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Energy and resource basis of an Italian coastal resort region integrated using emergy synthesis

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ABSTRACT

Sustainable development of coastal zones must balance economic development that encourages human visitation from a larger population with desires that differ from the local residents with the need to maintain opportunities for the local resident society and conserve ecological capital, which may serve as the basis for residents.

We present a case study in which the sustainability level of a coastal zone (Riviera del Beigua), located along the Ligurian coast of north-western Italy, was assessed through the lens of systems ecology using emergy synthesis to integrate across economic, social and environmental sub-systems.

Our purposes were (1) to quantify the environmental sustainability level of this coastal zone, (2) to evaluate the role of tourism in affecting the economy, society and environment, and (3) to compare emergy synthesis to Butler's Tourism Area Life Cycle model (TALC). Results showed that 81% of the total emergy consumption in the coastal zone was derived from external sources, indicating that this tourist-heavy community was not sustainable. Tourism, as the dominant economic sub-system, consumed 42% of the total emergy budget, while local residents used the remaining 58%. The progressive stages of the TALC model were found to parallel the dynamic changes in the ratio of external emergy inputs to local emergy inputs, suggesting that emergy synthesis could be a useful tool for detecting a tourist region's TALC stage. Use of such a quantitative tool could expedite sustainability assessment to allow administrative managers to understand the complex relationship between a region's economy, environment and resident society so sound policies can be developed to improve overall sustainability.

1. Introduction

Coastal zone management is an urgent issue of interest to industrialized and developing countries around the globe. The direct and indirect environmental and social impacts of tourism on coastal zones are of particular interest due to their economic and social benefits. These impacts are in part derived from increased human habitation, expanded recreational structures, beach erosion, and more air, land and water pollution. Often, the coast is subjected to a high concentration of anthropic pressures, which causes socio-economic development problems. For example, high rates of tourism can mean high levels of urbanization which alter land use and compromise the ecological balance of land and sea based ecosystems (Lomas et al., 2008). On the other hand, tourism plays a fundamental role in driving the coastal economy, especially for Mediterranean countries. Thus, there are competing interests of economic development, ecological conservation, and social opportunities.

Too much economic development increases the risks of exceeding the limits of the coastal ecosystems and local population to withstand drastic transformation. When sustainability is a goal of coastal zone management, all three aspects (i.e. economy, society and environment) must be evaluated and balanced in relation to their ability to drive and maintain the integrated coastal system over a long period of time (Cicin-Sain, 1993).

In the 1980s H.T. Odum introduced the emergy synthesis method which takes a holistic and quantitative view of what is required to operate a human-nature system (i.e. one that includes people's economic production and nature's ecological production). It solves the problem of multiple types of inputs derived from economic, social and environmental systems by transforming each input to the ultimate amount of solar energy required for its existence. Emergy synthesis provides, not only a reliable evaluation of a system's or region's performance, but a comparison of the system's or region's performance in relation to other systems or regions (Lei and Wang, 2008). Moreover, emergy synthesis allows for the comparison of the

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different contributions made by the environment, society and economy using a single quantitative metric. This integrative method enables a decision-maker to see the relative importance of each system driver (i.e. how much economic production was there relative to ecological production?).

1.1. Emergy synthesis

Emergy is defined as the ultimate amount of energy of one type that was required to make another type of energy (Odum, 1996). When dealing with the biosphere and environmental systems the convention in emergy synthesis has been to determine the ultimate amount of solar energy embodied in each type of energy, material or currency used to operate the system of interest. Thus, emergy synthesis has the unique ability to place all of the inputs necessary to operate a human-nature system on a single quantitative basis. Regardless of whether a key system driver is commonly measured in energy, mass or money, emergy synthesis can convert all to their ultimate amount of solar energy. Thus, the valuation of environmental inputs that are usually regarded as free in economic analysis can be compared with inputs measured in money.

Emergy synthesis is performed by converting the energy, mass or monied-value of the different inputs required directly or indirectly to make a good to the ultimate amount of solar energy required for their generation, which is called solar emergy Joules (sej) (Odum, 1988a). Solar energy is used as the base form of energy because it is the most important energy involved in all biogeochemical processes of the earth (Brown and Herendeen, 1996).

In emergy synthesis the solar emergy required per unit energy produced (sej/J) is defined as the solar transformity, which becomes a measurement of where an energy form falls in the globe's energy hierarchy (Odum, 1988a,b), but more importantly can be used to ease computations in emergy synthesis. That is, multiplying a form of energy by its most probable solar transformity provides the best estimate of its solar emergy. From a practical standpoint computation of the solar emergy of a system input cannot always be easily determined based on its energy flow. In some cases it is easier, computationally, to account for the solar emergy of a resource input based on its mass or money flow. In these cases inputs quantified in money are multiplied by the mean ratio of solar emergy flow to dollar-denominated economic activity (sej/€) and those quantified in mass are multiplied by their specific emergy (sej/g).

