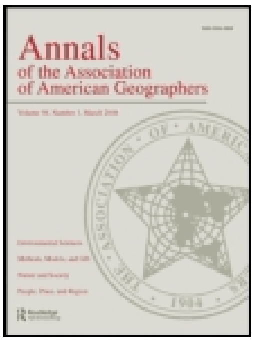

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The Role of Cross-Scale Social and Environmental Contexts in Household-Level Land-Use Decisions, Poyang Lake Region, China

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As rural households worldwide become increasingly engaged in urban economies and regional and global markets, agricultural land use is increasingly under influences of macrolevel forces. Investigating the cross-scale processes behind land-use decisions of rural households is important for understanding the deferential effects of macrolevel forces across local social and environmental contexts. We combined quantitative analysis of household surveys and qualitative analysis of interviews and participant observations in eight villages in the Poyang Lake Region of China to investigate how macrolevel forces associated with policy reforms in China (i.e., urban job markets and agricultural markets) interact with microlevel factors (i.e., the biophysical environment, location, and household demographics) to shape land-use decisions of rural households. We also found differential regional government interventions that reinforced preexisting biophysical conditions to affect household crop choices, contributing to the maintenance of intensive two-season rice production in select agricultural bases. Our use of multilevel modeling and qualitative analysis enabled an improved understanding of the cross-scale processes behind household land-use decisions, which has practical implications for securing food production and promoting sustainable land use. *Key Words: cross-scale processes, household land-use decisions, markets, mixed methods, off-farm income.*

随着全世界的农村家户逐渐参与至城市经济与区域及全球市场，农业土地使用正逐渐受到巨观层级力量的影响。探讨农村家户土地使用决定的跨尺度过程，对于理解巨观层级力量在不同在地社会与环境脉络中的差异影响而言相当重要。我们结合家户调查的量化分析，以及在中国鄱阳湖区域的八座村庄所进行的访谈和参与式观察，探讨有关中国政策改革（例如城市工作市场和农业市场）的巨观层级力量，如何与微观层级的因素（例如生物物理环境、区位，以及家户人口）相互作用，以形塑农村家户的土地使用决定。我们同时发现差别化的区域政府介入，透过强化既存的生物物理条件来影响家户作物选择，导致在所选定的农业基地上，维持两季度的集约稻米生产。我们使用多层级模式化与质化分析，得以改进对于家户土地使用决定背后的跨尺度过程之理解，并对确保粮食生产和推广可持续土地使用具有意涵。*关键词：跨尺度过程，家户土地使用决定，市场，混合方法，农场外收入。*

A medida que los habitantes rurales de todo el mundo se involucran cada vez más en las economías urbanas y en mercados regionales y globales, el uso agrícola del suelo se hace más dependiente de influencias de fuerzas a nivel macro. Investigar los procesos de escala cruzada que hay detrás de las decisiones adoptadas por la gente rural sobre uso del suelo es importante para entender los efectos deferentes de fuerzas a nivel macro a través de contextos ambientales y sociales de carácter local. Combinamos el análisis cuantitativo de las encuestas familiares y el análisis cualitativo de las entrevistas y las observaciones de los participantes en ocho aldeas de la Región del Lago Poyang, China, para investigar la manera como las fuerzas del nivel macro asociadas con las políticas de reforma de China (i.e., mercados de trabajo urbano y mercados agrícolas) interactúan con factores de nivel micro (i.e., el entorno biofísico, la localización, la demografía familiar) para configurar las decisiones sobre uso del suelo de los habitantes rurales. Hallamos también intervenciones diferenciales del gobierno regional que reforzaron las condiciones biofísicas preexistentes para afectar la selección de los tipos de cosecha, contribuyendo a mantener la producción intensiva de arroz de dos estaciones en bases agrícolas selectas. Nuestro uso del modelado a nivel múltiple y el análisis cualitativo habilitaron un entendimiento mejorado de los procesos de escala cruzada en que se basan las decisiones familiares sobre uso del suelo, lo cual tiene implicaciones prácticas para asegurar la producción de alimentos y para promover el uso sostenible del suelo. *Palabras clave: procesos a escala cruzada, decisiones familiares sobre uso del suelo, mercados, métodos mixtos, ingreso externo a la granja.*

