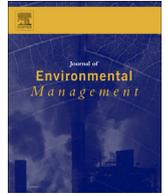




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Research article

Simulation of a dynamical ecotourism system with low carbon activity: A case from western China

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ABSTRACT

Currently, sustainable tourism is becoming more and more important in developing ecological economies. To achieve low-carbon development, some industries, such as logistics and municipal solid waste, have already taken action, but tourism has not attached sufficient importance to this issue. This paper designs an ecotourism system including tourism, carbon waste (solid waste and sewage), and ecology (water supply and green areas) to simulate low-carbon ecotourism through a quantitative approach. This paper explores the tourism system as well as some interactive factors and studies their quantitative relationship based on historical data. A feedback-loop dynamical system model is designed to simulate tourism, waste carbon, and ecology simultaneously. Finally, a case study applying the feedback-loop dynamical system model to Leshan City, a typical travel destination with colorful natural resources in western China, is conducted to indicate the development of ecotourism in an environmentally friendly economy, which verifies the positive effects of the model. Results show a coordinating upward tendency of tourism, solid waste carbon, and ecology from the dynamical model. When tourism increases, solid waste accumulation increases; however, the amount of sewage dumped directly into nature decreases sharply. After analysis of investment policy scenarios, the research indicates that more funds for sewage treatment will attract more tourists. To maintain the equilibrium of carbon waste, more funds shall be invested in solid waste treatment in the long term. Some discussions about local policy are included.

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1. Introduction

Tourism is a great driving force that promotes economic and social development, but the sheer size of the tourism industry means it can produce great impacts on ecosystem structures and processes because it can damage natural nonrenewable resources (Holden, 2003). For a popular site with abundant natural and cultural value, the possibility of being ruined by heavy visitation rises, which will damage the experience of tourists (Hillery et al., 2001). Ecosystems are changing in tourist destinations, related to the stress caused by the greenhouse gases of fuel consumption and waste disposal (Hall et al., 2015). It is time for local human societies and tourists to adjust their ecosystem-damaging behavior in response to the apparent damage to these systems (Scheffer et al., 2000). The residents in scenic destinations realize the tourism industry must depend on the services and functions guaranteed by

the destination's various resources (Lubchenco, 1998; Luck et al., 2003). Tourism ecosystem services must cover the following aspects: the presentation of special local goods (delicious local food, costumes, timber), basic living experience tours (natural air, fresh water, and climate change), spiritual tours (serenity, beauty, and cultural inspiration), preservation of options (conserving natural beauty and cultural variety for other tourism), and the disposal of waste left by tourists (Daily, 1997; Lubchenco, 1998). The ecological characterization of tourism ecosystem services needs to be defined locally, regionally, and globally. In addition to the natural capital, the service suppliers should offer relevant information and suggestions about the ecological trade-offs associated with optional courses of low-carbon tourist activity to the authorities (Daily, 2000). A socioecological approach, which integrates ecological, economic, and social issues, may make this possible. Often, scientists examine tourism, low carbon, or ecological system rather than the linkage between three systems (Ostrom, 2004). The increasing number of tourists and their exploration of previously remote areas of western China has intensified the potential contradictions of nature-based tourism. Therefore, the sustainability of tourism

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development is important to an ecological economy.

Leshan City is on the southwestern fringe of southern Sichuan province in western China. As one of the most popular tourist destinations in China, Leshan has rich tourism resources. In 1996, the Mount Emei Scenic Area was named a World Heritage Site by the United Nations Educational, Scientific and Cultural Organization. Because of its rich natural resources and local cultural heritage as well as a sufficient supply of quality accommodations and tourist services, Leshan has become one of the most popular tourist destinations in the world. In 2013, Leshan hosted more than 29 million visitors. The volume of visitation in Leshan has made the tourism industry the most important sector of the local economy. Tourism accounts for over 28% of the city's GDP.

The aim of this research is to predict dynamic ecotourism development with a systematic feedback cycle among tourism, waste carbon, and the ecosystem. After a brief literature review in Section 2, we design, in Section 3, 6 feedback circle chains for the ecotourism system, and we then provide a new system model for the development of ecotourism. In Section 4, based on the model and human awareness of environmental protection, we collect and process a series of related tourism data for Leshan City over 13 years. In Section 5, we summarize and discuss the local policy as well as necessary further work. In Section 6, we draw conclusions from our research.

