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Social Metabolism Using Emergy and Political Analysis

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ABSTRACT

After studying ecosystems and biosphere processes for decades, Howard T. Odum sketched a methodology for calculating the value of the biophysical resources and the products of human activity. The methodology of "emergy" or "solar energy previously added" measures the biophysical work embedded in biogeochemical cycles, resources and human labor. According to Odum, the economic value (price) and the biophysical value (work added) generally do not coincide, as the market ignores or does not consider all factors of production. This paper explains the analysis of production-consumption systems using emergy and discusses its potential utility in Regional Planning and Climate Mitigation.

INTRODUCTION

With respect to the concept of value and its measurement, there are two main lines of thought. One considers only objective factors (agriculture work according with the French Physiocrats or human labor in the vision of Adam Smith, David Ricardo and Karl Marx) and the other line believes that value is subjective (i.e., the apparent utility to the user). The theoretical proposal of H. T. Odum (1924-2002) considers the work realized by nature and by human labor. Thus:

Emergy of a resource is its integral work value.

Emergy is the potential energy (exergy) used, directly and indirectly, in the production of a resource. It is usually expressed in terms of solar emjoules (abbreviated sej), that corresponds to all the solar equivalent joules necessary to produce a unit of a resource (kg, J, etc.). In terms of currency, Odum (1996) recommends to use equivalent dollars per unit of resource.

It is necessary to remember that the emergy calculation is only valid when it considers all the inputs and all the products and co-products. The resources produced should not adversely affect other systems. If there are environmental and social costs the analysis of production systems should include the emergy necessary to solve the negative externalities created during the production process as additional services or as process changes in order to be more ecological.

Rationale

The basis of Emergy Science is Open Systems Thermodynamics and Systems Ecology that allow understanding how the natural and the anthropic ecosystems function in relation with the biosphere throughout history. It allows us to know the ecological sustainability, the biological support capacity and the critical level of resilience of the different ecosystems, the energy intensity of human lifestyles, the complete balance of the production and consumption systems, the role of information, the need to reserve area for native vegetation to provide critical environmental services, among others.

Objective

The aim of this paper is to introduce biophysical and economical process analysis from the perspective of the emergy methodology, while clarifying the relationship between cities and their support areas and discussing social metabolism and its relationship with human culture.

Systems representation

The elaboration of diagrams using the energy systems language (Odum, 1994), allows the analysis of physical, biological and economic systems, because they express the interactions between external forces and internal components in order to sustain the system and produce new resources.

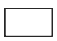
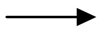
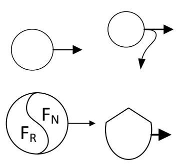
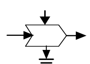
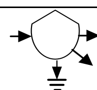
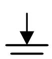
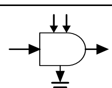
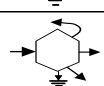
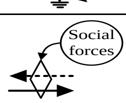
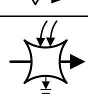
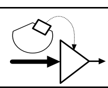
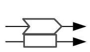
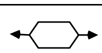
	**Box or Case**: Demarcation of the boundaries of a system or a subsystem or a process. An observation window.
	**Energy Path**: Energy, material or information flow.
	**Energy Source**: Flow of potential energy from an external source used by an ecosystem, such as sunlight, wind, rain, tides, waves on beaches, windborne seeds and birds. If the system cannot use all the potential energy, there is an outflow of incident energy, as solar albedo. It may be also a flow of energy from the economy with some renewable resources in its composition or a completely non- renewable stock.
	**Interaction**: A process that combines different types of energy and materials to produce a different resource (able to realize work).
	**Stock**: It is a resource accumulation. For example: biomass, soil, ground water, sand, nutrients, fossil energy deposits, minerals, industrial products, etc.
	**Heat sink**: Degraded energy dispersed during a process, which cannot be used any more, such as: evaporated water in photosynthesis, heat of animal metabolism or friction, etc.
	**Producer**: A biological unit that transforms solar energy and basic materials (nutrients) into biomass. Examples: wild and crop plants, trees, farms, gardens, parks, agriculture.
	**Consumer**: A biological unit that uses the biomass resources generated by producers. For instance, microorganisms, insects, livestock, humans and cities.
	**Transaction**: Exchange of energy, materials, services and money whose prices are determined in the past by the markets and, nowadays, by ideological and military forces.
	**Control device**: A combination of external forces triggers it allows occurring a process of short duration that is otherwise inactive, such as a fire or flowers pollination.
	**Amplifier:** An operator of an abundant energy source that uses a small flow of energy for modulation, as information.
	**Drag force:** A flow moved by another one, such as water vapor driven by wind, soil and sediments moved by water currents.
	**Flow according with potential:** The flow direction can be reversed, if there is a change in the potential driving force.