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One of the major goals of land-change science (LCS) is to provide explanations for the processes and factors (called *drivers*) affecting observable changes in land use and land cover (Turner et al. 1995; Global Land Project [GLP] 2005; Lambin and Geist 2006; Turner, Lambin, and Reenberg 2008). Understanding the human and social processes underlying land-use and land-cover change (LULCC) often requires examining factors that influence land-use decisions at the household level (Lambin et al. 2001; Laney 2002; Overmars and Verburg 2005). Today rural households in the developing world become increasingly integrated with urban economies and markets, and rural land use is under influences of many factors and forces at multiple levels from local communities to regional and global markets (Seto et al. 2012; J. Liu et al. 2013; Verburg et al. 2013; Müller and Munroe 2014). In particular, institutions and policies can play a crucial role in structuring how households can and do respond to changes in their environmental and social context (Wood and Porro 2002; Lambin and Geist 2006; Ostrom 2009). Investigating how these macrolevel forces interact with local social and environmental contexts to affect household land-use decisions is important but challenging.

China presents an interesting case of heterogeneous and dynamic institutional settings for land-use decisions. A wide variety of policy changes at the national level affect the contexts within which rural households make their livelihood and land-use decisions. These policy changes have liberalized aspects of the agriculture and industrial markets and created off-farm work opportunities for rural households (Nyberg and Rozelle 1999). As a consequence of these policy changes, off-farm work has become increasingly important for the livelihoods of rural households, in turn affecting their on-farm land-use decisions. In addition, although many of these policies have been initiated at the national level, policies in China are implemented at the local level, with significant variations in the degree to which policies are enacted and enforced (Skinner, Richard, and Alun 2001), where they play out through interactions among natural environment, location, and institutional characteristics (L. Liu 1999).

In this study we use a human–environment systems perspective (Lambin and Geist 2006; Turner, Lambin and Reenberg 2008) and combine quantitative analysis of household surveys and qualitative analysis of interviews and participant observations to investigate the cross-scale processes behind rural household land-use decisions. Our study draws on classic theoretical models of land-use decision processes suggested by von Thünen (location) and Chayanov (household life cycles). Our focus is, however, on examining how the macrolevel processes associated with policy changes (i.e., urban job markets and agricultural markets) interact with microlevel processes (i.e., location, household demographics, and the biophysical environment) to shape land-use decisions of rural households.

We carry out our work in the Poyang Lake Region (PLR) in Jiangxi Province, which is part of the Central Yangtze Basin. As with other rural areas in China, the PLR has been experiencing rapid and dramatic social, economic, and political changes due to policy reforms at the national level, and rural livelihoods in the PLR are deeply integrated into urban economies. Land use in the PLR is shaped by its history as a major base for rice production in Jiangxi Province and its location around Poyang Lake. Because the wetlands around the lake provide important wildlife habitat, land use in the PLR also has impacts on wildlife.

In the following section, we describe the conceptual background for this study, which includes existing theoretical frameworks in LCS and specific cross-scale processes we intend to evaluate in our study. Then, after a brief introduction to the geographical and policy dynamics in the study area, we present our multimethod approach to data collection and analysis, and the results of our analysis. Our discussions emphasize the importance of cross-scale land-use processes and the need for further research to examine these cross-scale processes in the broader context of development and institutional and policy settings.

Background

In terms of theoretical frameworks in LCS, one line of research (Alonso 1964; Chomitz and Gray 1996; Walker 2004) elaborates on the model of von Thünen, the basic insight of which is that location and transport cost affect farmer profits and decisions about land use. Another line of research has developed from the model of Chayanov and focuses on the importance of household life cycles and labor availability on land use (McCracken et al. 1999; Perz and Walker 2002; Entwisle et al. 2005; Carr 2009). The models of von Thünen and Chayanov provide insights into potentially important land-use drivers, but they are not sufficient on their own to explain the multiple scales of causation. Furthermore, von Thünen first applied his model to explain agricultural land-use patterns surrounding an urban center before industrialization, and transportation costs played a more important role in land-use decisions than they do under modern transport technologies. Chayanov developed his insights about household life cycles and land-use decisions by studying the peasant farm economy in rural Russia in the early twentieth century, where peasant farms had very little access to markets. He observed that as a rural household went through its life cycle from younger age with children to older age, its labor availability increased, which allowed it to farm larger areas. Today as urbanization proceeds in developing countries, rural populations worldwide are increasingly involved in off-farm work in the urban sector, and their agricultural activities are also increasingly linked to regional and global markets. Location and life-cycle stages might still be important determinants of agricultural land-use decisions, but how they affect household land-use decisions needs to be reexamined in these new contexts of development.

