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Exploring the sustainable horticulture productions systems using the emergy assessment to restore the regional sustainability

Elisa Sayoko Nakajima*, Enrique Ortega

Ecological Engineering Laboratory, Food Engineering School, State University of Campinas, SP, Brazil

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A B S T R A C T

This paper shows the environmental behavior of different horticultural production systems. Emergy assessment was applied for the analysis of three family-managed horticultural farms located in Ibiúna County and one horticultural subsystem of Yamaguishi Eco-Village in Jaguariúna County, both located in the state of São Paulo, Brazil. For Ibiúna and Jaguariúna farms the total Emergy varied from 2.36E+16 to 9.59E+16 seJ ha^{-1} year^{-1}, the Transformity ranged from 1.58E+06 to 4.98E+06 seJ J^{-1}, the Renewability from 17% to 55%, the Emergy Yield Ratio from 1.14 to 2.24 and the Emergy Investment Ratio ranged from 0.81 to 4.76. The Environmental Loading Ratio values showed a large variation, for organic production from 0.81 to 1.54 and for the conventional production from 4.77 to 4.88. Emergy Exchange Ratio showed a wide variation from 0.03 to 3.49. These results were compared to those obtained in an emergy analysis of five organic horticultural systems located in the highlands of Rio de Janeiro, a study performed by Nobre Junior (2009). The analysis of the whole set of results is that the renewability of Rio de Janeiro's systems is higher than Ibiúna and Jaguariúna systems because these last systems respond to the pressures of market to decrease prices increasing the volume of production using industrial aggressive inputs in a more intensive way. The conclusion will be made available to Ibiúna city government and population in order to promote a transition to Agroecological Systems involving the recovery of soil biota and native vegetation, recycling urban wastes and lowering pesticides and chemical fertilizers use.

1. Introduction

The development of the chemical industry focused on agrochemicals has been an important factor to increase the crop productivity in the last decades; but on the other hand, the intensive use of agrochemicals has become a major threat to the environment and to the social structure (Hole et al., 2005). Considering the ecological and social criticism to the energy-intensive model it has being developed organic techniques in many countries (Stolze and Lampkin, 2009).

In Brazil, during the 70 s, the chemical industry offered a technological package to small farmers in order to promote "economic development". The intensification of the use of fertilizers, pesticides and machinery did result in an increase of crop productivity (kg ha^{-1} year^{-1}), but it did not result in more income for the farmers (Lima Neto, 2001).

On the other hand, the world is now questioning the growing dependence of modern farming on non-renewable resources, as agrochemicals. Farm chemicals are questioned on grounds of cost but their widespread use also has implications for animal health, food quality and safety and environmental quality (Altieri, 1999).

The organic farming is an important strategy for sustainable agriculture as it avoids the use of costly industrial chemicals and improves the food crops quality and it provides control along the entire production chain through the certification process required (Castellini et al., 2006). Nevertheless, a discussion on the contribution of organic agriculture to the future of world agriculture is whether organic agriculture can produce sufficient food to feed the world. The yield in high level organic production can be critical. In particular to the role of legumes, due a crop rotation, a critical issue will be to which extent sufficient nutrients for this crop can be supplied (Ponti et al., 2012).

The organic production models based on the substitution of chemical inputs for biological ones has become a trend in the search for a more sustainable ecological agriculture (Guzmán et al.,

* Corresponding author. Faculdade de Engenharia de Alimentos, Universidade Estadual de Campinas (UNICAMP), Rua Monteiro Lobato no. 80, Campinas, Sao Paulo CEP 13083-862, Brazil. Tel.: +55 19 35214058; fax: +55 19 35214027.

E-mail addresses: sayokonakajima@hotmail.com, esayoko@fea.unicamp.br, sayokonakajima@gmail.com (E.S. Nakajima).

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2000). The agro ecological movement has emerged to meet both environmental and social issues for small farmers in Latin America (Altieri, 1999). In Brazil, recently family farming began to gain public recognition; until the 90 s it was considered a segment of marginal importance to the concerns of a society focused on the big agriculture based in monoculture (Altieri, 2002; Lima Neto, 2001).

In Ibiúna, a city located 70 km from São Paulo, a big city in Brazil standards, agriculture is a traditional activity. The county has about 73,400 inhabitants and two-thirds of its population lives in the rural area (SEADE, 2009). In recent years, some family farmers concerned with the excessive use of pesticides, soil degradation and motivated by the potential market for organic products decided to adopt the organic farming (Prefeitura Municipal de Ibiúna, 2008). Ibiúna is part of the "green belt" composed by a group of cities which provides most of the horticultural production that supplies São Paulo city needs. Ibiúna is also responsible for the conservation of the Jurupará forest park which is recognized by UNESCO as a biosphere reserve for the Atlantic Mountains rain forest.