Figure 1. *A basic set of symbols of the emergy methodology (H. T. Odum, 1994).*

Production, Consumption and Recycling in Nature

Figure 2 shows a sustainable biological system whose vegetable biomass is consumed by animals who return basic nutrients to plants. This system is able to increase its capacity to use available external energy according to the internal structures that it develops over time; these structures also determine the limits of the system's growth.

In order to use available resources, self-organized units of producers and consumers form networks that develop energy, matter and information links. The survival of these systems depends on the quality of the interactions. This energy chain expresses the ecosystem metabolism.

Economic relationship between the countryside and the city using currency

During the discovery of agriculture, humans replaced the natural flora and fauna by selected crops and animals. Innovations and external pressures have always affected rural production. In some cases, the traditional community can survive but not always. Rural producers can self-organize or a third party can organize them; in this case, the advantages are distributed between the partners (Figures 3a and 3b). If the farmers destroy natural stocks, the farm losses soil, fertility, productivity and eventually it can collapse.

The rural systems allowed the growth of villages and cities. The distribution of income within the cities was uneven and concentrated at the top of the social hierarchy.

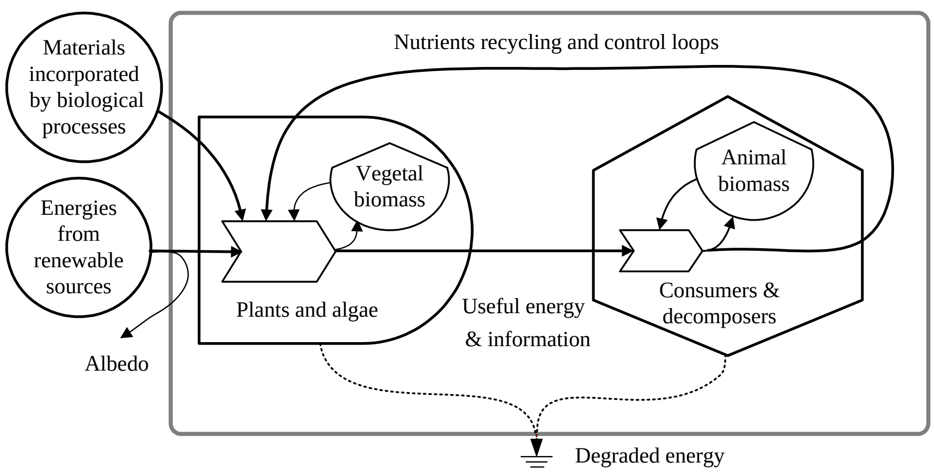


Figure 2. *Simplified food chain.*

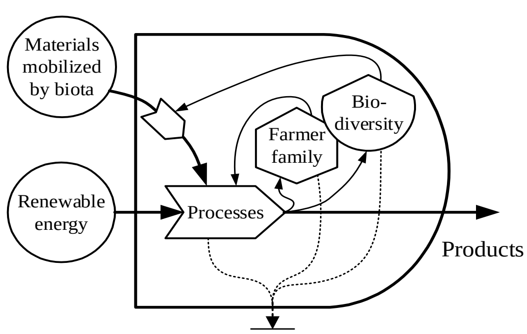


Figure 3a. *Individual farmer.*

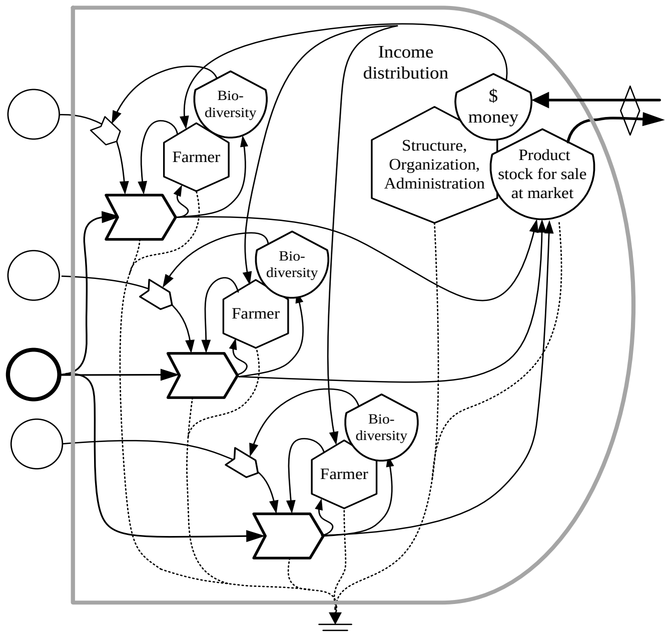


Figure 3b. *Associated farmers.*

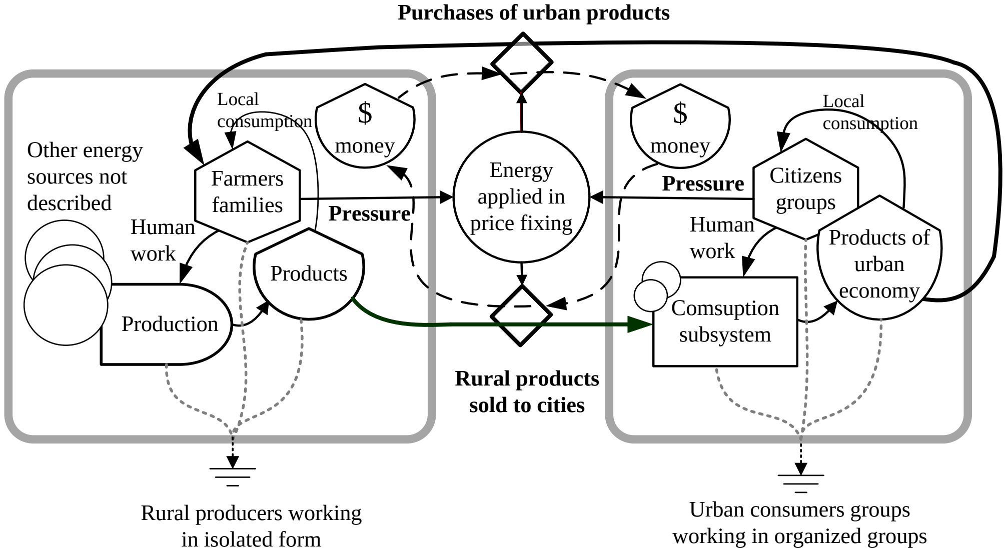


Figure 4. *Country-city relationship with use of currency.*

In the last three centuries, the global economic system became increasingly intensive in the use of non-renewables and in the predatory use of renewables, not replenishing stocks. For the urban economy, these resources have a minimal cost, because market price considers only the cost of removal without considering recovering. With these subsidized resources, the urban industries produce low-cost agricultural inputs. Fertilizers and biocides replace some of the work of nature and man on farms, but, at the same time, biodiversity is loss and as a result, and there is a decline in ecosystem services.