More recent perspectives integrate social and environmental processes in human–environment systems to explain LULCC and offer more comprehensive views of the variables affecting land-use change, including biophysical, economic and technological, demographic, institutional, and cultural factors that often interact across several levels of organization (Lambin and Geist 2006). Biophysical factors in general "define the natural capacity of land use and predisposing environmental conditions for land-use change," and the variability in the biophysical environment often interacts with human factors to produce changes in land use (Lambin et al. 2001; Moran et al. 2002; McConnell and Keys 2005). Economic factors are found to play a strong role in land-use change and, in many case studies, land-use changes resulted from individual responses to economic conditions that often involve market mechanisms. For example, market demand might drive the increase or decrease of certain land-use types (Myers 1997; Geist 2005; McConnell and Keys 2005), and access to off-farm work opportunities could reduce labor on farm and influence rural land use in agricultural zones (McConnell and Keys 2005). Market forces, such as price changes, can interact with biophysical factors and produce different outcomes in different situations (Rudel 2005; Unruh et al. 2005). But very few economic factors are found to be separable from the influence of governmental institutions. Specifically, national development policies can lead to changes in economic conditions (Agrawal and Yadama 1997; Lambin et al. 2001), including through subsidies and taxes (Barbier 1997; Myers and Kent 2001). Although land tenure institutions are directly linked with individual-level land-use decisions, institutions can also interact with biophysical factors, through investments in technologies, information, and infrastructure, to affect household decisions and resource use (Moran 2005; Ostrom 2009). All of these existing theoretical understandings of land-use drivers suggest the importance of examining cross-scale interactions while taking account of the specificity of cases.

This study employs a human–environment systems perspective, drawing ingredients from the earlier theoretical models of von Thünen and Chayanov (i.e., location and household demographics and labor) to investigate the cross-scale processes behind household land-use decisions (Figure 1). We expect that at the microlevel, the natural environment, household demographics, and location have direct influences over land-use decisions of rural households. We expect that at the macrolevel, urban job markets and agricultural markets liberated by national policy reforms in China affect agricultural land-use decisions of rural households. We also expect that variations of government interventions in some forms exist in the region. Furthermore, we expect that these processes at multiple scales interact to shape the land-use decisions of households ultimately by affecting their feasible off- and on-farm livelihood options and relative economic returns. We are particularly interested in examining the cross-scale processes behind household land-use decisions. Specifically, we intend to evaluate the following processes:

1. How do macrolevel processes associated with national policy reforms, specifically urban job markets and agricultural markets, affect household land-use decisions, and how do they interact with local-level processes (i.e., the biophysical environment, household demographics, and location) to affect land-use decisions of rural households?
2. What forms of variations in government interventions exist in the region, and how do they interact with other local processes to affect household land-use decisions?

