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Analyzing and measuring the sustainable development for a scenic area by applying an emergy analysis

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Abstract

Along with the progress of civilization, human being's improper acquisition and consumption of natural environment in terms of resource supply and wastes carrying functions have gone far beyond the load-carrying capacity of the natural system, thus resulting in the damage of ecological foundation and the vicious circle of declining resource productivity and degrading environmental quality. This study utilizes emergy analysis model to study the sustainable development of Cing-jing area in Taiwan. Findings showed that total emergy use in 2014 was 1.96×1023sej, emergy of renewable resources was 1.23×1022sej, emergy of nonrenewable resources was 1.16 ×1023sej, emergy of products from renewable resources was 1.08×1022sej, emergy of currency flow was 6.24×1022sej and emergy of wastes flow was 4.81×1022 sej. The foregoing findings indicate that Cing-jing area currently belongs to an economic development pattern based on high resource-consumption. The economic development is mainly established on the exploitation and utilization of nonrenewable resources. In particular, we estimate the ecological economic system of Cing-jing area as references in order for the responsible agency to maintain a balance between ecological preservation and tourism development.

Keywords— Emergy Analysis, Ecological Economic Ssystem, Sustainable Development

INTRODUCTION

With the transformation and upgrading of global industries in recent years, tourist industry has been universally acknowledged as one of the industries with the greatest development potential. According to Word Travel & Tourism Council [12], the contribution of travel industry to the global GDP in 2011 is US$6 trillion, accounting for 9%. It is predicted that travel and tourism industry will have an annual increase rate of 4% in next decade and global GDP will increase 10%, bringing an income of US$10 trillion. In addition, In the Travel and Tourism Competitiveness Report 2013 published by the World Economic Forum, Taiwan was ranked 33rd among 140 countries. Compared with its ranking in 2009 and 2011, Taiwan has advanced 10 and 4 places, respectively. These data demonstrate the substantial potential of Taiwan's tourism industry and the rapid demands for related growth.

Cing-jing area in Taiwan is the famous recreation sight-seeing resort with abundant natural resources and the suitable climate. With the rapid development of the tourism industry, however, came also issues pertinent to environmental impact of tourist activities. Under the idea of sustainable development of tourism resources and lessening of recreation-incurred impacts, how to ensure that our tourism is developed under the principle of sustainable operation and is beneficial to ecological conservation with biological diversity and climate shifting taken into account has become a crucial issue.

As the tourism industry continues to flourish, tourism-related environmental issues are becoming increasingly apparent every day. Tourism ecological capacity (TEC) has become the focus of tourism research. Current domestic and foreign studies of TEC typically emphasize methods for evaluating and applying TEC, specifically, using quantified analysis approaches and directly or indirectly measuring TEC [6,13,17]. Zhang, Yang and Yu [16] stated that although most existing sustainability evaluation methods can provide insights into the influence that human activities exert on various ecosystem functions, their applicability for evaluating relevant issues on a social and economic level is limited. In addition, most previous studies have not explored dynamic development trends. Hence, relevant literature has scope for improvement. Among existing research,

In the last two decades there has been intensive progress in the use of two appraisal tools: ecological footprint (EF) [11] and emergy analysis [7]. EF examines the index established for sustainability issues under the notion that human consumption behaviors depend on natural environments. emergy analysis is a technique of quantitative analysis, which determines the values of resources, services and commodities in a common unit of the solar energy it took to make them [2]. The methods of these approaches are different, but they aim to solve the same problems through accounting in some way or other humanities energy and resources throughput, estimating the gap between demand of humanity and natural services, and appraising the situation of natural resource utilization.

Whereas conventional economics cannot take biophysical points of view into account when utilizing currency value to evaluate natural resources, this study aims at applying the emergy analysis in ecological economics model to evaluate the status of ecological economic system of Cing-jing area in Taiwan. In terms of the key concept of the model, emergy analysis is to convert resources into an energy unit with universal quality (solar emjoules, sej), trace back all the energy inputs required in the early stages of providing products or labor services, use the flow direction of energy, amount of flow and quality to measure the interaction and interdependence between environmental system and natural system, with the hope of, through the measurement of natural resources, acknowledging the environmental loading capacity and the stress of current economic activities upon environment, thus to take them as the foundation of evaluating the benefits of different economic activities and regulating policies. According to the above, the application of emergy is not to replace the marketing function of currency, but to evaluate the effect of natural resources on ecological economic system. It is a powerful tool for policy analysis and decision-making researches. Therefore, this study will base on the theories of emergy analysis, formulation of emergy analysis tables, calculation and evaluation of emergy, transformity of emergy and calculation of other emergy indicators etc. to measure the environmental sustainable development of Cing-jing area in Taiwan.

