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## Hierarchical determinants of winter wheat abandonment in the North China Plain: A case study of Xingzhuangzi village in Hebei Province

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### ABSTRACT

Since the late 1990s, the North China Plain (NCP) has undergone large-scale shrinkage of area sown to winter wheat, accompanying with traditional double cropping system being replaced by spring corns. However, studies on the underlying determinants are rarely found. The goal of this paper is to detect the hierarchical determinants on farmers' cropping system decisions. A case study was carried out in Xingzhuangzi village of Hebei province, and multi-level statistic models were constructed using household survey data. Results show that plot level and household level were both crucial in explaining farmers' land use decisions: winter wheat was more likely to be abandoned on plots with lower land quality, unable to be irrigated, and with larger plot areas; at household level, both the non-agricultural income ratio and the land fragmentation played positive roles on farmers' abandonment of winter wheat while the role of household agricultural labor availability was negative. There was also a nonlinear relationship between average age of households' agricultural laborers and their cropping system decisions, and middle-aged farmers had a lower probability to abandon winter wheat. Overall, this paper provides empirical identification on hierarchical determinants of agricultural land use change in the NCP, and encourages policies aiming at adjustment of cropping systems, integration management of both surface and groundwater, and promotion of land transfer, in order to achieve the twin goals of ecological conservation and food security in water-scarce areas.

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### 1. Introduction

Agricultural land use changes are closely related to the social-economic development and have important consequences as agricultural areas provide a wide range of goods and services [1,2]. Understanding agricultural land use change processes and their drivers is crucial for improvement of future planning strategies and assessment of the influence of land related policies [2,3].

China is a nation with strong rural roots [4]. Since the economic reforms and open-door policy were initiated in 1978, China has experienced fast economic development, and extensive rural

labor has been migrating into the secondary and tertiary sectors [5,6]. Meanwhile, the agricultural land has undergone tremendous changes, varying in usage type and in intensity, mainly in the way of cultivated land conversion in peri-urban areas, land abandonment in sloping areas and cropping system changes in plain areas [7,8]. More specifically, changes of double cropping rice to single cropping rice have been specified in plain areas of southern China [9], while the North China Plain (NCP) have faced winter wheat abandonment and its accompanying cropping system changes [10].

The NCP is one of the major food production areas in China [11]. Winter wheat – summer maize double cropping has been the dominant cropping system in the NCP since the 1970s [12]. However, recent studies have found that large, spatially-continuous areas in the NCP which were previously winter wheat – summer maize double cropping system are being replaced by the single cropping system of spring corn; this has been termed “the spring corn planting belt phenomenon” [10,13,14]. Since winter wheat is a major cereal crop, the cropping system changes must have an impact

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on food security. The NCP is also amongst the global “hotspots” in terms of water scarcity and groundwater depletion [15], and winter wheat plays a key role in the development of water scarcity and the over-exploitation of groundwater, as more than 70% of irrigation water, i.e. the vast majority of total water use in the NCP, is consumed by winter wheat [16,17]. Therefore, the abandonment of winter wheat concurrently affect water balance of the NCP. In this context, identification of its drivers is critical to achieve the twin goals of food production and water conservation in the NCP.

Previous studies concerning determinants of agricultural land use changes in China have focused mainly on the impact of urbanization on cultivated land conversion [8,18,19]. There are also several studies relating to driving factors of sloping land abandonment in western China and rice cropping system changes in southern China [20–22]. Most of the results have indicated that the above mentioned rural labor out-migration is a critical element in addressing the agricultural land use changes, accompanying with other elements, including physical contexts, social-economic characteristics, policy-relevant indicators and so on [8,22]. However, to our knowledge there has been no study that has analyzed the determinants of winter wheat abandonment in the NCP [23].

In addition, household survey data are widely applied in empirical studies, since agricultural land use changes often result from the decisions of individual farming households, and conventional regression techniques, notably the multiple linear regression

model, the seemingly unrelated regression model, the Probit model and the Tobit model, are popular approaches to explore datasets and to test hypothesis between land use change variables and potential determinants [5,20,22,24]. However, farmers’ land use decisions are influenced by diverse interactive factors at multiple levels, for example physical contexts at plot level, demographic and social-economic characteristics at household level and policy-relevant indicators at macro levels, and conventional regression models are not optimal in resolving such nested relationships [21,25].

Multi-level modelling was introduced for the analysis of hierarchically structured data, which is a statistically sound methodology with regression models that explicitly takes variability at different levels into account [26,27]. Multi-level models have mainly been used in the social and medical sciences, and are becoming popular in geographical applications [28,29]. Multi-level models also hold great promise in understanding agricultural land use decisions with nested hierarchical structures. However, to date, there have been few empirical examples that applied this type of model to such analysis [21,25,30].

Considering the above shortcomings, this paper aims to unravel the hierarchical determinants of winter wheat abandonment in the NCP through a case study of Xingzhuangzi village in the Hebei province. For this, a multi-level statistical model is constructed to examine the relative importance of determinants on cropping sys-



Fig. 1. Location of the study area.

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