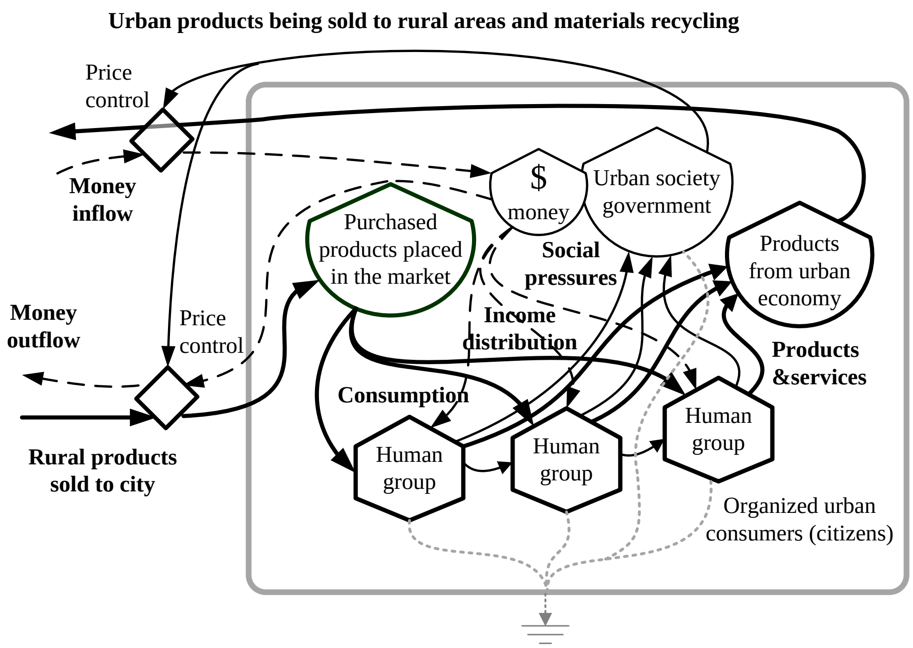


Figure 5. *Relationship of the city center to pressure for the appropriation of income.*

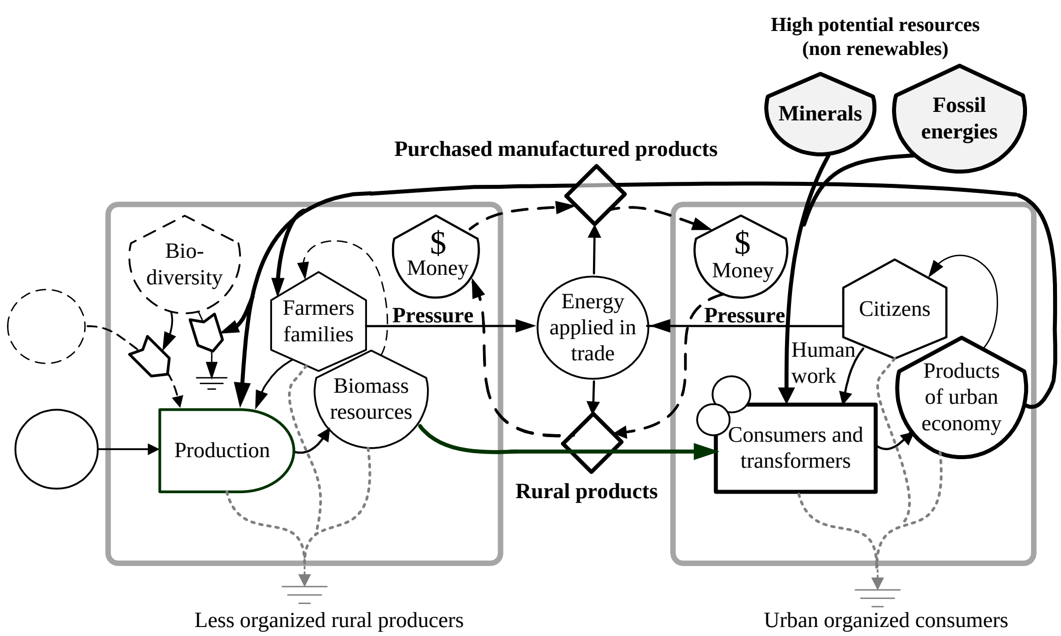


Figure 6. *Country fields-city relationship influenced by petroleum products and minerals.*

The use of fossil fuels by central economies allows more dominance over peripheral areas increasing wealth transference and generating social and ecological problems. Reduction of ecological resilience endangers the ecosystem's capacity to recover.

Analysis of a city (an economic system) within a region (an ecological system)

Figure 7 shows the diagram of a regional system. Every city needs areas for production of resources and environmental services. Regional planning should consider both spaces.

