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Trade-offs and synergies in ecosystem services for the Yinchuan Basin in China

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A B S T R A C T

The demand for a variety of ecosystem services in environmental management has been widely recognized. However, few of the researchers tried to quantify the interaction between ecosystem services. The aims of this study were to investigate the land use/cover changes (LUCC) in the Yinchuan Basin and to reveal the trade-offs and synergies in ecosystem services associated with those changes. Least-square fitting of orthogonal polynomials were applied to study the trade-offs or synergies between ecosystem services. The results suggest that the LUCC was large, with a 76% comprehensive land use dynamic degree. The ecosystem services were clearly varied, and there was a fluctuation in water retention that was mainly caused by LUCC. There were trade-offs between food production and extreme net primary productivity(NPP), wind prevention and sand fixation, and water retention and extreme food production. There were synergistic relationships between NPP, wind prevention and sand fixation, and water retention under three ecosystem services. Studying trade-offs and synergies between ecosystem services can improve ecosystem management and strengthen the implementation of decision-making processes. Results from this study have potential uses in land use planning, ecological construction, environmental management, and rational utilization of resources.

1. Introduction

Ecosystem services refer to the provisions or services that are produced (directly or indirectly) by an ecosystem. They can be utilized for human well-being actively or passively (Dickie et al., 2011; Fisher et al., 2009; Qin et al., 2015). More countries and studies throughout the world are paying increased attention to ecosystem services after the findings published in the millennium ecosystem assessment (MEA) and the economics of ecosystems and biodiversity (TEEB), which was launched globally in 2005 and 2010, respectively (MEA, 2005; TEEB, 2008). Recently, issues of synergies and trade-offs that could aid in better understandings of the hidden consequences of preferring one ecosystem service to another have been received the attention of studies in order to better understand the hidden consequences of preferring one ecosystem service over another (Eak et al., 2016; Hanes et al., 2017; Jopke et al., 2015; Landuyt et al., 2016a, 2016b; Ungaro et al., 2014). Synergy is a win-win situation that involves mutual improvements in two ecosystem services, and a trade-off is a win-lose or lose-win situation that involves losing one ecosystem service in exchange for gaining another (Haase et al., 2012). This is an interesting but complex problem, and an important research topic.

Over the last 20 years, the "ecosystem service" concept has attracted a great deal of attention. Costanza published a paper entitled "The Value of the World's Ecosystem Services and Natural Capital" in Nature, which was a major breakthrough in the evaluation of ecosystem services and established the relationship between land use change and the ecological environment (Costanza et al., 1997). In the implementation of the United Nations Millennium Ecosystem Assessment Project (MEA, 2005) in 2001, ecosystem services were divided into provisioning services, support services, regulating services, and cultural services for international cooperation. Subsequently, an increasing number of scholars began to direct their attention towards researching ecosystem services (Bettina and Claas, 2016; Christin et al., 2016; Cook et al., 2017; Costanza et al., 1997; Mccarthy, 2012; Robinson et al., 2014). Furthermore, the issues of ecosystem services were brought to the attention of policy-makers. For land use planning, ecological construction, environmental management, and rational utilization of resources, a better understanding of ecosystem services, their trade-offs or synergies and their relationship to LUCC is absolutely necessary (Austrheim et al., 2016; Oudenhoven and Groot, 2013; Locatelli et al., 2014; Lee and Lautenbach, 2016; Fu and Zhang, 2015; O'Sullivan et al., 2015). However, the estimation and integration of ecosystem services is

