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Determinants of cropland abandonment at the parcel, household and village levels in mountain areas of China: A multi-level analysis

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ABSTRACT

Cropland abandonment accompanying economic development has been observed worldwide. China has experienced a large amount of land abandonment in recent years. However, the reasons for it are not entirely clear. Although abandonment decisions are made by individual households, the underlying conditions reflect processes operating at multiple levels. Therefore, we aimed to detect the influences on land abandonment at the parcel, household and village levels. We developed and employed a multi-level statistical model using farm household survey data and geographical maps of Wulong County. Our model revealed that of the variance in occurrence of land parcel abandonment, 7% and 13% can be explained at the household and village levels, respectively, while the remnant 80% can be explained at the land parcel features itself. We found that land abandonment is more prone to occur on parcels that are on steep slopes, have poor quality soil, or are remote from the laborers' residences. Households with less agricultural labor per unit land area showed a high probability of land abandonment. We also found a nonlinear influence of labor age on land abandonment, with households comprising middle-aged laborers having a low land abandonment probability. Parcels in villages with high elevation, far from the county administrative center or with low prevalence of leased land are inclined to abandonment. We also found, surprisingly, that the household proportion of males among its agricultural laborers did not significantly influence the occurrence of land abandonment at the parcel level, probably due to the male agricultural laborers being overwhelmingly old (average age greater than 56 years). To alleviate land abandonment, we suggest improving land tenure and transfer security to ensure stable access to the land rental market, and also improving infrastructure in remote regions.

Introduction

Cropland abandonment, defined as complete withdrawal of agricultural management (Keenleyside et al., 2010), has been observed worldwide (Baldock et al., 1996; DLG, 2005; Gellrich et al., 2007; MacDonald et al., 2000). A large amount of land abandonment has occurred as a result of economic development and ensuing rural-urban labor migration (MacDonald et al., 2000). In European countries, considerable land abandonment has been documented since the start of the industrial revolution in the mid-19th century (Baldock et al., 1996; Mather, 2001), and lasted for the whole 20th century, with a significant decline in the last 30 years (Pointereau et al., 2008). In some new member states of the European Union, such as the Baltic countries, large-scale land abandonment happened after the collapse of socialism in the 1990s (DLG, 2005). However, such abandonment has not been limited to Europe. For example, in Austria, about 100,000 ha of land has been abandoned since the 1970s (Silber and Wytrzens, 2006). Land abandonment has only occurred recently in some developing countries, such as Chile (Díaz et al., 2011) and Argentina (Izquierdo and Grau, 2009).

Currently, China is experiencing fast economic development, with its GDP increasing by nearly 8% each year. During economic expansion, a large amount of rural labor has been migrating into the secondary and tertiary sectors (De Brauw et al., 2002; Yang, 1997; Zhang and Song, 2003). As a result, land abandonment has spread nationwide. Incomplete statistics show that more than 20 provinces (about 2/3 of the total) have reported domestic land abandonment since the1990s (Liu and Li, 2006).

Land abandonment has always first occurred in mountain areas where its labor loss cannot be supplemented by mechanization due to the restriction of terrain (MacDonald et al., 2000; Strijker, 2005; Zimmerer, 1993). Specifically, empirical studies show that land abandonment has often happened on shallow soils, salty soils, remote areas, or areas with poor infrastructure and steep

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landforms (Sluiter and De Jong, 2007; Díaz et al., 2011; Gellrich and Zimmermann, 2007; Gellrich et al., 2007). Thus, marginal cropland is likely to be abandoned for its low productivity and high cost of cultivation (Baldock, 1996; Brouwer et al., 1997).

Moreover, employing the framework that Von Thunen constructed to explain spatial distribution of agricultural practices (Carla, 1966), we suggest that land abandonment should occur when the land rent becomes sufficiently small. Since, in this framework, land rent is constrained by distance to market and land quality, with poor quality, distant sites, having the smallest profit margins even in the best circumstances, a labor shortage can relatively easily erase this profit, leading to abandonment of such sites. Furthermore, as Schultz (1987) has shown, rational peasants allocate their labor resources and land resources to achieve income maximization. Thus, within each household, labor would be allocated based on the comparison between the market labor rate and the probable income from cultivation.

As a geographical phenomenon, land abandonment is spatially autocorrelated. Thus, land use activity (or disuse, in the case of abandonment) is more similar within the same village than across different villages, due to the spatial distribution of natural resources. Similarly, land parcels will have a more similar probability of abandonment within the same household than among different households. Thus, the land abandonment decision is a result of nested structure activity, as it is the result of processes that act at different levels. To quantify the relationships between levels, a multi-level model is applicable, although conventional regression models have often been used in previous studies (Prishchepov et al., 2013; Silber and Wytrzens, 2006). However, conventional regression models cannot resolve such nested relationships (Overmars and Verburg, 2006).