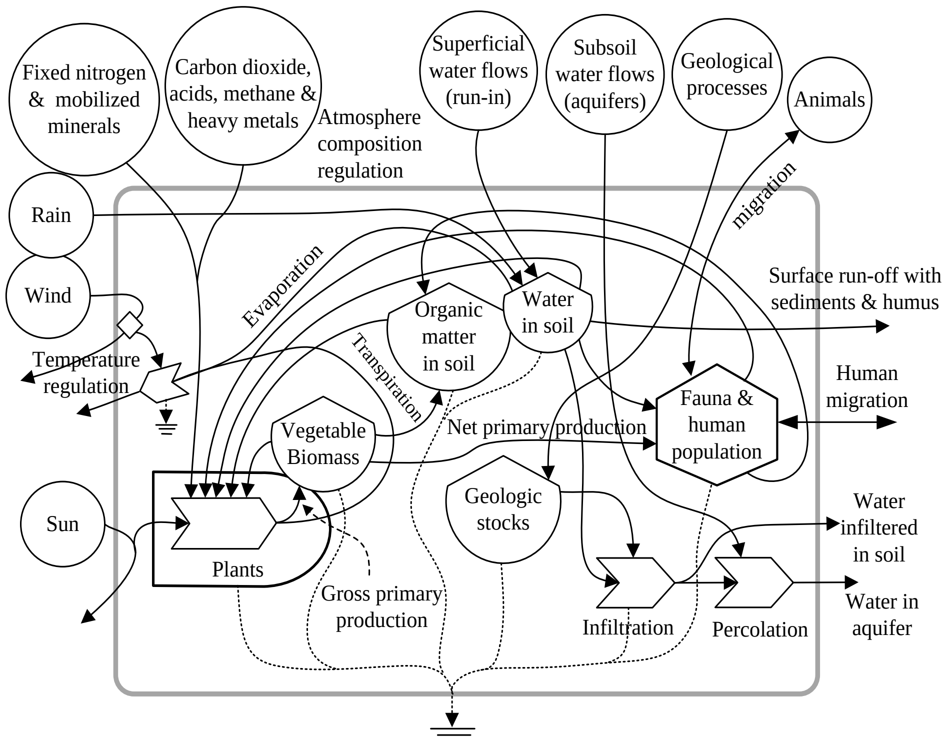


Figure 7. *Relationship of a city with its support region.* (Adapted from a diagram of *The Center for Environmental Policy, University of Florida*)

Analysis of an economic process within the biosphere

Coal, oil and gas have a high energy density, since their formation took millions of years (Figures 8 and 9), these resources make possible the production of chemicals that allow farming to go beyond the limits of nutrient recycling and biological control. As a result, nature and human work was lost in rural space (Ortega et al., 2005).

Conventional economic analysis focuses on monetary profit, hides ideological control, and cannot incorporate complex ecological and social issues; therefore, it is unable to analyze global warming, oil depletion, biodiversity loss, population concentration, CO_2 biological sequestration, pollution, fresh water availability reduction, political power concentration, rural exodus, and marginalization. The solution demands a cultural change and a new mode of production, consumption and recycling, as well as an understanding of recovering ecosystems and the flows of environmental services.

The biosphere diagram below highlights the contributions of nature and human beings to production processes. Our current economies use resources made by nature in ancient eras that sequestered carbon and generated biodiversity, and which in recent centuries supported social work that is responsible for "modern culture". The geological, biological and cultural stocks generate flows that make possible human life on the planet; the maintenance of these important stocks requires significant feedbacks.

