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Contribution of ecological policies to vegetation restoration: A case study from Wuqi County in Shaanxi Province, China

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ABSTRACT

Ecological policies can regulate and modify human activities, affecting land use, and eventually, regional vegetative cover. The impact of these policies on vegetation cover is mediated by natural factors as well as social and economic statuses. The former contains meteorological and topographical indicates, and the latter includes population density, per capita cultivated land, transportation convenience, etc. The chosen study area for this study was Wuqi County, situated in the northern Shaanxi Province of China. Using remote sensing and GIS spatial analysis techniques, land use and vegetation index data of Wuqi from 1995 to 2011 were obtained along with topographical, meteorological, and socio-economic data. Further, the vector and grid data were pooled using a village as a unit, to establish a spatial database in ArcGIS 10.2. Multiple regression models, including a geographically weighted model, along with spatial analysis, were applied to calculate the contribution of ecological policies to the vegetation restoration in the study area under the constraint of resource endowment, particularly ecological policies in terms of restoration of ecological land from cultivated land, conservation of forests and pastures. The results of spatial overlay showed an interesting spatial coupling between changes in land use and improvement in vegetation index. The results of the regression models could reveal the comprehensive and quantitative contribution of ecological policies to vegetation restoration since control variables such as resource endowments were included. Moreover, analyses based on both classical regression and geographically weighted regression indicated that land use has considerable influence on vegetation restoration, while the results of the latter showed a higher significance level and could reveal the spatial differences due to policy effects.

1. Introduction

To promote sustainable development of nature, economics, and society in fragile ecological regions, the Chinese government has implemented a series of important ecological security strategies, one of which is the “Sloping Land Conversion Program” (SLCP). Although the whole program is called SLCP and its most noticeable trait is returning crop production to forest and grass in sloping and steep land, it includes a set of policies or engineering measures, such as “Returning Sloping Cultivated Land to Forest and Grasslands” (RSCLFG), “Tending of Existing Woodlands” (TEWL), and “Grazing Prohibition for Existing Grasslands” (GPEGL). The subject of SLCP and the evaluation of its implementation effectiveness are currently topics of academic research. For instance, these topics have been referred to by 3225 papers from the *Science Citation Index Expanded* (SCI) and *Social Sciences Citation Index* (SSCI) databases provided by *Web of Science*.[1] If the same search is conducted using the CNKI (Chinese National Knowledge Infrastructure) database, 21,816 studies are retrieved. The objective of this study is to analyze the specific roles and mechanisms of the natural and human factors contributing to the regional vegetation restoration, to identify the effects of individual ecological policies of the SLCP, i.e., the RSCLFG, the TEWL, and the GPEGL. Vegetation index data obtained by remote sensing technique has been widely used to measure the vegetation coverage and its restoration (e.g., Zhang et al., 2016; Chen et al., 2017). In this study, Enhanced Vegetation Index (EVI) is applied for its improved ability in distinguishing the vegetation with high coverage (Didan, 2015).

The SLCP’s assessment as a land use policy and a part of the national development strategy indicates that its implementation has resulted in considerable environmental benefits (Long, 2014). In recent years,

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[1] The keywords used to fetch these data are *TS = ("slope* land conversion*" OR "grain for green" OR "pay* ecolog*" OR "ecolog* restor*" OR "ecolog* pay*" OR "restor* arable land to*" OR "restor* cultivated land to*" OR "cultivated land return*")*, with the publication date being set to between the first day of 1998 and the last day of 2016.

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many scholars evaluated the ecological consequences of the SLCP, such as its effects on regional vegetation cover, soil and water conservation, soil moisture, carbon fixation capacity, and climate change (Cao et al., 2009; Fu et al., 2011; Lü et al., 2012; Xiao, 2014). In addition, social scientists also paid attentions to the changes of households' livelihoods caused by SLCP (Yin et al., 2014; Li et al., 2015a; Zhao et al., 2015).

Most researchers observed that the implementation of the SLCP had resulted in ecological benefits such as an increase in forest cover (Cao et al., 2009; Fu et al., 2011; Xiao, 2014), improvement in vegetation index (Xiao, 2014; Li et al., 2015b), reduced rate of soil erosion (Fu et al., 2011; Lü et al., 2012; Wang et al., 2016, 2017b), and enhanced carbon sequestration efficiency (Lü et al., 2012; Wang et al., 2012). On the other hand, some researchers focused on the negative effects that accompany SLCP and doubted the ecological policy itself since they felt it was unnatural to replace the natural cycle of vegetation by artificial planting (Jia and Shao, 2014; Jia et al., 2017). For example, afforestation was known to increase transpiration, cause soil moisture loss, and expand the dried soil layer, which would aggravate the water loss and potentially increase the risk of soil erosion (Cao et al., 2009, 2011; Wang et al., 2013; Jiang et al., 2016). Some studies showed that the drying of soil layers in woodlands was much more extensive than in other types of lands (Shao et al., 2016; Liu et al., 2017). Chen et al. (2015) held the view that it was unnecessary to implement large-scale reforestation in the Loess Plateau, and only the process of natural succession should be permitted to play the main restoration role. Zhang et al. (2017b) pointed out that long-term and potential risks should be carefully considered while developing an ecological restoration policy and formulating ecological engineering plans. Cropland conversion and vegetation restoration have greatly changed the hydrological state of the local area, which increased transpiration and reduced soil water content and surface runoff (Zhang et al., 2015; Wang et al., 2016, 2017b); The limitation of water shortage for large-scale vegetation restoration and the aggravated contradiction between the cropland and the people caused by cropland conversion have become the determinants of sustainable development in the Loess Plateau (Wang et al., 2017a).

