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Short Communication

Changes in land-uses and ecosystem services under multi-scenarios simulation

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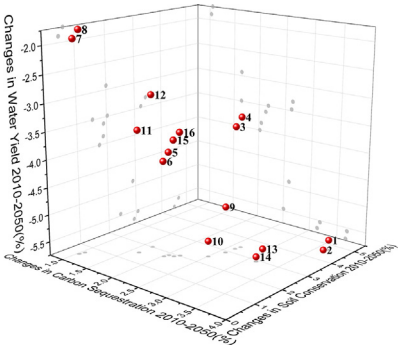
HIGHLIGHTS

- Combinations of climate and policy scenarios.
- Land-use of scenarios were obtained.
- Interactions exist among ecosystem services.

GRAPHICAL ABSTRACT



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ABSTRACT

Social economy of China has been rapidly developing for more than 30 years with efficient reforms and policies being issued. Societal developments have resulted in a greater use of many natural resources to the extent that the ecosystem can no longer self-regulate, thus severely damaging the balance of the ecosystem itself. This in turn has led to a deterioration in people's living environments. Our research is based on a combination of climate scenarios presented in the fifth report of the Intergovernmental Panel on Climate Change (IPCC) and policy scenarios, including the one-child policy and carbon tax policy. We adopted Land Change Modeler of IDRISI software to simulate and analyze land-use change under 16 future scenarios in 2050. Carbon sequestration, soil conservation and water yields were quantified, based on those land-use maps and different ecosystem models. We also analyzed trade-offs and synergy among each ecosystem service and discussed why those interactions happened. The results show that: (1) Global climate change has a strong influence on future changes in land-use. (2) Carbon sequestration, water yield and soil conservation have a mutual relationship in the Guanzhong-Tianshui economic region. (3) Climate change and implementation of policy have a conspicuous impact on the changes in ecosystem services in the Guanzhong-Tianshui economic region. This paper can be used as a reference for further related research, and provide a reliable basis for achieving the sustainable development of the ecosystem.

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1. Introduction

Ecosystem service refers to the benefit people derive from the ecological system directly or indirectly. It mainly means that the ecological system delivers energy and materials to the social economic system, receives and translates the wastes of the social economic system, and directly provides people with service resources (food, wood, clean air, water, etc.) (Fisher et al., 2009; Galati et al., 2016; Papanastasis et al., 2015). Ecosystems offer people a variety of interests through some of its features, such as regulating climate, conserving water, food supply and entertainment (Yang et al., 2015). When external influence is sufficiently low, the ecosystem will provide services for people persistently through self-regulation (Liu et al., 2016). Since the ecosystem's ability of self-adjustment is limited, once external influence exceeds the threshold, the ecosystem will become vulnerable and may even be broken down entirely, which will seriously limit the benefits of people (Cai, 2000; Feng-jin and Hua, 2002). As both human society and economics develop, the deterioration of the ecological environment is becoming more serious and, consequently, more and more people pay attention on safeguarding environment (Adugna et al., 2015; Mol and Keesstra, 2012). It is widely accepted that human activities have a huge influence on land-use changes, which would affected the ecological environment and services in reverse (Adugna and Abegaz, 2016; Khaledian et al., 2016; Liu et al., 2014; Mohawesh et al., 2015; Shelef et al., 2015; Yu et al., 2015). The Millennium Ecosystem Assessment (MA) report has shown, on a global scale, human activities are affecting the natural function of ecosystems and will continually affect the benefits to humanity, for a long time into the future (Millennium Ecosystem Assessment, 2010).

Change in land usage has significant impacts on ecosystem services. In order to explore the relationship between ecosystem services, research usually investigates situations based on changes in land usage. The MA report, through scenario simulation, shows that increases in cultivated land leads to increases in grassland and forestation, and from 2000 to 2005/6 the trade-off relationship between ecosystem services provided by grassland and forest land had a trade-off relationship with ecosystem services provided by cultivated land. Researchers working on domestic ecosystem services explore the changes in ecosystem services under different land use types by simulating “planning scenarios”, “optimization scenarios”, “baseline scenarios”“ and “development scenarios” (Yang et al., 2015). Butler et al. (2013) confirms the trade-off relationship of food supply and water quality regulation, and the relationship between water quality regulation and fisheries, through simulation scenarios. Chen et al. (2013) explored the ecosystem services changes in forest land, grassland and wetland by using the CLUE model. Nelson et al. (2009) predict the trade-off relationship of American Willamette river basin ecosystem services on biodiversity by using the InVEST model.