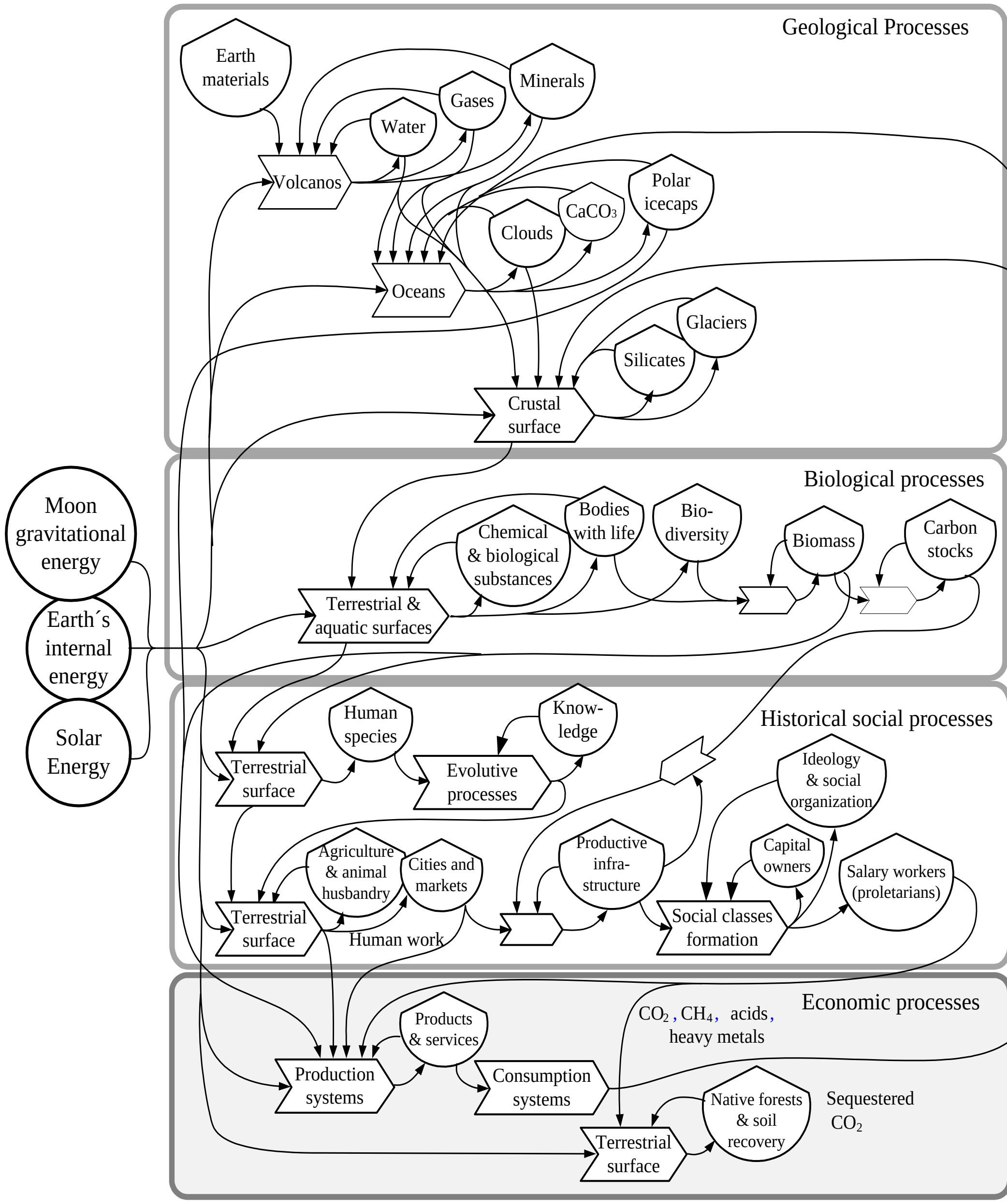


Figure 8. *The biosphere economic, geological, biological and cultural processes.*

Oil, coal and gas depletion can bring a sharp decline in population, given the global dependence on these resources (Odum and Odum, 2000 and 2001) and the depletion of biodiversity can slow the recovery of ecosystems productivity during degrowth.

The finite natural stocks are under rapid depletion by central economies without considering negative externalities. The market price is very small compared with its real value. This blind spot is leading to the collapse of the biosphere and human economies.