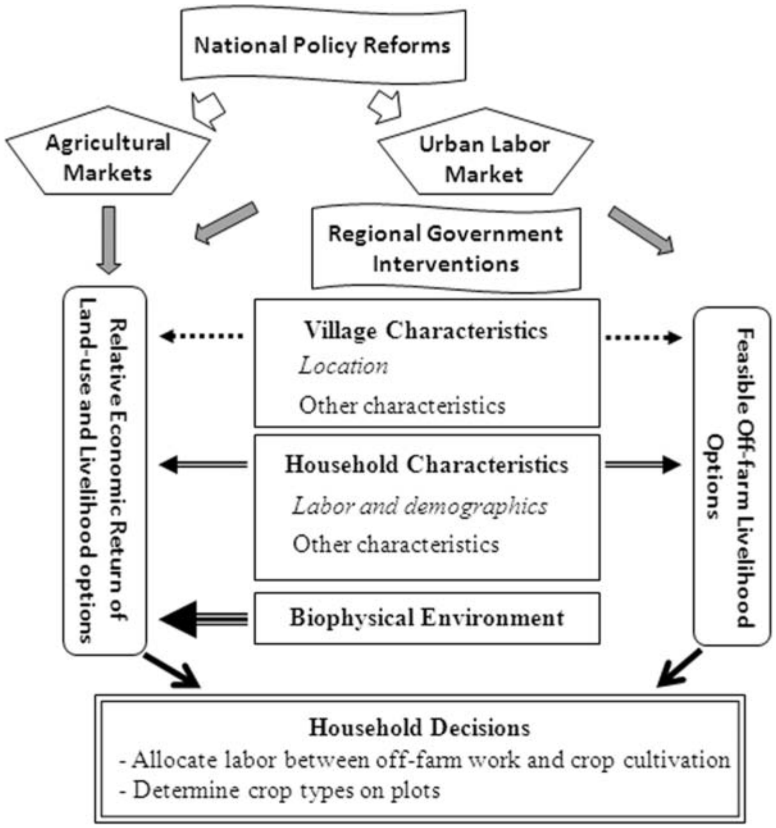

Figure 1. Framework for analysis of cross-scale processes behind rural household land-use decisions in the broader context of development. Different styles of arrows indicate factors at different scales.

Study Area and Policy Changes

The PLR is a largely rural area in Jiangxi Province that includes ten counties, two cities (Nanchang and Jiujiang), and a total area of 20,970 km^2 (Figure 2). According to the Chinese census in 2010, the total population in the PLR was about 9.2 million, and 78.3 percent of the population in the PLR outside the two cities was classified as rural. As a major agricultural production base, the PLR produced 19 percent, 32 percent, and 35 percent of the total grain, cotton, and aquaculture products, respectively, in Jiangxi Province in 2004, according to the 2005 *Jiangxi Statistical Year Book* (Bureau of Statistics of Jiangxi Province 2005). Rice cultivation has traditionally dominated, and is still the major agricultural practice in the PLR. Rice can be grown in one season, from mid- or late June to early October, or two, from late April to mid-July and again from mid- or late July to late October or early November. Cotton is usually planted in May and harvested from October until the end of the year. As an upland crop, cotton can tolerate dry conditions better than rice. Other agricultural products include rapeseed, sweet potato, and peanut. The PLR is agriculturally productive, but it is also subjected to flood hazards from Poyang Lake (Zhao and Guo 2001; Huang and Dai 2004; Jiang et al. 2008). Flood hazards have been mitigated to some extent by construction of a massive levee system in the region, which protects more than 5,000 km^2 of flood-prone land (Jiang et al. 2008), but some of this land has been reclaimed for agricultural production and increased risk of flooding due to levee failure.

As with other rural areas in China, the PLR has been experiencing rapid and dramatic social–economic–political changes due to policy reforms at the national level. From 1949 to the late 1970s, development policies in China focused on heavy industries under strong central planning (Lin 2009). Prices for agricultural products were fixed at low levels and production quotas were assigned to local governments. Communal farming systems were in place from 1966 to 1978. Rural–urban migration was not permitted and