The assessment of the alternative and conventional horticultural systems is important to provide information to decision makers who aim to maintain environmental services and to reduce environmental impacts in that region. There are several forms to assessment the sustainability of agricultural systems, among of them the Emergy which is total energy used to produce biosphera resource. The Emergy evaluation is environmental accounting methods which uses the thermodynamic basis of all forms of energy, resources and human services, and converts them into equivalents of one form of energy, usually solar emergy.

Emergy evaluation has been used to assess agricultural systems. Zafiriou et al. (2012), have studied the white asparagus production in Greece among conventional, integrated and organic farming systems and also the effect of farming to greenhouse gas emissions to decide best management strategies. Hansen et al. (2001) examined a need to expand and develop organic farming system in line with increasing demands for organic food and growing environmental concerns in Denmark in the light of European Policies. In China the agricultural diversification using more intensive techniques was evaluated using emergy indicators (Zhang et al., 2012), the results showed that although economically feasible, the intensification of agricultural activities became environmentally unsustainable. Lu et al. (2010) evaluated the integrated emergy, energy and economic evaluation of rice and vegetable production systems and the studies showed that long-term rice was the best choice for sustainable development, followed by rotation systems. The emergy assessment of a soybean biodiesel production chain in Brazil showed that the agricultural step uses the highest amount of non-renewable resources (Cavalet and Ortega, 2009). The sustainability assessment of a large-scale ethanol production from sugarcane in Brazil was calculated using fossil fuel embodied energy analysis and emergy assessment adopting Life Cycle Analysis (LCA) concepts and considering two production phases, farming and industrial processing, resulting in a low renewability (Pereira and Ortega, 2010). In Sicily, it was applied to evaluate resource use, productivity, environmental impact and overall sustainability in red orange production and the results showed better performance for the system in which the use of economic resource is more intense (La Rosa et al., 2008). Agostinho et al. (2008) used emergy analysis in association with Geographical Information System (GIS) for comparison of three small farms, located in Amparo County, in São Paulo state, Brazil, the results showed that the agroecological farm was more sustainable and that it could be used as a model for small farms in their transition to ecological agriculture. Wood et al. (2006) compared environmental impacts in an organic and a conventional farm and the results showed that direct energy use, energy related emissions, and greenhouse gas emissions are higher for the organic farm than for the compared conventional farm. Nevertheless, the indirect contributions for all factors are much higher for the conventional farms. Bos et al. (2014) compared organic and conventional performance related an energy use and Greenhouse gas emissions and they obtained similar results.

Ibiúna region is facing socio-environmental problems. Horticultural producers desire a change from conventional to more ecological production systems. The aims of this research is to explore what are the options for horticultural production considered more sustainable, by comparing energy performance of small family-managed horticulture farms.

The research was realized in three properties of Ibiúna: (1) a farm with two subsystems (organic and conventional), (2) an exclusively organic farm, (3) an exclusively conventional farm, and finally, one farm in Jaguariúna County (4) a horticulture subsystem of a complex agroecological farm (Eco Vila Yamaguishi). At the end of this research, the results is compared with those obtained by Nobre Junior (2009) in the emergy assessment of horticulture systems in Rio de Janeiro in order to provide a better profile of horticulture in the Southeast of Brazil.

2. Methodology

Emergy evaluation was applied for four properties of the State of São Paulo, with data base of the year 2008. Fig. 1 shows the location of Ibiúna and Jaguariúna in São Paulo state, Brazil.

2.1. Emergy evaluation

Emergy evaluation is a form of environmental accounting that considers the energy flows of a system, in terms of the amount of energy previously used, directly or indirectly, expressed in a single base: solar emergy, expressed as solar equivalent Joules (seJ) (Odum, 1996; Ulgiati and Brown, 2004). Emergy analysis demands to follow some steps described in the following lines:

2.1.1. Construction of emergy diagram

The system diagram schematically depicts all the inputs, the internal processes as well as the outputs which are essential in the emergy methodology for understanding a system.

2.1.2. Building Emergy evaluation tables, derived directly from the diagrams

When building Emergy evaluation table, each row in the table represents an input of energy from the diagram of the system under study and each row is multiplied by it respective Unit Emergy Value (UEV) to express each inputs as emergy flow. In first lines, it is analyzed the contribution of nature (I), $I = R + N$ where nature's renewable resources are represented by word R and non-renewable by N. Below, in the following lines it is described contribution of resources from the economy (F), $F = M + S$ where M represents the materials and S the services. At the end of the table, it is determined the value of the total emergy used by the system (Y), $Y = I + F$. All the flows are measured in solar equivalent Joules per hectare year. In this work the emergy indicators is calculated according to Odum (1996) and also considering the partial renewability of economic inflows proposed by Ortega et al. (2002), manifested in the Materials (M_R), and in the Services (S_R), as showed in Table 1.

2.1.3. Emergy indicators calculation

The emergy indicators are calculated as described below:

Transformity (Tr): Intensity of energy embodied in the product. It measures the amount of solar equivalent emergy (seJ) used to