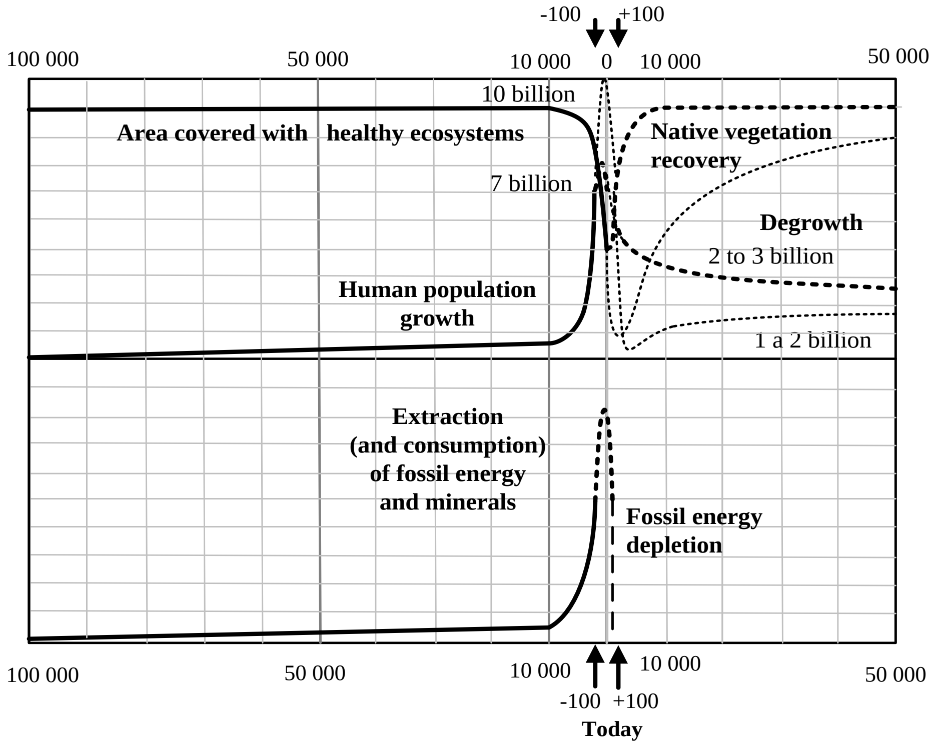


Figure 9. *History and trends of the biosphere (data from several sources and imagined scenarios).*

Emergy analysis and public policy

The Emergy methodology can calculate the real prices of resources and products, the authors suggest offering these values in public media as a reference to promote an alternative market price structure.

When resources are abundant, the economy tends to mobilize them as quickly as possible. When high-quality stocks become scarce, economic activity will become more diversified and less intensive. As the availability of resources varies over time, policies must change along the evolutionary stages. To guarantee resources for the future, we must recognize the work of nature and invest in its recovery and preservation, so that it can continue to provide environmental services, as well as make evident the real costs of nonrenewable fuels and their negative externalities.

Analysis of an alternative for production systems using the emergy methodology

The current Growth Economy degrades ecosystems and reduces environmental services. This type of economy only serves the interests of central countries, causes social erosion, concentrates property and political power, transfers abroad potential energy; it produces a small number of rural jobs and many greenhouse gases.

The alternative model ("Rural Integrated Ecological Systems") is shown in Figures 10 and 11; it is based on the integrated production of food, biomass energy and environmental services for human decentralization and environmental recovery. This proposal (Bacic et al., 1988) allows for population movement to rural areas and can support a new network of smaller cities. Its design should consider the absorption of carbon dioxide, methane and NO_2, regulation of temperature and water, biodiversity preservation, incorporation of unemployed people into the labor force.

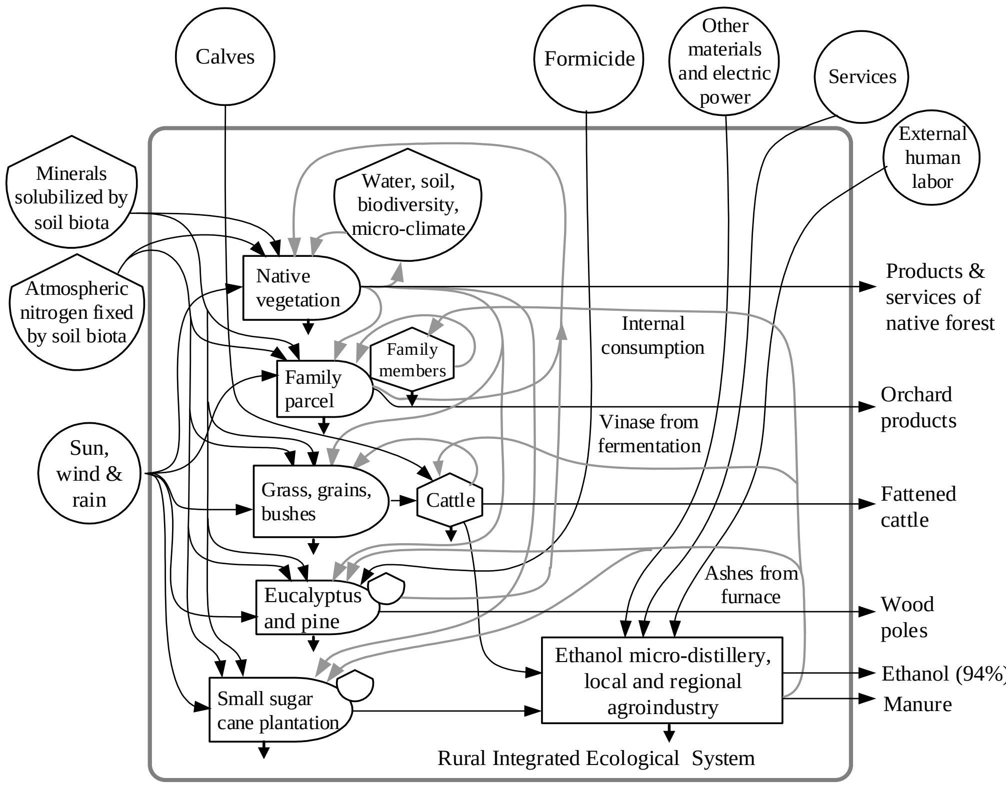


Figure 10. *System of food production, energy and environmental services (Ortega, 2008).*