1.2. Sustainability and equity

Emergy considers a system with larger boundaries and realizes the environmental inventory together with the evaluation of the human impact on them (Siche et al., 2007). This inventory includes the sorting of fluxes according to their origin and/or renewability. That is, emergy allows evaluating the quantity and quality of resources employed in a process (Vassallo et al., 2006) and this is why we could refer to it as an environmental sustainability indicator. In fact, the greater the emergy flow necessary to sustain a process, the greater the quantity of solar energy consumed or, in other words, the greater the environmental cost (Bastianoni et al., 2001). Moreover, in Daly's (1990) perspective a process is sustainable only if the resources consumed are used at a rate that does not exceed the rate at which they are renewed. As a consequence one gauge of system sustainability is its ability to support itself for an extended period of time. Long term sustainability means to rely solely upon indigenous, renewable energy sources (Tilley, 1999).

In this context, Tilley and Swank (2003) offered a systems-based definition of sustainability. Although this definition was pertinent to ecosystem management, it can also deal with human influenced systems. They wrote that ecosystem sustainability is about securing the ecological integrity, structure, and function of ecosystems across multiple generations, balancing the needs of today with the needs of the future. Their idea was based on principles developed in the field of general systems theory (Odum, 1971; Von Bertalanffy, 1968), which states that a sub-system must contribute to its larger system (e.g. economy, society) in an amount commensurate with parallel sub-systems and in proportion to the feedback it receives from the larger system of which it is a part, if it is to remain a viable component of the system. If, due to non-use or extremely low intensity use, a system provides little value to its larger system, it increases the risk that the larger system will consider it to have little value and discard it (Region 1 in Fig. 1). On the other hand, highly intensive use will likely degrade the ecosystem's structure and function, affecting its ability to perform satisfactorily in the future (Region 3 in Fig. 1). Sustainable management aims to be in Region 2 of Fig. 1 where development intensity is neither too low nor too high (Tilley and Swank, 2003).

In other words, sustainable management cannot only be concerned with minimizing the intensity of resource use; it is a balancing act between low intensity use and high intensity use; the former conserves local ecological integrity, while the latter diminishes the risk of being banished from the larger system (Fig. 1). Taking these appraisals into account, it becomes clear that, as far as concerns coastal zones, the real challenge resides in finding the development intensity that is sustainable. In fact coastal zone management is nowadays approached as a dynamic process aiming at a development regulation able to manage human activities preventing damages both to environmental and economic resources (Clark, 1994). This consists in ensuring optimum sustainable use of coastal natural resources but also in aiming at tangible objectives as, for example, supporting fisheries or attracting tourists. Troubles in pursuing these targets may arise when stakeholders interested in coastal zones have different and often competing goals. The limited coastal space, relatively high population densities, diverse marine and terrestrial habitats in close proximity, and the many economic and social interests all increase the potential for conflicts over coastal space and resources (Suman, 2001).

Consequently, coastal zone managers must attempt to achieve equity among competing users. That is, they must satisfy the multiple demands of the larger public who want to use the coastal zone for beach sun-bathing, marinas, wild and farmed fishing, or other recreational desires. Emergy synthesis, by measuring the

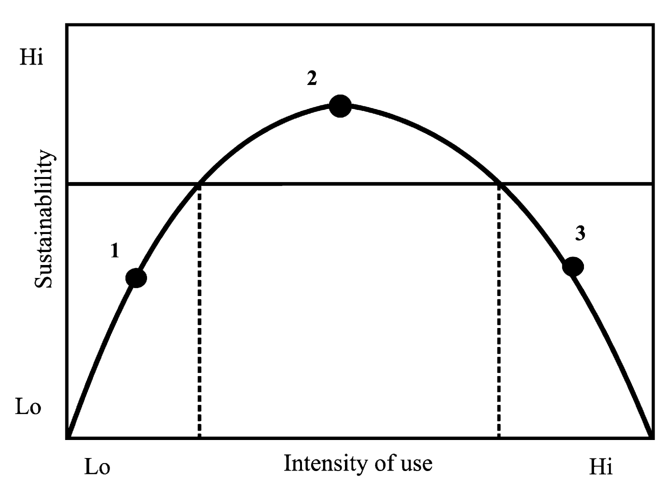

Fig. 1. Likelihood of achieving sustainability is highest when the intensity of land use is intermediate (based on Tilley and Swank, 2003).