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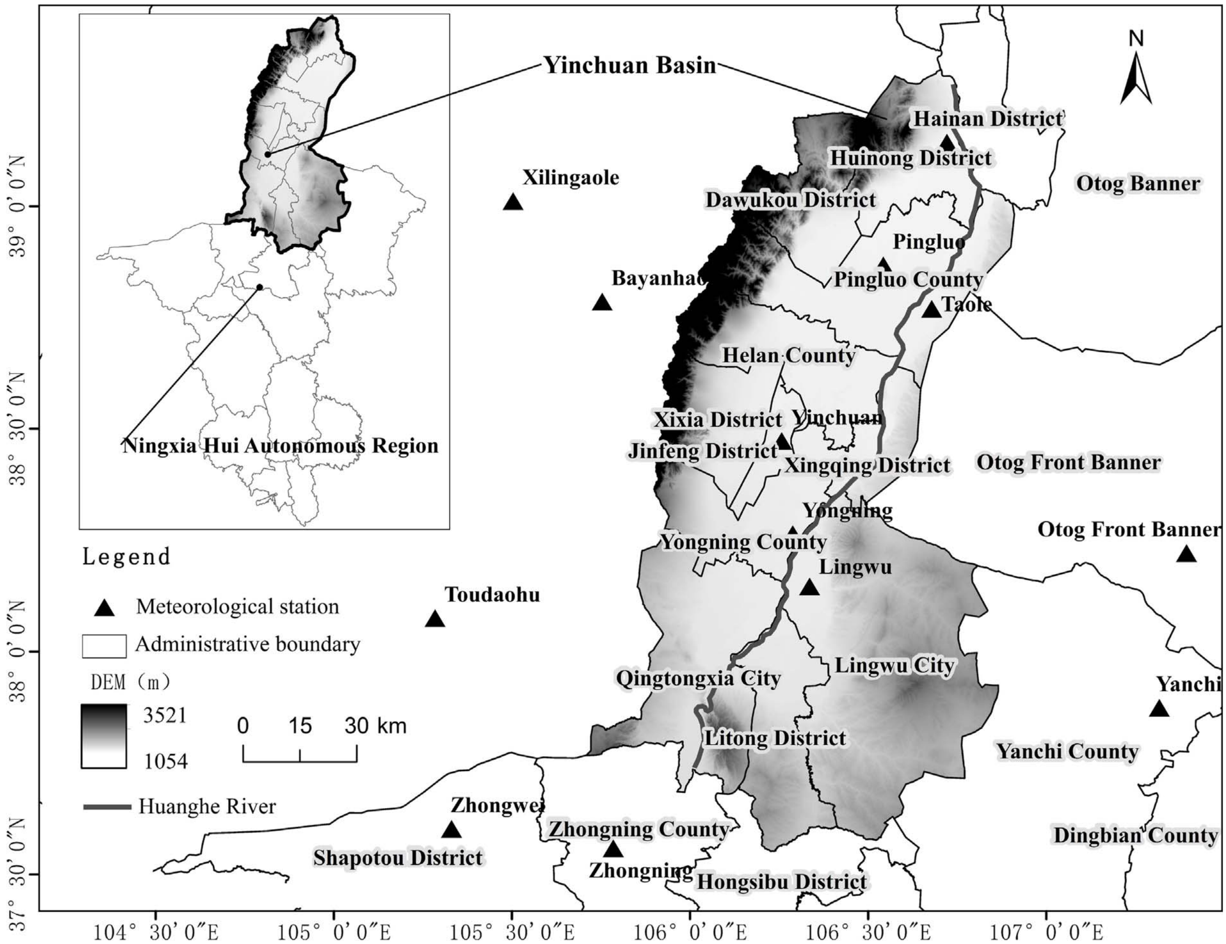

Fig. 1. The locations of the Yinchuan Basin and the study area.

challenging because we face a full range of overlaying ecosystem processes, functions, and respective services due to types and mechanisms of ecosystem services (Peng et al., 2017; Song et al., 2016; Kindler, 2016), scale of ecosystem services (Crouzat et al., 2015; Wurster and Artmann, 2014; Quijas et al., 2012), and uncertainties in ecosystem services (Landuyt et al., 2016a, 2016b; Noe et al., 2016; Thomas et al., 2016).

Unlike the widely studied LUCC, studies to data on the ecosystem services of the Yinchuan Basin have been focused on identifying temporal and spatial changes in single service items, and few investigations have been concerned with multiple ecosystem services. The interactions between ecosystem services have so far been ignored, and a large number of problems have yet to be solved. Therefore, in this paper, we focus on 5 ecosystem services, and the relationships between them. Yinchuan Basin has a typically temperate semi-arid and sub-humid continental climate and is characterized by windy, with wind-blown sands, short hot summers, early and cool autumns, long and cold winters, sparse snow and rain, abundant sunshine and strong evaporation. The ecosystems in the Yinchuan Basin are among the most sensitive in the world. The aims of this study were to (1) investigate the LUCC in the Yinchuan Basin, (2) evaluate the trade-offs and synergies in ecosystem services associated with such changes, and (3) discuss the implications for the least-square fitting of orthogonal polynomials in the Yinchuan Basin. Understand how ecosystem services interactions change as LUCC can be recognized as mitigate the trade-offs or enhanced synergism and maximize the desirable values (Bradford and D'Amato, 2012). Identifying trade-offs and synergies between ecosystem services may improve ecosystem management and enhance the implementation of decision-making processes (Jia et al., 2014).

The remainder of this paper is organized as follows: in Section 2, the study site, data sources, and six methods are introduced. Then Section 3 gives analysis of the spatio-temporal dynamics of LUCC, NPP, water retention, wind prevention and sand fixation and the relationship between trade-off and synergy in ecosystem services. Section 4 discusses the limitation and future research direction of ecosystem service. Finally, we conclude this paper in Section 5.

2. Materials and methods

2.1. Study site

The study area is located in the Ningxia Hui Autonomous Region, China, and ranges from 37°46′N to 39°23′ N and 105°45′E to 106°56′ E (Fig. 1). It lies to the north of Shizuishan City, to the south of the Qingtongxia Gap, to the west of Helan Mountain, and to the east of Ordos, and the total area is 1.44×10^4 km^2 (Yinchuan Municipal Statistics Bureau, 2015; Shizuishan Municipal Statistics Bureau, 2015; Wuzhong Municipal Statistics Bureau, 2015; Litong Municipal Statistics Bureau, 2015). The study area is under the jurisdiction of the Yinchuan Basin (including the Xixia District, Xingqing District, Jinfeng District, Yongning County, Helan County, and part of Lingwu City); the Litong District, which is the part of Wuzhong City; and Shizuishan City (Dawukou District, Huinong District, and Pingluo County).

2.2. Data sources

The data used in this paper were obtained from the following sources: