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RESEARCH ARTICLE

Impacts of the north migration of China's rice production on its ecosystem service value during the last three decades (1980–2014)

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Abstract

The ecosystem services value (ESV) of rice system has received increasing attention in agricultural policy decision. Over the last three decades, China's rice production presented an obviously trend that moving towards north locations. However, the impacts of this migration on the ESV of rice production have not been well documented. In this paper, we analyzed the change of the ESV of rice production in China under "north migration" and "no migration" scenarios during 1980–2014 based on long-term historical data. The results showed that both the positive and negative ESVs of rice production were lower under "north migration" than under "no migration" scenarios. The total ESV during 1980–2014 was reduced by 15.8%. "North migration" significantly reduced the area-scaled ESV since the early 1990s; while its impact on yield-scaled ESV was not significant. The effects of "north migration" on ESV showed great spatial variation. The greatest reduction in total and area-scaled ESV was observed in south locations. While the yield-scaled ESVs of most south locations were enhanced under "north migration" scenario. These results indicated that "north migration" has generated adverse effects on the ESV of rice production. An adjustment in the spatial distribution is essential to protecting the non-production benefits of rice ecosystem.

Keywords: ecosystem service value, north migration, rice ecosystem, spatial variation, historical change

1. Introduction

Rice paddies, providing nearly 26.5% of global cereal grains production, play an important role in world food security especially in Asian countries (FAOSTAT 2015). Besides food production, rice paddy cultivation also has multiple positive or negative ecological functions, such as flood mitigation, summer temperature cooling and chemical pollution (Matsuno *et al*. 2006). Many studies have been conducted to evaluate the integrated ecosystem service value (ESV) of these non-production functions; the results presented that rice paddies provide more positive values in maintaining the sustainability of regional or even global ecosystem (Kim *et al*. 2006; Chiueh and Chen 2008; Yoshikawa *et al*. 2010; Xiao *et al*. 2011; Natuhara 2013). The ESV of rice paddy cultivation has gained increasing recognition and consideration in agriculture policy reform (Zhang *et al*. 2007; Liu *et al*. 2010a).

China ranks the first in annual rice production around the world. During the past decades, rice cultivation in China has migrated northward due to the natural, social and economic

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factors (Anwar *et al*. 2013; Abraham *et al*. 2014). Chen *et al*. (2012) reported that the north boundary of Chinese rice cropping regions was extended northward 80 km in 2006 compared to 1970 with the increased minimum, maximum and mean temperatures during rice growing season. The planted area of single rice in northeast China has increased by 485% from 1980 to 2010 because of the higher profit of rice than that of other crops; and the area of double rice in south China has decreased by 48% due to the shortage of agricultural labor, as most farmers left country for urban jobs with the rapid urbanization (Feng *et al*. 2013). The center of rice production has moved toward northern China (Tong *et al*. 2003). Some studies have reported that north migration of rice cultivation worsen the shortage of agricultural water in northern regions, reduced the yield potential and increased the transport cost of rice grain, which would generate adverse effect on food security (You *et al*. 2011; Xu C *et al*. 2013). However, it is still unclear the impact of this migration on the ESV of rice cultivation.

Rice paddies distributed widely from tropical areas (nearly 18°N) to temperate areas (50°N) in China. Great spatial variation may exist in the ESV of rice production because of the difference in climate, soil and agronomy factors in different regions (Xiao *et al*. 2011; Burkhard *et al*. 2013; van Berkel and Verburg 2014). For example, the results from field experiments showed that the greenhouse gases emitted from paddy field were significantly higher in south double rice cropping areas than in north single rice cropping areas, largely due to the high temperature during rice growing season and double rice planting system in south areas (Yan *et al*. 2003; Saddam *et al*. 2015). Conversely, the flood controlling ability of paddy field should be higher in south areas than north areas because of the higher precipitation in south China during rice growing seasons. Though, some studies have been conducted to evaluate the ESV of rice field in China (Li *et al*. 2006; Qin *et al*. 2010; Xiao *et al*. 2011). Little is focused on the impacts of north migration of rice paddies on its ESV. This limits the overall evaluation of the effect of north migration on the sustainability of rice paddy ecosystem in China and impairs effective decision making.

Therefore, we conducted this study to investigate the impacts of north migration on the total amount, density and spatial variation of ESV of rice production in China. Our objects are to provide references for the spatial distribution plan and rice production selection for the sustainable development of rice cultivation in China.

2. Materials and methods

2.1. Source of data

Rice is mainly cultivated in four agro-eco zones in China (Fig. 1). Zones I to IV locate in northeast, central east, southwest and south areas of China, respectively provide 15.9, 27.0, 14.9, and 39.5% of total rice production in China. The primary rice cropping system is single middle rice and double rice (early and late rice) in zones I and IV, respectively. As in zones II and III, middle rice-upland crops rotation is the dominant rice cropping system. The principal data of rice cultivation (planting area, yield, total production) for every location in four zones were obtained from the Chinese National Statistical Database (http://www.stats.gov.cn/tjsj/). The data of fertilizer, agricultural film and pesticide used in rice cultivation were obtained from the National Information Summary of the Cost and Income of Agricultural Products (http://tongji.cnki.net/kns55/Navi/HomePage.aspx?id=N2013100048&name=YZQGN&floor=1). The daily meteorological data in rice growing seasons were obtained from the Chinese National Meteorology Statistical Database (http://www.cma.gov.cn/2011qxfw/2011qsjgx/).

2.2. Calculation of ecosystem service value

In this study, two scenarios ("north migration" and "no migration") were evaluated to assess the impact of spatial change of rice cultivation on ESV. "North migration" scenario represented the truly spatial change of rice cultivation in China from 1980 to 2014. The data used in the evaluation of "north migration" scenario were the historical statistic data of rice production during 1980–2014. "No migration" was a hypothetical scenario used as a control to compare with the "north migration" scenario. In this scenario, we assumed that the percentages of rice planting area in each location of four

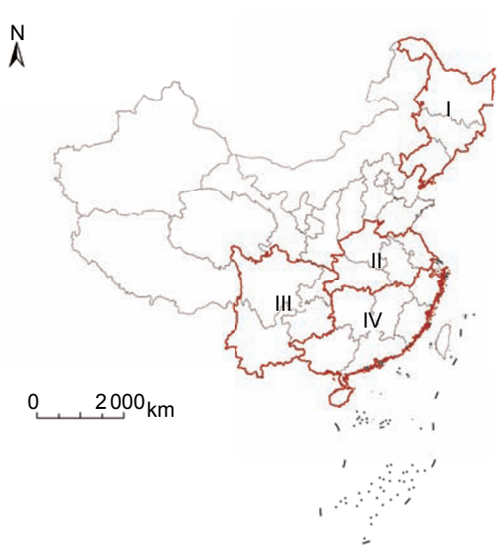

Fig. 1 The spatial distribution of four primary rice cultivation zones in China.