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Emergy account for biomass resource exploitation by agriculture in China

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Abstract

On the basis of Odum's ecological economic measure of emergy as embodied solar energy, a system account of biomass resource exploitation by agriculture in China 2004 is developed in this paper, which supplements a former study on corresponding long-term historical trends during 1978 to 2000 (Chen et al., 2006. Emergy-based analysis of the Chinese agriculture. Agriculture, Ecosystems and Environment 115, 161–173). The aggregate fluxes and indicators for biomass resource exploitation in China 2004 are calculated and illustrated when compared with those for 2000 to elucidate the latest status of the Chinese agriculture as the exploitation sector for biomass resource. Data sources and algorithm are presented in detail as basic references for related analysis involving the ecological economy of biomass exploitation in agriculture.

Keywords: Emergy; Biomass; Agriculture

1. Introduction

As the socioeconomic sector for exploitation of biomass resource, the Chinese agriculture, with a long history and fundamental status in the national economy, fed 22% of the world's population with only 10% of the world's arable land. Its impact is further reinforced due to the growing exploitation of agricultural product as biomass resource (NDRC, 2006). The efficient exploration and utilization of agriculture-related resources demand systematic researches based on overall and unified accounting in different scales, which have made considerable progress recently (Chen and Chen, 2006a, b Chen et al., 2006a; Chen and Chen, 2007a, b, c, d, e, f; Chen et al., 2007).

Based on the concept of embodied energy out of a combination of energetic (Lotka, 1956) and systems ecology (Odum, 1983, 1996, 1994; Odum, 1996; Odum, 1994), emergy analysis was firstly presented in 1983 by Odum, to fully integrate the value of free environment investment, goods, services and information in a common unit. As a thermodynamic-based environmental accounting approach, emergy evaluation tracks the total amount of resources required to produce something by tracing all resource flows back to the conventionally believed Earth's ultimate energy source of solar radiation (Odum, 1994; Scienceman, 1987). Emergy in terms of embodied solar energy represents all the solar energy insolated by the earth to produce and sustain a certain level of output. As a measure of energy used in the past, emergy analysis is totally different from conventional energy analysis which merely accounts for the remaining available energy at present, therefore proved a more feasible approach to evaluate the status and position of different energy carriers in the universal energy hierarchy. Till now, various systems have been evaluated by emergy analysis on a regional (Higgins, 2003) or national scale (Ulgiati et al., 1994) around the world. Emergy analyses have also been carried out for agro-ecosystems and agricultural industries, such as some farming systems (Bastianoni et al., 2001), ethanol production (Bastianoni and Marchettini, 1996) and meat and dairy production (Serrano et al., 2003).

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In the mainland China, emergy analyses of Chinese society on national and regional scales were first introduced by S.F. Lan (Lan and Yu, 1993; Lan and Odum, 1994; Lan et al., 2002). Referring to the Chinese literatures published in the mainland in recent years, a research upsurge of emergy-based analysis emerged, involving the exploration of the theory itself (Cai and Qin, 2004; Shen et al., 2004), the application of emergy approach on macro social economic systems on different scales (Zhao and Li, 2004; Dai and Zhou, 2005), and in various fields including industries (Feng et al., 2005; Wang et al., 2006), business (Wang, 2005) and agricultural systems, of which agriculture as one of the most important sectors in mainland China was paid more attention and related studies were more than 60 covering most Chinese provinces, autonomous regions or municipalities as shown in Fig. 1 (Liu et al., 1999; Su et al., 1999; Zhang et al., 1999; Li et al., 2001; Chen and Xu, 2002; Dong and Gao, 20003; Min et al., 2004; Li et al., 2003; Dong, 2003; Dong et al., 2004; Liu et al., 2004; Ai and Liu, 2004; Lu et al., 2004; Zhang, 2004; Zhang et al., 2005; Fu et al., 2005; Lu et al., 2005a; Lu et al., 2005b; Liu and Li, 2005; Liu and Li, 2005a; Zhang et al., 2005; Zhang et al., 2006; Li et al., 2006; Duan and Xu, 2006; Wang et al., 2006; Zeng et al., 2006; Bai et al., 2006; Lu et al., 2006; Dong et al., 2006).

Most researchers focused on some specific areas, such as the cropping and pasture ecotone in North China (Dong, 2003; Lu et al., 2004; Fu et al., 2005; Li et al., 2006; Dong et al., 2006), the arid region of Northwest China (Li et al., 2001; Chen and Xu, 2002; Min et al., 2004; Li et al., 2003; Liu et al., 2004; Liu et al., 2005b), and the Loess Plateau (Dong and Gao, 2003; Dong et al., 2004; Zhang, 2004).

On a national scale, Yan integrated the national and provincial agricultural products in 1995 (Yan, 2001). In 2002, Lan presented a preliminarily study for three departments of farming, animal husbandry and fishery

Fig. 1. Regions in mainland China covered by emergy analysis for biomass exploitation via agriculture.

with the data in the separate years of 1988 and 1998 (Lan et al.,2002; Lan, 1995). A recent paper by Chen et al (Chen et al., 2006b) revealed the overall panorama of the Chinese agriculture during 1980–2000 against historical background with drastic political and socioeconomic transitions, in which emergy analysis was applied to diagram, explain and illustrate the Chinese agro-ecosystem, to evaluate environmental and economic inputs and harvested yield, and to assess the sustainability of the Chinese agriculture as a whole. In the work mentioned above, the structure of inputs/outputs and various system indicators were also examined from a historical perspective for the contemporary Chinese agriculture in the two decades after Reform and Open in the late 1980s. As a result, the temporal variation of indicators such as increasing environmental load ratio (ELR), decreasing emergy self-support ratio (ESR) and emergy yield ratio (EYR) illustrated a weakening sustainability of the Chinese agro-ecosystem characteristic of profound transition from a self-supporting system to a modern industry based on nonrenewable resources (NR) consumption.

As a basic reference for the related analysis involving the ecological economy of agriculture as exploitation sector of biomass resource and also an elucidation of the latest development, this paper presents an emergy system account of the exploitation of biomass resource via Chinese agriculture for the year 2004 focusing on the data sources and corresponding algorithms.

2. Methodology and data source

In principle, emergy-based analysis can be conveniently used to measure and aggregate all heterogeneous natural resources and human-helped products. As the biosphere is usually thought driven by solar energy and most kinds of available energy are assumed derived from solar energy directly or indirectly, emergy as abbreviation of embodied solar energy is accepted as a common measure. Solar transformity, i.e. solar energy joules per unit energy joule in unit of sej/J, is used to measure the quality of resource and its position in the universal energy transformation hierarchy. The larger the transformity, the more solar energy required for the production and maintenance of the resource, product or service of interest, and the higher their position in the energy hierarchy of the universe (Odum, 1996; Odum, 1988).

With the use of energy circuit symbols, a typical diagram associated with agriculture as exploitation sector of biomass energy is shown in Fig. 2 followed with previous researches (Chen et al., 2006b; Odum, 1996; Odum, 1994). Inputs to agriculture are generally categorized into four types as shown in the diagram: free local renewable resources (RR), such as sunlight, rain and wind; free local nonrenewable resources (NR), soil erosion, for instance; nonrenewable purchased inputs (NP), such as purchased fossil fuels and chemical fertilizers; and renewable purchased inputs (RP), such as water resources taken from