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Emergy evaluation of organic and conventional marine shrimp farms in Guaraíra Lagoon, Brazil

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ABSTRACT

Organic products are often appreciated by the consumers as being more environmentally friendly and sustainable compared to their conventional counterparts. However, in the case of aquaculture, scientific information regarding environmental impacts and costs of conventional and organic farming systems is scarce. Scientific methods able to measure the sustainability of production systems are of great relevance to identify best management practices and ensure consumers the sustainability of the production process of aquaculture products. The objective of this study was to compare organic and conventional marine shrimp farms located in Guaraíra Lagoon, Brazil, using emergy analysis. The principle of emergy analysis is to express all costs of a process or product in solar energy units (sej), making it possible to compare systems with different inputs, outputs and environmental impacts. Emergy accounting was used at this study to integrate ecological and human dimensions of conventional and organic marine shrimp farms systems located at Brazilian northeast in order to better discuss and understand the multiple dimensions of the sustainability in such systems. The results showed several emergy indicators in favor of organic farming system: the renewability indicator, the emergy yield ratio indicator and the emergy investment ratio indicator. Both systems (organic and conventional) showed large flows of concentrated non-renewable emergy. Further improvements of the organic system are needed to increase the efficiency and to ensure its economic sustainability.

1. Introduction

Shrimp contributes with a sizeable share in value of the internationally traded sea food. In 2007, the total production of shrimp and prawn from aquaculture was 3.3 million tons (FAO, 2007), 2.3 million tons of which were white shrimp (*Penaeus vannamei*), worth 8.8 billion US$. A large amount of shrimp originates from developing countries where the shrimp industry has become an important economic activity responsible for creating rural jobs and generating foreign exchange earnings (Lem, 2006).

The rapid increases in the world's shrimp production has been achieved by an increase in productivity of the marine shrimp farming (kg/ha/yr) as well as an increase in total area converted to marine shrimp ponds in the past years. This trend has created controversies regarding the sustainability of shrimp production. Although the marine shrimp industry is increasing the income in several developing countries, it is also associated with negative social and ecological impacts (FAO et al., 2006; Páez-Osuna, 2001; Graaf and Xuan, 1998; Flaherty and Karnjanakesorn, 1997; Vigneswaran et al., 1999). The main negative impacts attributed to marine shrimp farming include the conversion of mangroves into marine shrimp ponds, salination of the ground water and agricultural land, use of fish meal to feed shrimp, water pollution due to marine shrimp ponds effluents and social conflicts in coastal regions (FAO et al., 2006).

Brazil is the third largest producers of farmed white shrimp in Latin America (FAO, 2007). The Brazilian production was estimated at 75,900 tons in 2004 (ABCC, 2004), however, it has been decreasing since that year (FAO, 2007). At the national scale, Rio Grande do Norte State (RN) is the leading producer of marine shrimp farmed in Brazil. In 2004, this state produced 30,807 tons of marine shrimp farmed and showed the highest productivity of 4905 kg/ha/yr (ABCC, 2004).

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Guaraíra Lagoon is located in the oriental coast of Rio Grande do Norte State. A large number of marine shrimp farms under semi-intensive and intensive management are located at Guaraíra Lagoon. Despite public concerns about the ecological sustainability of the local shrimp industry and the declining shrimp prices in the international market, marine shrimp industry around Guaraira Lagoon has been growing steadily.

In 2002, one of the conventional shrimp farms located at Guaraíra Lagoon switched to organic management. Under this organic production, natural pond biota is used as the main feed source for shrimp contrary to the conventional system where artificial feed forms a major source of food for shrimp. It should be noted that the management without feeding is not a requirement of organic certification but results from the lack of certified organic feed in the region. In December 2003, this farm became the first certified organic marine shrimp farm in Brazil and was the only one in Rio Grande do Norte state during the study period.

Organic products are often appreciated by the consumers for the environmental friendly nature of their production compared to the conventionally produced products. Often consumers associate organic production methods more sustainable as compared to conventional methods. However, in the case of the aquaculture, scientific information regarding the sustainability of conventional and organic farm systems is scarce and measuring the sustainability of production systems in aquaculture through scientific methods is still a major challenge.