MATERIAL AND METHOD

Study area:

Cing-jing area-the research site used in this study, which is located in central Taiwan. Cing-jing area is a popular location for leisure and recreation attractions, and an important asset to develop international tourism and attract foreign tourists, by virtue of its special terrain and landscape combined with the unique cultural heritage of the indigenous Truku people. However, restricted to land usage division, Cing-jing has no land for building hotels except for those built in the early stage, such as Cingjing Guest Hotel, cabins and camping sites that have already been planned. In order to meet tourists demand, local residents provide accommodation to tourists in the way of bed and breakfast (B&B). However, mountain areas have deep terrain, fragile geology, heavy and concentrated rainfall. Building B&B will definitely have severe impact on ecological environment as well as maintenance of water and land resources. Therefore, in the concept of sustainable development of tourist resources and lower recreational impact, it has no time to delay for hotel industry to make use of resources effectively, to reduce cost and increase operational efficiency, to ensure tourist industry can develop under the principle of sustainable development and to benefit the conservation of environment ecological system.

In this study, we observed that the topography, ecological environment, and existing facilities of Cing-jing area are similar to those of other mountain areas in Taiwan.

Therefore, the evaluation model established in this study can be applied to assess similar types of-mountain ecological systems.

Method:

energy analysis is the process of determining the energy required directly and indirectly to allow a system (usually an economic system) to produce a specified good or service [7]. The concept assigns value to nature's environmental effort and investment to make and support flows, materials, and services and to contribute to the economic system [3]. In emergy accounting, various forms of energy are translated into solar energy equivalent, or solar emergy, using a conversion factor (transformity) that reflects the qualitative value of the energy [15]. By multiplying the inputs and outputs by their respective transformities, the emergy amount of each resource, service, and corresponding product can be calculated [5]. If the flow is evaluated as mass, then it can be converted to emergy using the specific emergy, which is the ratio of solar emergy to mass (unit sej/g)[1]. In general, the quantity of equivalent solar energy per unit product, expressed in sej/J or other units, can be defined as the unit emergy value (UEV)[9]. Emergy methods have been widely applied in many fields [10,14,4].

Energy Systems Diagram of the Cing-jing area :

The emergy evaluation procedure of Cing-jing area consists of the following steps. Firstly, evaluation starts with overview diagramming to identify sources and pathways in the interactive networks of a system. Diagrams are constructed of special emergy language symbols invented by Odum [7] and Odum, Brown and Williams [8]. An emergy systems diagram of Cing-jing area is shown in Fig. 1.

Conversion of Raw Data into Emergy Flows:

After the Cing-jing area system has been defined and mapped and all the flows have been quantified, the conversion of energy and/or mass to emergy can be compiled. This is performed by multiplying the quantified flows of the Cing-jing area in units of mass and energy by the corresponding transformity values of those flows using the equation below (Eq.1):

$$\text{Emergy (sej)} = \text{energy or mass (j or g)} \times \text{transformity (UEVs) (sej/j, g)} \qquad (1)$$