The Loess Plateau is known to be a typical fragile ecological area and is one of the two priority areas chosen for the implementation of the SLCP. Previous studies have pointed out that the ecological improvement in the Loess Plateau was caused by multiple factors, although there was no consensus as to the leading factor. Some scholars attributed the transformation of land use type as the main reason, pointing out that the vegetation coverage index had significantly improved after the conversion of cultivated land to forest and grasslands (Liu et al., 2010; Xiao, 2014). Thus, anthropogenic factors were recognized as the driving factors of vegetation restoration in the fragile ecological area of the Loess Plateau (Li et al., 2013). However, others argued that natural phenomena, especially increased precipitation caused by global climate change in recent years, contribute to vegetation restoration to a larger extent (Ning et al., 2015; Wen et al., 2016).

It should be noted that some existing studies consider only the effects of natural factors and attribute the residuals of the estimated model to human disturbance (e.g., Evans and Geerken, 2004; Cai et al., 2006; Peng et al., 2010), and this makes it difficult to identify the contribution of different ecological policies towards the improvement in the vegetation index. In addition, as is mentioned above, the SLCP is likely to be perceived as returning crop production to forest and grass in sloping land and steep land literally, and thus neglecting the effects of other policy measures along with it, such as the conservation and maintenance of woodlands and grasslands, which may also contribute to the regional vegetation restoration. However, few previous studies make decomposition of the SLCP policies like this, and it may result in biased conclusions about the contribution of ecological policy and human disturbance to the vegetation coverage change. In this study, Wuqi County in the Loess Plateau of the northern Shaanxi Province of China serves as the study area. Data pertaining to its land use and vegetation cover were obtained for the period 1995–2010 along with its topographical, meteorological, and socioeconomic data through GIS spatial analysis and remote sensing technologies. Using the GIS platform, all the above-mentioned data were integrated at the village level and a spatial database for the study area was established.

With respect to model selection, Lan and Yin (2017) provided an overview of the scope and options of different quantitative models for policy evaluation. In this research, the data for land use and vegetation cover are in two cross-sections, while topography and meteorology are long-term data. In order to match different data, we applied the first-order difference model of panel regression. Since there are only two periods of data, it is equivalent to the fixed effect model, or the difference in differences model that contains the control variables (Wooldridge, 2010). It should be noticed that the policy variables here were not binary, but continuous variables that indicates the implementation intensity. Thus linear regression model was applied to analyze the contributions of the ecological policies, namely the outcomes the RSCLFG, the TEWL, and the GPEGL have in restoring vegetation, mediated by the natural conditions. Furthermore, spatial heterogeneity can be observed extensively across the practice subject and object for the implementation of the policy, e.g., Zhao et al. (2015) found that spatial heterogeneity affected the productive efficiency of households participating in SLCP, and thus geographically weighted regression (GWR) was applied in addition to the classical regression.

2. Study area

Wuqi is located in the north-central part of China (Fig. 1; 107° 39′–108°33′E and 36° 33.5′–37° 24.5′N), and it is affiliated to Yanan City located in the northern region of Shaanxi Province. The total area of Wuqi is about 3,791.5 km^2. In the year 2013, its total population was 147,000, including an agricultural population of 106,000. Wuqi belongs to a typical hilly area of the Loess Plateau that comprises many crisscrossing gullies and valleys of various sizes. The study area was divided into two main water basins developed along the Wuding River and Beiluo River. Their altitudes vary from 1222–1812 m above sea level. Wuqi is located in a warm temperate zone, and has a semiarid climate that experiences the continental monsoon. Thus, it encompasses dry and windy springs, experiences alternating droughts and floods during summers, cool and moist autumns, and cold and dry winters. Wuqi has extreme temperatures, varying between a maximum of 37.1 °C and minimum of −25.1 °C, and its annual mean temperature is 7.8 °C. Its average annual rainfall is 483.4 mm, while the average annual frost-free period consists of 146 days.

Wuqi County has become a focal point for ecological restoration ever since the SLCP was initially implemented in the year 1998. Considerable improvement has been achieved in Wuqi (Yin et al., 2005; Li et al., 2015a); its forest and grass cover presently stand at about 80% (Government correspondents of Wuqi County, 2017).

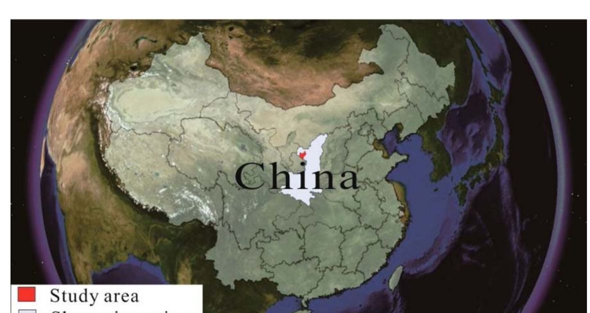

Fig. 1. Location of the study area.