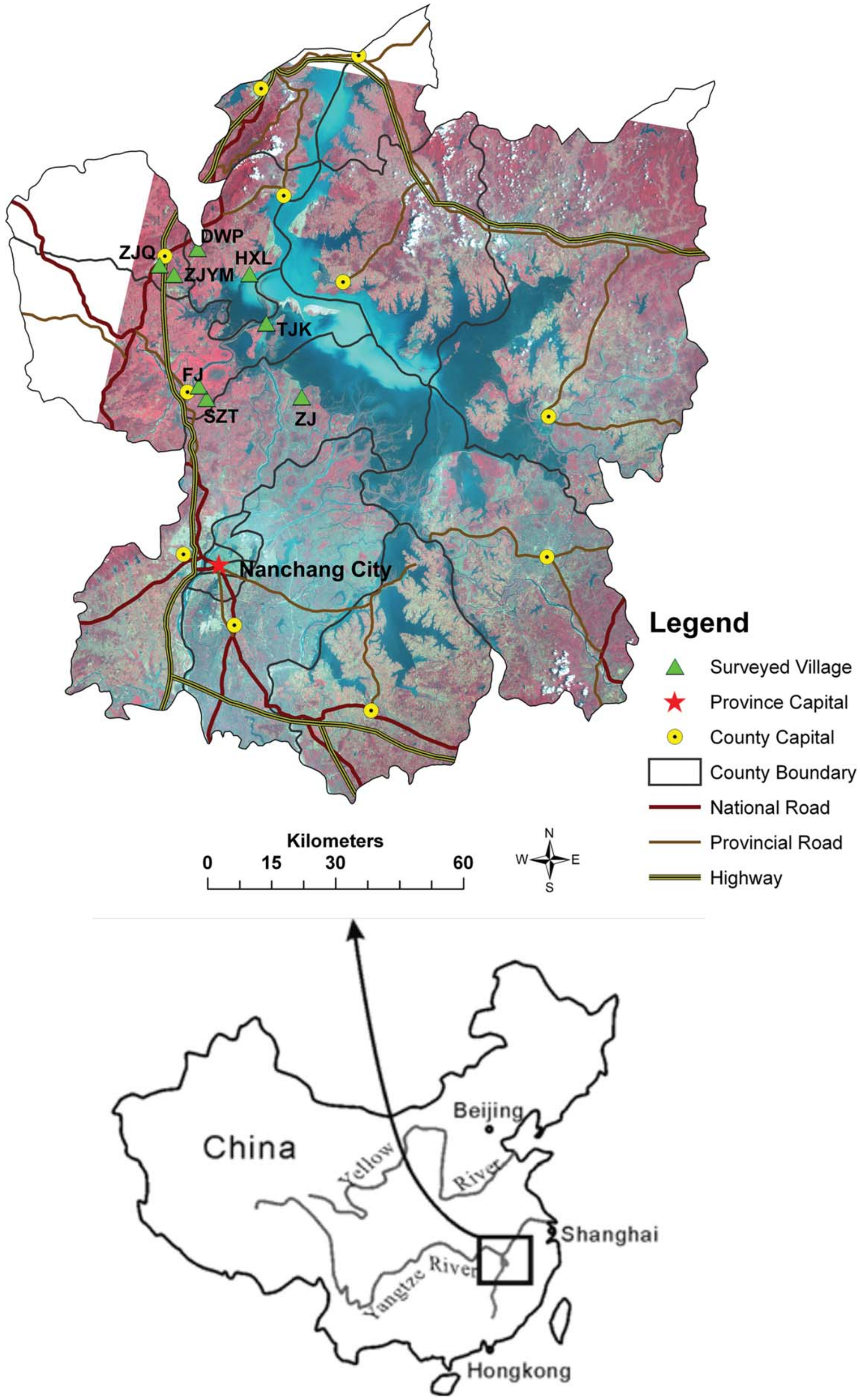

Figure 2. The Poyang Lake Region and surveyed villages. The lower map shows the approximate location of the region in China. The image is from Landsat TM taken on 24 July 2004. (Color figure available online.)

was controlled by the household registration system (called *Hukou*).

To promote agricultural production and rural development, the Chinese government began a series of policy reforms in the late 1970s (Heerink et al. 2007). The period from 1978 to 1984 saw the initiation of the Household Responsibility System (HRS), in which the commune system was dismantled. Prices for agricultural products were increased to encourage agricultural production, and production that exceeded a quota could be sold at higher but controlled prices. The period from 1985 to 1993 saw a decrease in the state control of marketing and purchasing agricultural products. The dual price system was expanded for major products; prices were fixed for the procurement quota and surplus production was allowed to be sold at market prices or negotiated contract prices. In 1993, procurement quotas were reduced, and in some regions even eliminated. In this period, some products such as fruits and fish were freely traded on the market. The period from 1994 to 2003 marked the reintroduction of a government procurement system for grain, as maintaining grain production and securing affordable food supplies became a priority for the Chinese government. Grain prices were raised above world market prices to promote grain production, and the government subsidized grain procurement, export, and storage. The Governor's Grain Bag Responsibility System was implemented, giving provincial and local governments responsibility for agricultural production to ensure food self-sufficiency at the provincial level.

The growth of the industrial sector, resulting from economic reforms, also created labor demand in urban areas. Beginning in 1991, the government liberalized urban jobs and implemented housing policies that encouraged rural-to-urban migration. Beginning in 2004, agriculture taxes were eliminated and subsidies in the form of cash, high-quality grain seeds, and machinery have been made to households to stimulate grain production. Public investments in rural infrastructure have been increased and off-farm work opportunities have been further stimulated. These policy reforms have had a great impact on land use and agricultural production in the PLR (Zhou and Huang 2003; Heerink et al. 2007; Jiang et al. 2008).