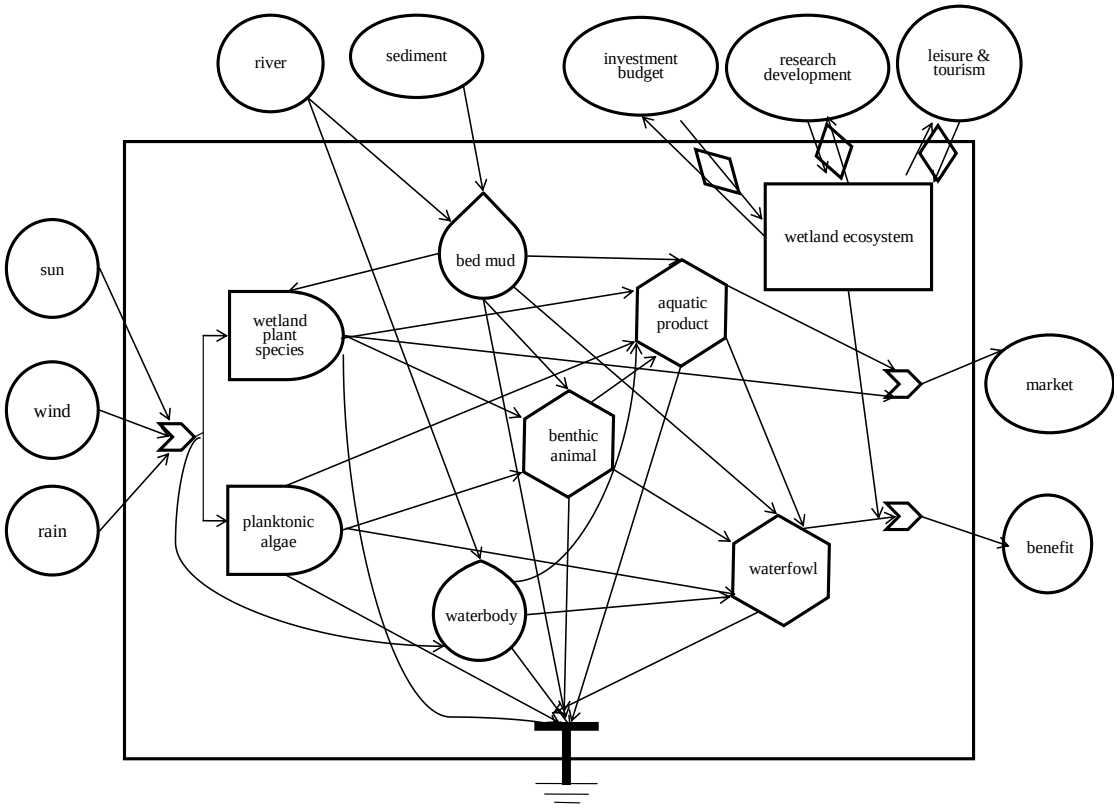

Fig 1. Emergy systems diagram of Cing-jing area

RESULTS AND DISCUSSION

The calculation method of this study refers to the results of relevant studies made by Odum [7] and Odum, Brown and Williams [8]. It collects data of nature, environment and social development in Cing-jing area in 2014. In computing the unit of energy, joule is used in principle, matter is represented by weight, resource of economic system is computed by currency. Because the unit should be unified before computing, energy is converted into same emery unit and macroeconomic value is computed. Through the conversion and analysis processes of the above data, Cing-jing area's emergy analysis table of environmental economic system in 2014 can be acquired.

In Cing-jing area's ecological economic system in 2014, emergy flow consists of 5 components: renewable resources, products from renewable resource, nonrenewable resources, currency flow and wastes flow. The total emergy use was 1.96×10^{23}sej, among which emergy of renewable resources was 1.23×10^{22}sej, emergy of nonrenewable resources was 1.16×10^{23}sej, emergy of products from renewable resources was 1.08×10^{22}sej, total input emergy in currency flow was 6.24×10^{22}sej, total emergy of wastes flow was 4.81×10^{22}sej. Among renewable resources, the proportion of rain resource was about 60.62 %, indicating that the economic development of Cing-jing area is taking the consumption of abundant water resource

as a cost. Therefore, reinforcing water-saving economy and increasing the utilization efficiency of water resource is the problem demanding prompt solution for Cing-jing area's sustainable development. Among products from local renewable resources, the largest proportion was taken by fruits and meats (50.82%). Among the consumption of nonrenewable resources, Pesticide accounted for the highest proportion (48.29%), displaying the nonrenewable resources required in Cing-jing area ’s economic development is mainly cement. Besides, electric energy and steel products also take significant proportions. Among waste flows, the proportion of waste gas was 60.17%, telling that the major environmental pollution in Cing-jing area is atmospheric pollution; the proportions of waste water and solid wastes were 32.57% and 5.84% respectively. Therefore, the improvement of ecological environment in Cing-jing area requires proactive strengthening of preventative measures against waste gas.