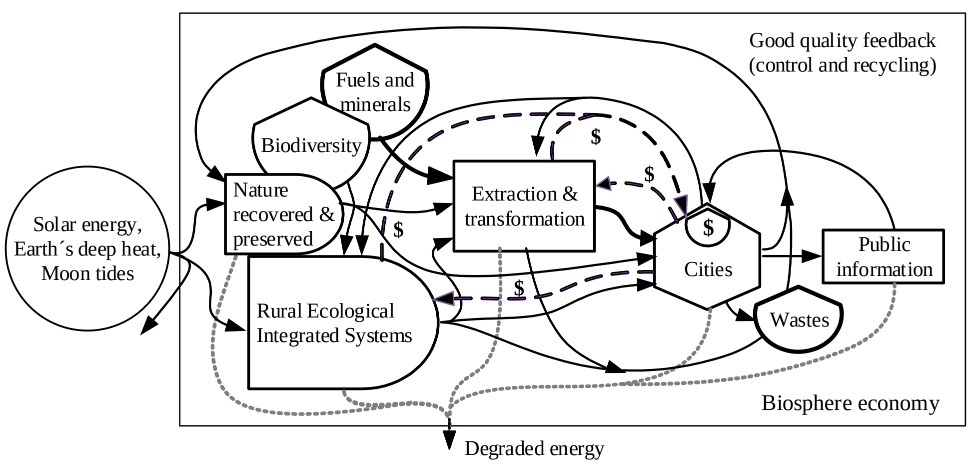


Figure 11. *Sustainable interactions between city and rural areas (adapted from Odum, 2007).*

DISCUSSION

The fossil fuels emergy drives the flows of nature and economy in the biospheres' engine designed and controlled by humans. The oversimplified vision of monetary flows and stocks fails to recognize the importance of many Biosphere components. Therefore, a biophysical economic approach is necessary, with emergy flows and stocks detailing the complexity of biological, social and political systems.

Emergy Science allows the critical study of ecological-economic systems in order to calculate resource values to clarify whether a market price is correct or imbalanced in valuing nature's contributions (Campbell and Cai, 2007). This information is essential for public policies that can incorporate emergy value in the price, through either taxation or rationing, to guarantee resources recovery, and to ensure future sustainability and governance.

Finally, Emergy Science can help society to imagine and numerically/dynamically describe new perspectives for human and natural biota consortiums in different regions, considering, within the Rural-Urban Integrated Ecological Systems Design, new ecological and political variables and criteria, such as: support capacity, resilience, balance between internal and external political forces, and the capacity for political empowerment. However, this possibility demands to be pro-actively open to social and scientific demands and critiques.

In order to attend demands in relation with systemic scientific knowledge, Emergy Science should build interfaces with other scientific and philosophical approaches. The main points to discuss are:

[01] To review the baseline considerations (ideas from various researchers);
[02] To consider renewability of inflows and modification of emergy indices;
[03] To consider environmental services as products in agricultural projects;
[04] To include negative externalities (social and environmental impacts);
[05] To discuss services inflows (as added work) in national and agricultural systems;
[06] To consider social indicators in emergy terms;
[07] To continue critical discussions of certain emergy indices (EYR, ESI);
[08] To include economic subsidies as inflows;
[09] To develop emergy indices for ideological, military, and cultural flows and stocks
[10] To measure the power of social organization, financial and military sectors etc.
[11] To develop emergy indices to evaluate climate change impacts;
[12] To develop emergy indices to evaluate climate change mitigation;
[13] To develop emergy indices for ecological and social resilience;
[14] To develop emergy indices for internal stocks;
[15] To include the issues of environmental and ethical debts in Emergy Synthesis.

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