Multi-level models are also known as both random coefficient models and hierarchical linear models (Raudenbush and Bryk, 1986; Raudenbush, 2002). They are designed to simultaneously investigate relationships within and between hierarchical levels of grouped data (Arnold, 1992), Application of these models has largely been limited to social and medical sciences, whose data are often nested in hierarchical structures (Hox, 2002). In contrast, these models have rarely been applied to LUCC (Land Use and Coverage Change) topics (Hoshino, 2001; Overmars and Verburg, 2006; Pan and Bilsborrow, 2005; Qian et al., 2010). However, multi-level statistical models would seem to hold great promise in helping to understand the nested structure activity that underlies land abandonment decisions. Nevertheless, probably due to the models' strict structural data requirements, until now this type of model has not been applied to land abandonment analysis.

Indeed, in general, empirical studies on land abandonment in China have been very rare. Moreover, the empirical studies that have been done have been published only in the Chinese language, limiting the dissemination of the resulting knowledge on this subject. The present paper aims to increase the understanding of the process of cropland abandonment by detecting the determinants at three levels: parcel, household and village. For this, a multi-level statistical model is constructed based on first-hand data collected by means of a household survey. Additionally, possible countermeasures to abandonment are proposed in the last part of the paper.

Materials and methods

Study area and data description

The study area is located in Wulong County, in southwestern China (Fig. 1). The study area includes 186 villages nested in 26 towns, and comprises approximately 2901.3 km^2. Its population is about 410,000 people. This is a mountainous area, with two mountains (Wuling and Dalou) lying in the northern and southern parts, respectively. The Wujiang River runs through the middle of the county and three main national or provincial roads pass through the county (Fig. 1). The elevation varies from 125 m to 2006 m, with much of the land in this region very steep. Most of the land (about 2/3 of the total) is covered by forest, while ca. 20–30% is cropland. The climate supports a double-cropping system, but farmers usually plant only one crop per year due to a lack of labor. The main crops for this area are maize, rice, sweet potato, potato, and some cash crops such as tobacco. Sweet potato and potato are always interplanted with maize, which is the most popular crop, accounting for almost half the cropland.

According to the statistical data published by the Statistical Bureau of Wulong County (2001), major rural-to-urban migration emerged in 2001. Through the end of 2009, rural labor had diminished by nearly 20% compared to 2001. Over the same period, data from the Statistical Bureau of Wulong County (2001, 2010) show that nearly 10% of cropland was abandoned. The data used in the model came from two kinds of sources. The first comprises maps, specifically digital elevation maps (DEMs) and village administrative maps. The DEM data were downloaded from the geospatial data cloud (http://www.gscloud.cn), whereas the village administrative maps were supplied by the local government. From these maps, we could obtain the locations and elevations of the sampled villages.

The second kind of data source was our first-hand data which was collected by a household survey conducted between July and August in 2011, in which households were interviewed about their land use practices and their characteristics using a semi-structured questionnaire. The sampled households were selected by hierarchical sampling and systematic sampling. The sampling procedure was as follows: First, we chose 17 out of the 26 towns (the total) according to their terrain, to ensure the selected towns covered almost all kinds of terrains in the county. Second, two or three villages were selected from each town randomly provided that the sampled villages were evenly distributed spatially. Finally, in each village about ten households were investigated randomly. In all, the survey involved 2/3 of the towns and 22.04% of the villages in the county, covering 330 households and 1423 land parcels. The total cropland involved was 206.42 hm^2, of which 19.62 hm^2 (9.51% of the total) of the land was abandoned.

The questionnaire obtained abundant information on households and the land parcels with which they were associated. For each household, information was collected on each member, including their age, gender, amounts of time devoted to agricultural work and off-farm work, and their income. For all land parcels associated with each household, including parcels that they owned (cultivated by them, abandoned or rented out to others for cultivation) or that they rented from others (for cultivation), we recorded ecological information, including land slope, soil quality, and distance from the residence. Additionally, management practices for each parcel, including inputs and outputs were recorded. Generally, the households in the study area owned about ten land parcels. These parcels would usually be small and dispersed in multiple locations with an average area smaller than 0.5 mu (1 mu $\approx$ 666.67 m^2) per parcel. For the analysis in this study, only a subset of the variables was used.

Multi-level model specification

Because land abandonment is a binary response variable, a logistic model is an appropriate tool for this type of analysis. In this section, we start with an ordinary logistic regression model to explain how we arrived at the multi-level model that we will use to explain land abandonment. For simplicity and clarity, only one