Table 1 is the emergy indices of ecological economic system in Cing-jing area, wherefrom the structure and functions of ecological economic system in Cing-jing area can be analyzed, the impact of human activities on environment and the utilization of resources can be acknowledged.

Environmental loading ratio (ELR) is the ratio of total input emergy of nonrenewable resources to total input emergy of renewable resources, showing the stress of economic activities upon environment. ELR is an alarming index of economic system. If the system stays in a relatively high ELR for a long time, the system function will degrade or lose. The ELR of Cing-jing area in 2014 was 21.85. From an emergy analysis point of view, the enormous emergy input from the outside and the excessive development of local nonrenewable resources are the major reasons resulting in the deterioration of environmental system.

Energy self-sufficiency ratio (ESR) is the ratio of emergy input of local resources to the total emergy use of a country, region or city. This value reflects the self-sufficiency capacity of a region on the one hand; it can help understand the level of foreign exchanges and economic development of the region on the other hand. Cing-jing area's ESR was 39.80% in 2014, as indicates Cing-jing area lacks resources and its resource demand for economic development increases, displaying that Cing-jing area is in a high resource consumption-based economic development pattern.

Emergy/money ratio is the ratio of the total annual emergy use to the gross domestic product (GDP) in the same year. It can be told from Table 1 that the emergy/money ratio of Cing-jing area is higher. The reason why Cing-jing area have higher emergy/money ratio is because the emergy its economic activities require mainly comes directly from the natural environment resources that need no payment and its development level is higher.

Electric emergy ratio is the emergy use of electric power to the total emergy use. Electric energy is high quality energy and the use of electric power can reflect the development level of a country or region at people's standard of living. In 2014, the electric emergy ratio of Cing-jing are was 22.90%. This indicates that the abundant electric resources in Cing-jing are not only provide indispensable energy for tourism but also bring convenience to people's living, all of which supply favourable conditions for Cing-jing are's economic development.

Emergy density (ED) is the ratio of total emergy use to the total land area. It not only reflects the emergy use of unit area, but also reflects the density and level of assessed object's economic development. The bigger the figure is, the more developed its economy is. Cing-jing area's ED in 2014 was $1.36x10^{6}$sej/ m^{-2}. This indicates that Cing-jing area is a typical foreign-oriented tourism region.

Table 1: The emergy indices of ecological economic system in Cing-jing area, 2014

ELR	ES (%)	Emergy/$ Ratio	Electric emergy ratio	ED
21.85	39.80	2.94	22.90	1.36

CONCLUSIONS

After applying the emergy analysis method to sustainable development evaluation of Cing-jing area, this paper has come to the following conclusions:

Although Cing-jing area's ecosystem is in ecological reserve and a secure state, it is suggested that tourist area's competent authority pay adequate attention to the adverse effect of tourism development on sustainable development, keep a moderate development speed, control tourist number and raise environmental awareness, otherwise, too many tourists would put too much pressure on the environment of tourist destination and damage the environment on which ecotourism relies for existence and in that case ecotourism will be unable to realize sustainable development.

Based on the conclusions above, this paper suggests, in order to effectively control biocapacity and achieve the goal of conservation and sustainable development of Cing-jing area, the regulations on land planning and use should continue being used and a more explicit conservation program geared to Cing-jing area's regional resources characteristics should be formulated, so as to realize long-term preservation of the unique and beautiful natural environment, flora & fauna ecosystem and historical relics therein. In addition, the management office should designate special persons for patrol and inspection to keep a strict control of recreational activities in the scenic area and prevent tourists' improper behavior which may damage or contaminate the environment and should meanwhile demolish illegal buildings or facilities. As for transport, apart from catering to the demand for transport and recreation, appropriately widening and renovating the road, so as to ensure smooth transport, it is also suggested that CO_2-emission-reduction and energy-saving leisure tourism be popularized and people be encouraged to use mass traffic & transportation means or ride low-carbon, low-power-consumption and low-pollution bicycles, while prudently assessing the safety of geographic environment and road.

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