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Emergy evaluation of cropping, poultry rearing, and fish raising systems in the drawdown zone of Three Gorges Reservoir of China

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ABSTRACT

The agricultural production in the drawdown zone of Three Gorges Reservoir of China has been gradually attracting people's attention in recent years. As influenced by both excessive farming and artificially regulated water level fluctuation, the environmental sustainability of the agricultural system in the drawdown zone is being concerned widely with its production mode and increasing use of agricultural chemicals. Emergy method was used in this study to evaluate the environmental performance of the three agricultural production systems, i.e., cropping, poultry rearing, and fish raising system in the drawdown zone of Three Gorges Reservoir of China. Additionally, to attain a comprehensive understanding of the driving force of respective system's production, some economic indicators are selected to learn the economical efficiency of the three systems referred. The results indicate that the purchased nonrenewable resource accounts for a major portion in cropping production, whereas the renewable resource input constitutes the main part in poultry rearing and fish raising systems. The emergy yield ratio (EYR), environmental loading ratio (ELR), emergy sustainability index (ESI), and economic output/input ratio indicate that the cropping system is less well performed than the poultry rearing and fish raising systems on environmental sustainability, albeit with a relatively higher economic output and net profit. To achieve an environmental sustainable agricultural production, green and clean energy should be advocated to use in the cropping system. At the same time, the government should provide some policy supports to develop an intensive poultry rearing and fish raising productions for raising local farmers' income. Besides, it should be noted that, a controversy about whether the drawdown zone land should be used or not is gradually becoming a social dilemma in Three Gorges Reservoir area. In the long run, the cooperation between the government and local farmers is crucial for alleviating this contradiction, whereby the drawdown zone area's agricultural production could achieve a sustainable development with a light environmental impact.

1. Introduction

With the completion of China's Three Gorges project, the water level of Three Gorges Reservoir (TGR) was manipulated at a lower elevation of 145 m during summer to a higher elevation of 175 m in winter, resulting in formation of the drawdown zone with a total area of 350 km^2 (Zhong and Qi, 2008). Besides, as most areas surrounding TGR are gentle slope hills and slope plough land accounts for a large proportion, the arable land in TGR is not nearly enough to ensure local farmers' agricultural production. For these reasons, farmers that living nearby naturally look for ways to use the land in drawdown zone, (Li et al., 2013). On the other hand, as the water level fluctuation of TGR is opposite to natural river flooding rhythms in China (Chen et al., 2014), the land-use period in drawdown zone usually lasts from April to September within a year. To accommodate this specific alteration, the copping, poultry rearing, and fish raising systems are pervasively fostered and adopted in drawdown zone area, which are considered to be feasible and with economic benefits for peasants' livelihood.

However, aside from social and economical benefits, the cropping, poultry rearing and fish raising production systems in drawdown zone have also brought great pressure and damages to local ecological environment. At some gentle slope areas in drawdown

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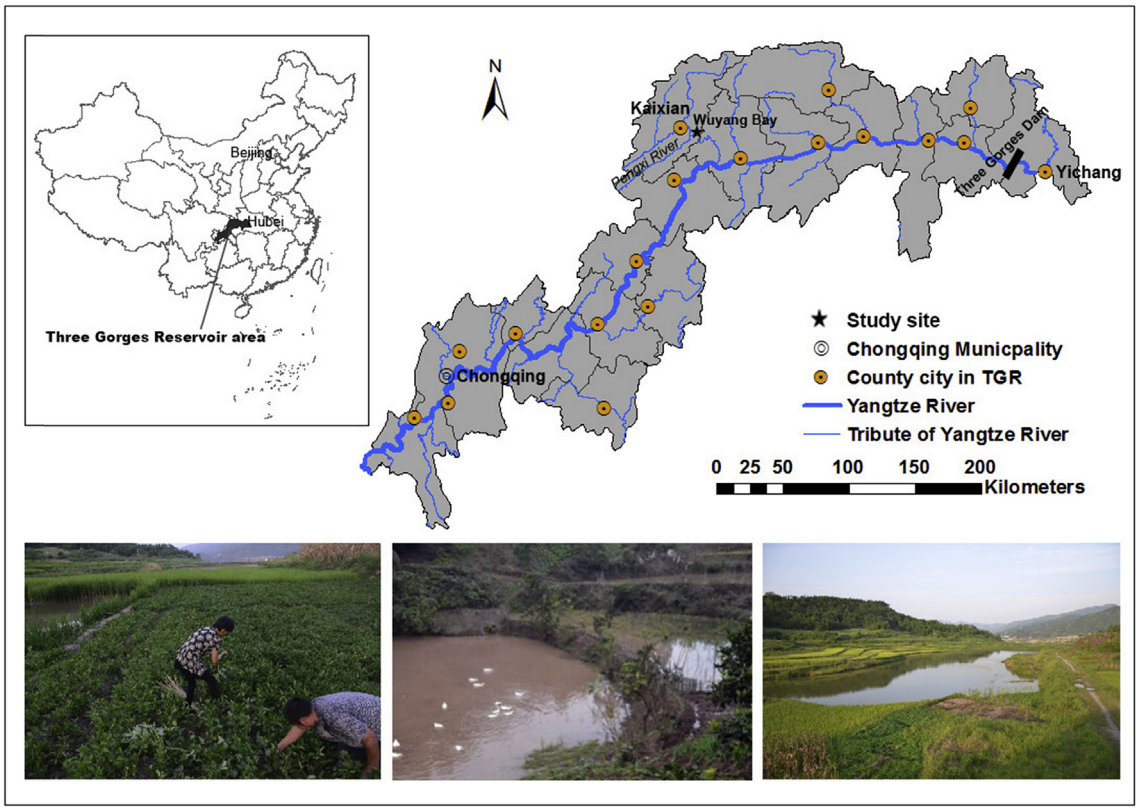

