 2 shows the Brazilian emergy signature, where the contribution of each region is highlighted. Summary of flows and indices for Brazil and its regions is shown in the Appendix.

Northern Region counts with the largest renewable flows (rain chemical energy, tide and geothermal heat). Northeast states depend mainly on tidal emergy and wind. Agricultural Production is more pronounced in the South and Midwest regions, where also the top soil loss is significant. Livestock production is more significant in the Midwest, but has similar contributions from all other regions. The Southeast Region has the highest consumption of resources originating from the economy, especially minerals, metals, and imported services. In the overall picture, renewables and non-renewables contribute far more significantly to the Brazilian system than the resources provided by outside. This situation can be easily noticed by the analysis of the emergy ternary diagram (Figure 3).

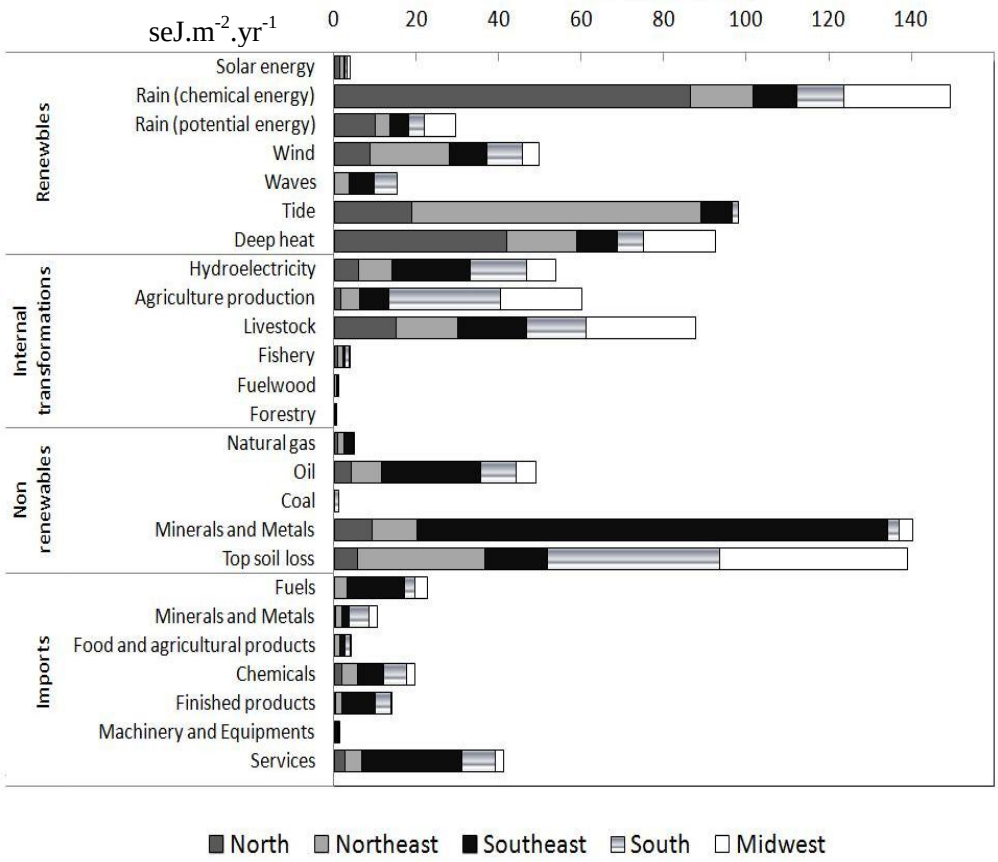

Figure 2. *Brazilian emergy signature.*

North, Northeast and Midwest regions are located in the long term sustainability area of the ternary diagram. Southern Brazil is characterized by a strengthened agriculture and a well-established industrial park, and is located at the medium term sustainability area. Southeast region is the most economically developed and presents short term sustainability. Points relating to Brazilian regions are located near the NR axis (Figure 3). These results make it clear that the overall sustainability of Brazil is maintained by regions North, Northeast and Midwest. While Southern and Southeastern regions, with lower emergy/money ratio, are less sustainable. However, even the most economically developed regions still shows the percentage of purchased inputs below 50%.

The contribution of each state to the Brazilian sustainability is shown in Figure 4. From the 26 states, 17 show long term sustainability, and 19 states show low environmental loading ratio. Regarding the emergy yield, all Brazilian states have EYR higher than 2.

