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Emergy synthesis of tourism-based urban ecosystem

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Abstract

Macao is a tourist city with a dense population, but is short on natural resources. Almost all of the life-support resources of the city depend on imports from outside. During the past 20 years, Macao has experienced an economic boom accompanied by rapid social development. The tourism industry (including gambling, hotel accommodation, restaurant dining, and shows) have become the city's main economic activity since 1991. This paper uses emergy flow analysis to investigate and characterize the urban evolution and city development that have occurred in Macao from 1983 to 2003. Macao's tourism industry has existed almost from the establishment of the city, with the legalization of gambling in Macao occurring in 1850. Tourism has become the biggest industry in Macao, contributing more than half of the city's revenues since 1995. The emergy flow related to tourism was tracked and analyzed to measure its contribution to Macao. In addition, we used statistical analysis to divide the various emergy-based indicators into three categories: positive, negative, and insensitive indicators.

Keywords: Emergy synthesis; Emergy-based indices; Net emergy; Net emergy ratio; Tourism; Gambling; Macao

1. Introduction

Since the concept of "embodied energy" (emergy) was first introduced in the 1980s, emergy has become of increasing interest to researchers. Emergy analysis considers all systems to be networks of energy flows and determines the emergy value of the systems involved through a synthetic approach. "Emergy is a universal measure of real wealth of the work of nature and society made on a common basis" (Odum and Odum, 2001). Synthesis of emergy flows provides an energy basis for quantification or valuation of the goods and services embodied in ecosystems. Since the early 1980s, the emergy framework has been widely used to analyze systems as diverse as ecosystems, industries, and economies. The relevant indices and ratios based on emergy flows can be used to evaluate the behavior of ecological economic systems (Brown and Ulgiati, 1997).

Emergy synthesis is necessary to obtain not only a reliable evaluation of a system's or region's performance over a period of time, but also a comparison of the system's or region's sustainability compared with other systems or regions. Time-series analyses have proved to be very useful in understanding the dynamic trends in sustainability (Huang and Odum, 1996; Cialani et al., 2005; Hagström and Nilsson, 2005) because this approach can be applied to systems ranging in size from cities to countries. Studies using this approach have highlighted the importance of regularly updating regional and national statistics, since the time series can reveal variation in the ecological parameters of economic systems.

For the purposes of this paper, we have defined tourism as the activities of persons traveling to places outside their usual environment for leisure, business, and other purposes not related to receiving monetary remuneration from the place being visited. The World Tourist Organization (WTO) defined sustainable tourism development as "a form of development, provision of amenities, or tourist activity that emphasizes respect for and long-term preservation of natural, cultural, and social resources and

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makes a positive and equitable contribution to the economic development and fulfillment of people living, working, or staying in these areas''.

Since the early 1980s, the framework of emergy synthesis has been used to analyze tourism (Abel, 2000, 2003; Brown and Ulgiati, 2001). Brown and Ulgiati (2001) have studied tourism resorts in Mexico and Papua New Guinea, and proposed that sustainable development was related to the net emergy benefits, and that sustainability was likely to result from a positive emergy balance. This paper applies the approach of emergy synthesis to investigate Macao's emergy changes from 1983 to 2003 from economic and environmental perspectives.

2. Environmental and economic characteristics of Macao

Located on the west coast of the Pearl River estuary in southeastern China, Macao is characterized by more than 400 years of cultural mixture between the Western world and China, and has a population of 465,333. Macao lies between longitudes 111°31′33″E and 111°35′43″E, and between latitudes 22°06′39″N and 22°13′06″N. Macao consists of the Macao Peninsula, Taipa Island, Coloane Island and some reclaimed land (Fig. 1). In total, it covers an area of 27.5 km^2 (The Statistics and Census Service, 2004).

Colonized by the Portuguese in the 16th century, Macao was the first European settlement in the Far East. Pursuant to an agreement signed by China and Portugal on 13 April 1987, Macao became the Macao special administrative region (SAR) of China on 20 December 1999. Because of Macao's architectural heritage, the city has officially been listed as a World Cultural Heritage site since 2005.

Tourism (including gambling-related activities), manufacturing, finances and insurance, and construction and real estate development were thought of the four pillars of Macao's economy since 1980. Since then, Macao has become a consumer economy, particularly after both the agriculture and the fishery sectors began to decline in 1990. Moreover, the manufacturing sector has found it increasingly difficult to compete with factories in Mainland China, leading to a migration of factories to southern China. Although Macao's daily necessities for life (water, food, fuel, raw materials, and goods) depend upon imports, the economy has maintained robust growth and sustained prosperity based on the gambling and tourism industry (henceforth, the ''tourism'' industry). In 2003, Macao's GDP reached MOP 63.37 billion, or about $10 billion at an exchange rate of 8.021 MOP per $. The booming tourism industry contributed taxes amounting to $1.9 billion from gambling (The Statistics and Census Service, 2004). By liberalizing the gambling industry, the government has also set in motion further tourism redevelopment. Two new casinos were opened under new foreign gambling licenses issued in 2004. In the future, it appears likely that Macao's economy will rely increasingly on tourism and trade-related services to sustain its growth.

3. Methodology

3.1. The emergy accounting method

Emergy synthesis was used to quantify both environmental and economic systems. The energy inputs from environmental sources (R, also referred to as the ''renewable resource inputs'') are tides, waves, and rain; the energy and materials imported from outside Macao (F) are water, raw materials for industry, minerals for infrastructure construction and the reclamation of land, food, fuel, a small input of electricity, goods, and labor. The outflow of energy (Y) comprises products and tourism service exports. The waste emergy (W) involves urban rubbish that is incinerated, municipal wastewater discharged after treatment, and gaseous emissions of pollution into the ambient air.

Within this context, emergy is defined as all the energies that are consumed to produce a product, with each of these

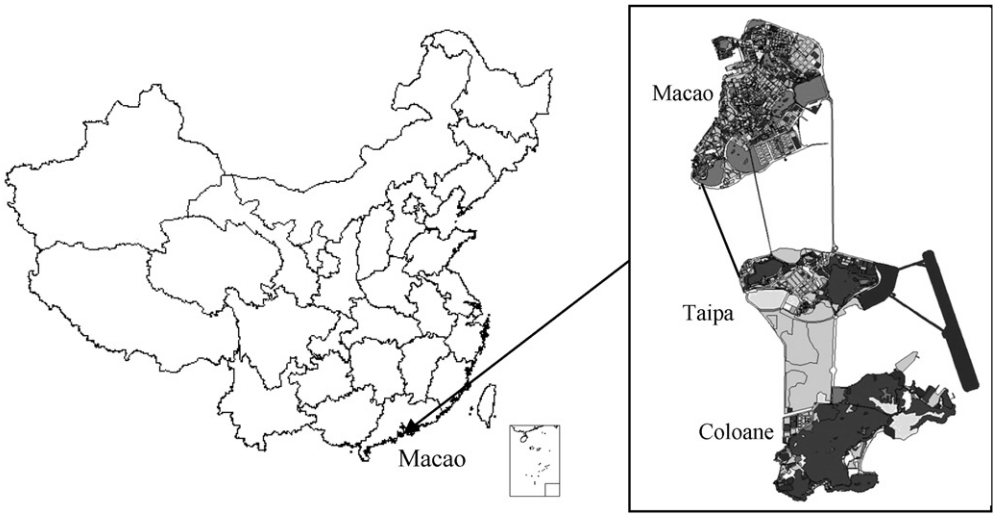

Fig. 1. The location of Macao.