Spatial-temporal variation of grain production after the Grain for Green Project in the Loess Plateau, China

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Abstract. The Grain for Green Project (GGP) has been implemented for 17 years, promoting the regional environment significantly, but the impact on local food production is still an issue worth studying. This paper analysed the temporal and spatial variations of grain production in the Loess Plateau of China, using county-level statistics from 2000 to 2012. The results showed that the total grain yield and the unit area grain yield was continuously improved while the grain planting area was declined, which showed that ecological construction does not affect grain production. Besides, the regional differentiation of grain production efficiency in the Loess Plateau was decreasing.

1. Introduction
GGP began in August 1999, aiming at the conversion of cropland to forest, grassland and lake in a planned way, changing the unreasonable land use, such as steep land reclamation and deforested-land reclamation, suppressing the ecosystem degeneration. The soil erosion area of Loess Plateau is one of the key regions to carry out GGP. Since the implementation of the project, a lot of issues had been widely concerned by the society and scholars, mainly including eco-environmental effects \cite{1, 2}, Land use and land cover change \cite{3, 4}, impacts on farmers' behaviour and livelihood \cite{5, 6}. The effectiveness of GGP has not been well documented \cite{7} and there was few studies paid attention to the spatial-temporal variation of grain production after the GGP.

The Loess Plateau is located in the area with high population density, fragile ecological environment and poor quality of cultivated land, the implementation of GGP increased the pressure of regional food security (Figure 1). The project ended in 2011 and its impact on local grain production is a problem worth of study.

2. Data and methods
The statistical data (yield, planting area and unit area yield of grain, wheat, corn, soybean and potato) used in this study were obtained from statistical yearbooks and statistical communiques of each city from 2000 to 2012, taking municipal districts, county-level cities and counties as the basic statistical units (hereinafter referred to as the county). In order to ensure the continuity of the data, this paper adopts the 2006 national county-level administrative zoning map as the base map and merged the municipal districts that belong to the same city, finally formed 283 counties.
Based on the county-level data from 2000 to 2012, and spatial analysis module in ArcGIS software, we can draw out the spatial distribution maps and Triangulated Irregular Network (TIN) images of the grain production in the Loess Plateau, wherein the method of drawing the TIN images of unit area grain yield including following 4 steps: 1) points arrangement. Points were set at counties’ seat of government and were joined to the data of unit area grain yield; 2) Grid interpolation. Use of the inverse distance weighting (IDW) interpolation method to generate the grid surfaces; 3) Contour maps. Forming the contour maps using raster surface module in ArcGIS software; 4) Create TIN. Using TIN module of GIS 3D Analyst tools to draw the TIN images and adding the hill shades.

3. Spatial-temporal change of grain production in the Loess Plateau

3.1 Grain planting area
The fluctuation trend of grain planting area in the Loess Plateau was decreased first and then increased and gradually stabilized in the following year. From 2000 to 2004, with the fast development of GGP, grain planting area decreased sharply, reached the lowest value in 2003. Then with the structural adjustment of the project in 2004, the grain planting area began to increase gradually and back to the basic level in 2008. Since then, regional grain planting condition seemed to be stabilized from 2009-2012.

The standard difference coefficient of variation was 4.61% and the range variation coefficient was 14.15%. We divided the grain planting area in the Loess Plateau into 5 types in according to the above coefficients and analysed the spatial variations (Figure 2). From 2000 to 2004, 35.17% of the counties had a decreasing rate over 14.15%, located chiefly in the loess hilly region. 5.17% of the counties had an increasing rate of grain planting area over 14.15% from 2004 to 2008, while there were 24.83% of the counties have no significant changes in 2008-2012.

3.2 Grain yield
The total grain yield in the Loess Plateau generally increased by 47.83% (1379.53 million tons) from 2000 to 2012 and its proportion of the national total grain yield increased from 6.51% to 7.43%. The annual increasing rate is 3.31%, higher than national average level of 2.17%. According to grain yield, 84 counties’ annual growth rate of grain yield is beyond 5%, mostly located in Shaanxi province and Shanxi province. But we can also find that 46 counties’ annual growth rate is negative, mainly located in the key areas of GGP. In addition to the above two types, the annual growth rate of most counties is among 1% to 4%. The special distribution showed that regions used to have a low original grain yield led a higher growth rate, such as arid area and hilly and gully region, correspondingly, the Guanzhong
Plain and irrigation areas, which had a higher grain yield at the beginning, leading to a lower growth rate.

Figure 2. Spatial-temporal change of grain planting area in the Loess Plateau

Figure 3. Spatial-temporal change of the unit area grain yield in the Loess Plateau (kg/ha)

3.3 Unit area grain yield
The unit area grain yield of the Loess Plateau in general is at a low level, but grows rapidly (Figure 3). From 2000 to 2012, the unit area grain yield increased from 2858.6 kg/ha to 4165.50 kg/ha, while at the same period, China’s average unit area grain yield increased from 4087.12 kg/ha to 5157.59 kg/ha.
According to the TIN images (Figure 4), Northwest and southeast region tended to have relatively higher levels of unit area grain yield and the middle of the region made a rapid growth, it is clearly that the gap of unit area grain yield is narrowing, showing that regional food production is becoming more balanced.

The productivity of farmland can be divided into five levels, high level ($\geq 6000$ kg/ha), up-middle level (4500-6000 kg/ha), middle level (3000-4500 kg/ha), below middle level (2000-3000 kg/ha) and low level ($< 2000$ kg/ha). Seeing from the variation degree, the unit area grain yield is increasing, along with the obvious decrease in low level type. High level productivity farmland increased from 5.65% to 15.55% in 2000-2012. Up-middle level and middle level productivity farmland also increased, it jumped from 39.57% to 63.25% during the period.

4. Conclusions
GGP is an important policy to combat the degraded ecological environment in China, with the primary goal to replace farmland in fragile areas with trees, grass and lake, which covered 25 provinces, municipalities and autonomous regions, Loess Plateau is a typical region implementing the project. This paper took this area as an example to analyse the impact of grain production after GGP and the result showed that grain yield made a substantial increase while the grain planting area fluctuated under the influence of GGP. Due to space limitations, this paper mainly discussed the spatial and temporal variation of grain production after the GGP, an influencing factors analysis should be discussed at a micro scale further.

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