The implementation of China's Western Development strategy gives prominence to the social economic development of the Guanzhong-Tianshui economic region and this has contributed to the promotion of the social economic development of the western region as a whole. However, the rapid development of the economy brings with it a series of negative effects on the area's ecosystem, and the incompatibility between economic development and environmental protection is increasingly obvious. Therefore, discussions on how to solve the conflict between ecological protection and the economic development of the Guanzhong-Tianshui economic region, and how to put in to practice the coordination of ecologic and economic goals, have a great significance for the sustainable development of the Guanzhong-Tianshui economic region. This paper suggests a number of scenarios covering policy and climate change, predicting the distribution of land-use under various scenarios in 2050. It also estimates three kinds of ecosystem services in various situations in 2050 according to land-use in 2050, determines the trade-off or collaborative relationship of carbon sequestration, soil conservation and water yield, and discusses the influence of policy and climate change on the three kinds of ecosystem services.

2. Materials and methods

2.1. Study area

The Guanzhong-Tianshui economic region is located in the northwest part of China, and includes central Shaanxi and the southeast of Gansu (geographical coordinates are 104°34′47″E—110°48′38″E, 35°51′17″N—33°21′38″N),including the Guanzhong plain area in Shaanxi and Tianshui area in Gansu (6 cities and 1 area). It has a total area of approximately 8.01 km^2 (Fig. 1). The Guanzhong-Tianshui economic region was approved by the state council in 2009 and confirmed in the eleventh national five-year plan as one of the three key economic regions in western development. The economic region has diverse terrain. And it is a warm temperate zone with a semi-humid climate. It has little precipitation and four distinct seasons. The primary type of land use consists of forested areas, grasslands and farmland.

2.2. Research method

(1) Land use prediction - LCM model

LCM (Land Change Modeler) model is the module of ecological sustainable land change, which is the integration of a module in IDRISI. Clark laboratory and International Conservation cooperated for many years and designed the IDRISI. The LCM model aims to solve the problem of rapid land change and biodiversity transformation that has occurred in recent years. It is one of the common models used to estimate land use change. LCM mainly includes MLP-ANN, Markov Chain, Cellular Automaton, Soft and Hard Prediction Model. It can predict future land use situations through the existing land use situation and is a good reference for policy makers to make plans and develop protection policies (Shi et al., 2014). We can also use the LCM model to analyze land cover change, affecting factors of land pattern change, biological diversity change, etc. This model is readily available, easy to operate, intuitive and has a wide range of applications (Liang et al., 2017; Wilson and Weng, 2011). Specific steps of LCM modeler can be learned through the website (http://www.idrisi.cn/).

(2) Scenario Settings

This paper uses four kinds of atmospheric radiation intensity scene - representative concentration pathways (RCPs), mentioned in the IPCC's fifth assessment report - and uses the corresponding land use demand scenario in four scenarios. This paper also puts forward two sets of policy scenarios on the basis of the climate situation. And they are respectively whether to abandon China's family planning policy and whether to levy a carbon tax (Appendix I).

(3) Ecosystem services of Guanzhong-Tianshui Economic region under the scenarios.

We choose to quantify 3 types of ecosystem services—carbon sequestration (Appendix VI), soil conservation (Appendix VII) and water yield (Appendix VIII) in this paper because they are representative in arid and semi-arid area. At the same time, these three ecosystem services can also serve as a representative of the provisioning services and regulating services. When we calculate each scenario in 2050 for the Guanzhong-Tianshui Economic region for carbon sequestration, soil conservation and water yield, we lack relevant basic data such as temperature, precipitation, solar radiation, etc. Consequently in this paper, we assume that the change of ecosystem services are mainly caused by land use change. In calculating the ecosystem services for each scenario, only land use changes, while other factors remain unchanged. By identifying changes in land use from 2010 to 2050 and calculating the average value of different ecosystem services corresponding to different land use

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