Despite of the favorable conditions observed in figure 4, the sustainability index of the country is diminishing along the years. Figure 5 shows the ternary diagram with results from different evaluations performed to Brazil since 1981 (Odum, 1983; Comar, 1998; Sweeney et al., 2009, Coelho et al., 2009).

The historical series of Brazil sustainability valued by different authors, show that Brazilian development is based on the exploitation of its nonrenewable resources. In a period of 30 years, there is a slight increase of the use of purchased inputs (less than 5% seJ/seJ), and an increase in the consumption of non renewables (20% seJ/seJ). Also in this period, Brazil left a situation of long term sustainability in the 80s and 90s, to a medium term sustainability.

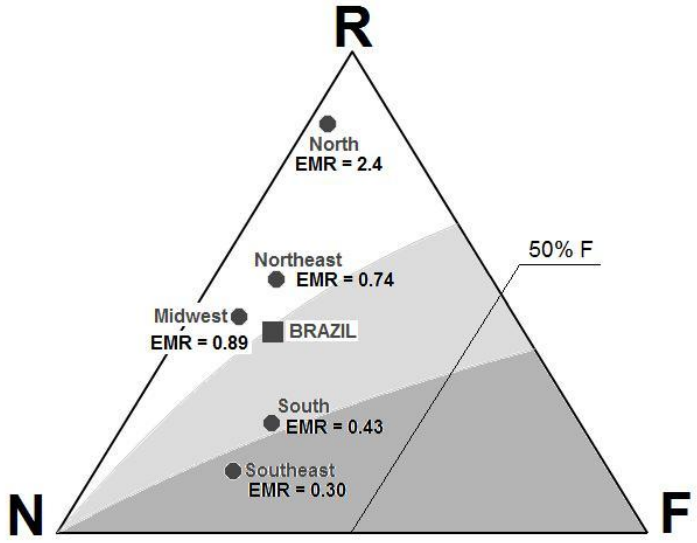

Figure 3. *Emergy ternary diagram for the Brazilian regions. EMR values shown in the figure are divided by 10^{13} seJ/$ (see Appendice); short term sustainability (ESI < 1, dark grey); medium term sustainability (1<ESI<5, light grey); and log term sustainability (ESI>5, white).*

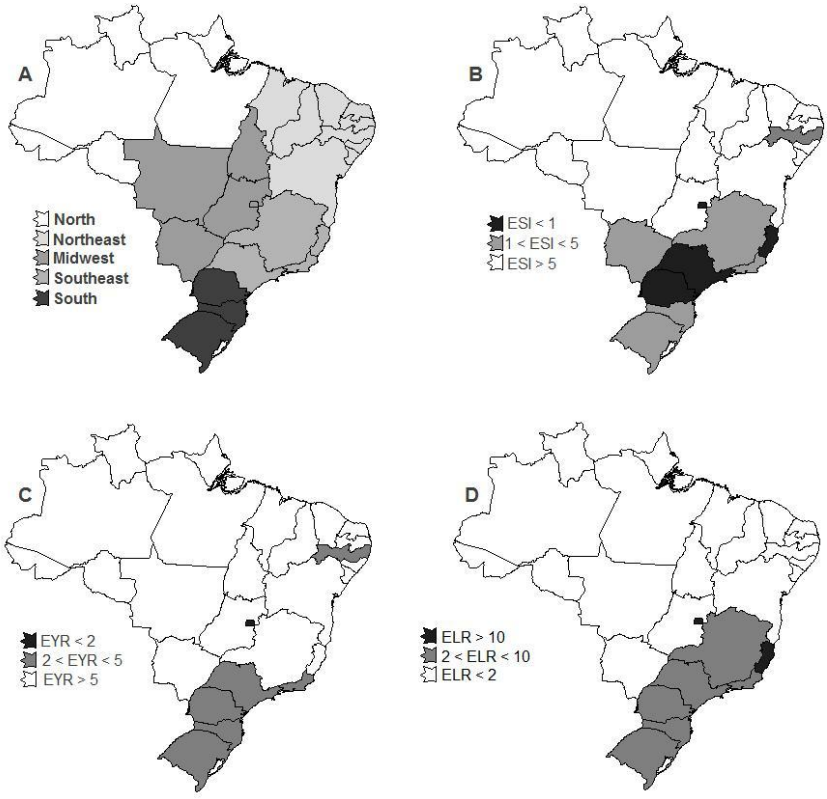

Figure 4. *Emergy indices of Brazilian states. A: Brazilian regions, B: ESI; C: EYR; and D: ELR.*

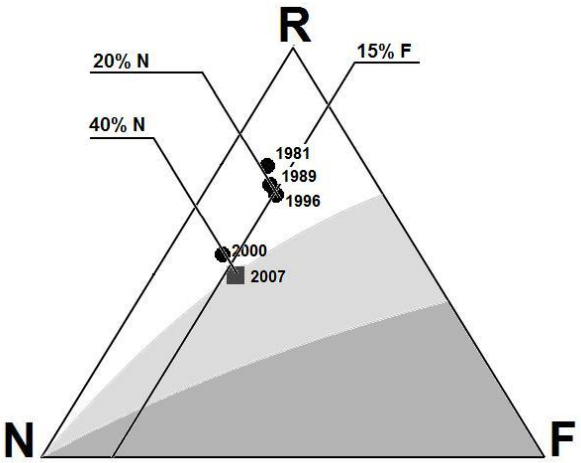

Figure 5. *Ternary diagram of Brazil along the years: 1981 (Odum, 1983); 1989 (Comar et al., 1988); 1996 (Coelho et al., 2009); 2000 (Sweeney et al., 2009), 2007 this work.); short term sustainability (ESI < 1, dark grey); medium term sustainability (1<ESI<5, light grey); and log term sustainability (ESI>5, wthite).*

CONCLUSION

In this work, the environmental and economical indicators of the Brazilian states were analyzed. These results make it clear that the overall sustainability of Brazil is maintained by regions North, Northeast and Midwest. While Southern and Southeastern regions, with lower emergy/money ratio, are less sustainable. Brazilian economic development is leading the country to conditions of medium term sustainability.

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APPENDIX

Table. Summary flows and indices reported by the emergy accounting for Brazil and its regions.

Indicators	Unit	**BRAZIL**	North	Northeast	Southeast	South	Midwest
Renewable (R) /10^{23}	sej/yr	**31.09**	15.15	7.54	3.24	2.43	5.24
Non Renewable (N) /10^{23}	sej/yr	**34.95**	2.13	5.25	15.76	5.53	5.44
Imports (F) /10^{23}	sej/yr	**11.31**	0.55	1.51	5.63	2.65	0.97
Total Emergy (U) /10^{23}	sej/yr	**77.35**	17.83	14.30	24.64	10.60	11.65
Exports (P1E) /10^{23}	sej/yr	**23.44**	4.86	2.40	10.24	3.73	2.29
Imports minus Exports /10^{23}		**-12.14**	-4.31	-0.90	-4.61	-1.08	-1.32
Exports / Imports	sej/yr	**2.07**	8.86	1.59	1.82	1.41	2.36
Renewable Resources ratio	%	**40.20**	84.97	52.75	13.16	22.88	44.98
Economics Resources ratio	%	**14.62**	3.08	10.54	22.87	24.97	8.31
Imported Services Ratio	%	**5.31**	1.47	2.81	9.83	7.77	1.69
Free Resources ratio	%	**60.21**	88.99	75.73	20.13	63.15	84.85
Use per area, / 10^{15}	sej/ha	**9.08**	4.63	9.20	26.65	18.40	7.25
Use per person /10^{16}	sej/per	**4.04**	11.61	2.67	3.04	3.83	8.38
Population / 10^{6}	persons	**191.47**	15.36	53.59	80.92	27.72	13.90
Carrying Capacity /10^{6}	persons r	**76.97**	13.05	28.26	10.65	6.34	6.25
Developed Carrying Capacity /10^{6}	persons	**615.72**	104.41	226.11	85.18	50.75	50.00
EMR /10^{13}	sej/$	**0.52**	2.40	0.74	0.30	0.43	0.89
Electricity ratio		**8**	3.93	6.50	9	15	7
Fuels per person /10^{15}	sej/ persons	**2.85**	3.21	1.62	3.27	3.50	3.40
EYR		**6.84**	32.48	9.48	4.37	4.01	12.03
ELR		**1.49**	0.18	0.90	6.60	3.37	1.22
EIR		**0.17**	0.03	0.12	0.30	0.33	0.09
ESI		**4.60**	183.58	10.59	0.66	1.19	9.83
HDI		**0.69**	0.76	0.72	0.82	0.83	0.82
GDP /10^{10}	$	**147.85**	7.42	19.32	83.40	24.60	13.11