Fig. 1. Location of the study site and plots of the cropping-poultry rearing-fish raising systems in Wuyang Bay.

Table 1
Land-use types of the agricultural system in Wuyang Bay of TGR.

Type	Sub-type	Area (m^2)	Percentage (%)
Cropping land	Paddy field	27306.62	9.34
	Corn field	23648.32	8.09
	Peanut field	2650.53	0.91
	Vegetable field	12663.64	4.33
	Potato field	1272.73	0.44
Forest land		107625.09	36.80
Grass land		34782.21	11.89
Pond		29241.49	10.00
Residential land		13047.87	4.46

zone, the land has been suffered excessive reclamation and farming in recent years, accompanied with mass use of chemical fertilizers and pesticides. This kind of land-use ways have not only decreased local agricultural system's productivity, but also have deteriorated both the drawdown zone and its off-site's environmental sustainability (Zhao et al., 2007). The ecological sustainability of the cropping, poultry rearing, and fish raising systems is now in question in light of current land-use pattern, therefore an integrated approach to quantify both environmental resources, economic inputs, and human activities in aforementioned systems was highly in need. In this context, emergy method (Brown and Ulgiati, 1997; Odum, 1996) was used as an accounting tool for quantifying both environmental resources and economic inputs (Lu et al., 2010) that invested to the agricultural systems in drawdown zone of TGR.

Emergy theory was first introduced by H.T. Odum and his colleagues during the 1980s, offered a common denominator for quantifying both economic and environmental contributions to a system in equivalent units, solar emjoules (Odum, 1986; Lu et al., 2010). Emergy has been proposed as a bridge between ecology and the economy by some scientists (Odum, 1996; Ulgiati et al., 1993; Brown and Ulgiati, 1997; Copeland et al., 2010; Lan et al., 1998, 2002) for a long time. The theoretical and conceptual basis for emergy methodology is grounded in energetic and general system ecology (Odum, 1996). One of the main strengths of emergy is the feasibility to evaluate resources and services in ecological economic system on a common energy basis and to quantify the external costs that normally considered free (Zhang et al., 2007). Emergy method has been widely used to evaluate the agricultural system on different kinds of scales, varied from a single farm to a nationwide agricultural ecosystem, with regard to their resource use efficiency, productivity, environmental cost, and overall sustainability (Ulgiati et al., 1993; Odum, 1996, 2004; Lan et al., 1998; Bastianoni et al., 2001; Lu et al., 2006; Rigby and Caceres, 2001; Lefroy and Rydberg, 2003; Martin et al., 2006). Respecting the agricultural systems with similar production scale like this study, emergy analysis was also successfully applied in some cropping and farming production systems (Giannetti et al., 2011a; Lu et al., 2010; Zhang et al., 2011, 2012). However, to the best of our knowledge, there is still no specific emergy evaluation for the cropping, poultry rearing and fish raising systems in the drawdown zone of Three Gorges Reservoir of China.

Emergy analysis was presented in this study to evaluate the agricultural production of the cropping, poultry rearing, and fish raising systems in the drawdown zone of TGR. The objectives of this paper are: (1) to assess the emergy investment structure of the three agricultural systems; (2) to compare the respective agricultural system's emergy performance and environmental sustainability by emergy indices and economic indicators; (3) to explore the policy implications for local sustainability and ecological

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