2. Literature review

It is undoubted that tourism contributes to climate change and that its contribution will increase in future (Hall et al., 2015). A study showed that 4.4% of global CO₂ emissions are caused by tourists, and the emissions are expected to increase at an average rate of 3.2% annually (Peeters and Dubois, 2010). Hall et al. (2015) stated it is time to encourage and welcome tourism-related adaptation and mitigation measures. Some scholars have focused on reduction of the energy consumption of hotel and accommodation facilities (Teng et al., 2012; Tsai et al., 2014), which are important sections of the tourism industry. Although most anthropogenic emissions of greenhouse gases are caused by the consumption of fossil fuels, as Lin's (2010) and Becken and Patterson's (2006) research on carbon dioxide emissions from tourism transport showed, waste is another large contributor to climate change. Ackerman (2000) pointed out most of the carbon that decayed aerobically from organic waste in landfills was gradually released to nature, half as carbon dioxide and half as methane, which accounted for about 4% of all greenhouse emissions. A variety of food turns out to be a significant tourist attraction that is important to the visitor experience (Cohen and Avieli, 2004). However, food production and consumption in the tourism industry make a range of contributions to global emissions of greenhouse gases (Gössling et al., 2011). Especially, Venkat (2012) reported food waste resulted in lifecycle greenhouse gas emissions of at least 113 million metric tons of CO₂ per year, which is equivalent to 2% of national emissions in the United States. Some scholars use the low carbon index system to value scenic areas for tourist attractions, which will help develop low-carbon tourism (Cheng et al., 2013).

Tourism, as an important sector of the economy in developing countries, heavily depends on the quality of the country's natural resources. Meanwhile, it uses the water and land resources, directly or indirectly, to establish a tourist-friendly infrastructure of accommodation, routes, and services as well as produces waste, litter, and sewage (Butler, 1991; Hubacek et al., 2009; Rico-Amoros et al., 2009). For instance, after empirical analysis of hotel water consumption, Deyà Tortella and Tirado (2011) pointed out tourist water consumption could cause serious sustainability problems where a large part of world tourism is concerned. In addition, Iglesias et al.

(2007) indicated tourist water consumption was about three times higher than local demands in the Mediterranean, and the permanent water demand for tourism facilities and leisure structures was increasing. Other scholars have put forth the similar idea that a large number of tourists have often generated negative effects on sustainable water use, which in turn has damaged ecosystems (Gössling, 2001; Gössling et al., 2012). Tang (2015) used an index system including green areas, water volume, waste water, and solid waste utilities to evaluate the coupling coordination between tourism and the environment. Mateu-Sbert et al. (2013) estimated the impact of the tourist population on municipal solid waste generation. They concluded each additional tourist generates 0.160 kg of solid waste per day. Xu et al. (2017) reported the nature of tourism's impacts was determined by the relationship flows and interactions between subsystems of economics, the natural environment, and sociocultural variables. However, few scholars have focused on the dynamical feedback circle among tourism, solid waste, sewage, green areas, and water supply.

Dyson and Chang (2005) and Karavezyris et al. (2002) used a differential dynamical system model to forecast solid waste generation. Martínez-Fernández et al. (2000) modeled the dynamic evolution of traditionally irrigated lands. Although some scholars predicted tourism demand with a dynamical economic model (Garín-Muñoz, 2006; Garín-Muñoz and Montero-Martín, 2007), few scholars have done the research on ecotourism using a dynamical system model. In light of the evolution of structured or semistructured forecasting techniques, dynamical modeling is taken as a promising approach for simulating ecotourism issues.

3. Proposing dynamical systems

To realize the development of low-carbon ecotourism in Leshan City, an ecotourism system is designed and the causal relationships are explored. A feedback model will be proposed to indicate the tendencies of the ecotourism system.

3.1. Dynamical system design

Ecotourism is a kind of environmentally friendly travel to previously remote natural areas, which lays more stresses on environment protection. To ensure human beings can continuously enjoy the beauty of nature (and any other cultural features, past and present) in a way that promotes conservation, ecotourism produces lower negative tourist effects on nature and provides positive socioeconomic involvement of local residents (Ceballos-Lascurain, 1998). The International Ecotourism Society (TIES, 2015) defined ecotourism as "responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education." Honey (2002) described details of ecotourism in 7 characteristics: ecotourism (1) involves travel to natural destinations, (2) minimizes impact, (3) builds environmental awareness, (4) provides direct financial benefits for conservation, (5) provides financial benefits and empowerment for local people, (6) respects local culture, and (7) supports human rights and democratic movements. In this conception, there are rules for tourists to obey when they travel, or there is an economic target description. However, ecotourism is an activity and involves interaction between visitors and the local environment when tourists arrive at the destination. Few scholars have viewed it from this perspective or defined ecotourism as a dynamical system caused by tourists. In this paper, we define ecotourism as a feedback dynamical system interacting among 3 subsystems—a tourist subsystem, carbon activity subsystem, and ecology subsystem (see Fig. 1). This definition absorbs the ideas of Honey's definition of ecotourism and describes the attraction of higher-quality ecological

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