Measuring the sustainability of production systems in aquaculture is essential to compare different production systems and management practices. In a broader aspect, scientific methodologies that allow the comparison of the sustainability of production systems can provide important information for the elaboration of public policies for the development of sustainable systems of production in aquaculture. A number of papers dealing on emergy analysis of aquaculture activities have been published but evaluation of the sustainability of the organic aquaculture system is still a novelty. For this study, marine shrimp ponds of both organic and conventional farming systems located at Guaraira Lagoon, Brazil, were compared using a methodology called “emergy analysis” in order to measure in a objective way and scientific sound method the differences between both systems on a broad basis.

The emergy evaluation proposed by Odum (1996) is an attempt to quantify all direct and indirect effects of an activity in solar energy units as a single “currency” and thereby appears a suitable tool to compare the two aquaculture systems with different resource use. Emergy accounting was used at this study to integrate ecological and human dimensions of conventional and organic marine shrimp farm systems located at Brazilian northeast in order to better understand and discuss the multiple dimensions of the sustainability in such production systems. In a wider scenario, this study highlights emergy analysis as a tool to compare organic and conventional systems in aquaculture, in addition to providing information relevant to the discussion of organic aquaculture and sustainability, and even broader, the comparison of environmental cost of different production systems and their products.

2. Material and methods

2.1. Site description

2.1.1. Macroview over the Rio Grande do Norte State and Guaraíra Lagoon

This study was carried out at marine shrimp farms located in Guaraira Lagoon, Rio Grande do Norte State in North-eastern Brazil (06°11′ and 06°18′ South, 35°02′ and 35°18′ West). Rio Grande do Norte State has 53,077 km^2 of territorial extension and a coast line of 410 km (IDEMA, 2005). Rio Grande do Norte State is host to 2,776,782 inhabitants with more than half of the total population living in the coastal area.

More than half heads of household in Rio Grande do Norte state have income lower than the minimum salary, including 13.53% who do not have any nominal income (IBGE, 2000). Most of the local rural population has little formal education. The sanitary system is equally underdeveloped with only 26 of the 126 municipalities in Rio Grande do Norte state being connected to a sewer system (IDEMA, 2005). The human development index of the municipalities (PNUD, 2000) is 0.705 − 19th in the national ranking of all 25 states.

Guaraíra Lagoon is a highly vulnerable ecosystem under high risk of eutrophication due to the discharge of P into the lagoon. In the lagoon, the risk of eutrophication is increased by the lower dilution of the nutrients continuously released by several anthropogenic sources (IDEMA, 2004) compared to an open coast line. According to Lacerda et al. (2006), the annual emissions of N and P by natural sources via atmospheric deposition and soil runoff are 1–2 orders of magnitude lower than those from anthropogenic sources in the estuaries located at Rio Grande do Norte State. The local marine shrimp farms besides other activities like animal husbandry and agriculture are sources of N and P discharge (IDEMA, 2005).

2.1.2. Considerations concerning the conventional and organic marine shrimp ponds

Table 3 shows notable differences between the organic and conventional grow-out ponds with regards to density, pond size, number of cycles/yr, productivity, mortality rate, as well as the use of artificial feed, aerators, and fertilizers. Both organic and conventional systems yielded shrimp of similar final weight.

The organic pond studied differs from the semi-intensive marine shrimp pond in several management practices. First, the organic pond does not use formulated feed in an attempt to enhance growth of shrimp although the organic standards allow the use of feed. The organic management practices include the use of organic fertilizer before stocking and throughout the rearing cycle. This organic fertilization, which is applied according to water transparency, aims at increasing the natural pond biota that is the only source of food for the shrimp in the organic pond. In the semi-intensive pond the addition of feed is fundamental input for enhancing the growth of shrimp. The natural food is only supplementary to formulated feeds supplied during the rearing cycle.

Table 1
Emergy flows used in the environmental accounting.

Inputs and services	Description
I: Nature contribution	$R + N$
R: Renewable resources from nature	Rain, materials, and services from preserved areas, nutrients from soil mineral and air.
N: Non-renewable resources from nature	Soil, biodiversity, people exclusion, water input.
F: Feedback from economy	$F = M + S$
M: Materials	$M = M_R + M_N$
M_R: Renewable materials and energy	Renewable materials from natural origin
M_N: Non-renewable materials and energy	Minerals, chemicals, steel, fuel, etc.
S: Services	$S = S_R + S_N$
S_R: Renewable services	Manpower supported by renewable sources
S_N: Non-renewable services	Other services (external), taxes, insurance, etc.
Y: Total emergy	$Y = I + F$

Source: Odum (1996).