Methods

We combined quantitative analysis of household surveys and qualitative analysis of interviews and field observations (Figure 3) to investigate the cross-scale processes behind rural household land-use decisions in the PLR (Figure 1). We conducted household surveys in eight villages in the PLR and followed up with interviews and participant observations. We developed a three-level regression model for one-season rice and cotton (two dominant crops in the PLR of national importance) separately to capture the biophysical properties of plots (Level 1), the characteristics of households (Level 2), and the location of a village (Level 3) and to evaluate the effects of urban job markets (represented by off-farm income) on crop choices on individual plots. Our interviews and field observations yielded rich information about how these factors at multiple scales affected household decisions and further accounted for the effects of macrolevel processes associated with national policy changes (off-farm income earned in urban job markets and price changes in agricultural markets) and regional government interventions on household land-use decisions, which were not available in surveys. The quantitative and qualitative analyses together support interpretations of cross-scale processes behind household land-use decisions.

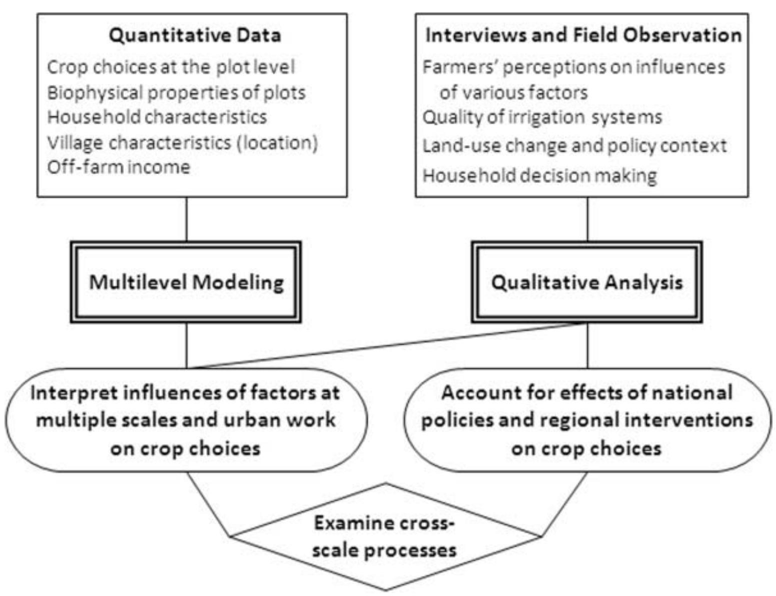

Figure 3. Data collection and analysis methods.

Survey Village Selection

To account for locational and environmental variability in the PLR, we stratified the natural villages (自然村) around Poyang Lake by variables representing elevation and location relative to urban centers. Using a digital elevation model (DEM), adjusted with geographical information systems data that represent levee location and height, we classified villages into two types based on adjusted elevations: high elevation (≥21.68 m) with low risk and low elevation (<21.68 m) with high risk. Because county capitals serve as the center of economic and administrative activities for the county and are usually much larger than other towns in the county, we also classified villages into two types based on distance: close to county capital (within 5 km) and far from county capital (beyond 5 km). Using a two-by-two matrix formed by these two classifications, we identified four types of villages and randomly selected six candidate villages of each type. We then collected information about production structure, migration labor, income per capita, farmland per capita, number of households, and population of these villages and chose two villages of each type, for a total of eight villages (Figure 2). Due to road construction at the time of survey, three preselected villages were replaced by other nearby villages that had similar characteristics.

Household Surveys

Surveys were field tested in the summer of 2006, then conducted orally in January 2007, just before the Spring Festival, to increase chances that houses would be occupied. The Spring Festival is a national holiday celebrating the lunar New Year, in which most Chinese travel to their hometowns to celebrate with family. Twenty-five percent of the households in each village were randomly chosen for the survey (Table 1), although the actual proportion of surveyed households in each village varied slightly depending on field conditions. Based on our surveys, off-farm income contributed almost 65 percent of total household income across all surveyed villages, suggesting the large degree to which urbanization affected rural populations in this area. Major off-farm livelihoods included local or migrant urban work and business, which contributed 56 percent and 8 percent of total income, respectively. Resource-based income sources included crop cultivation, fishing, forestry, and aquaculture. They contributed about 22 percent, 5 percent, 3 percent, and 2 percent of total income, respectively.

The surveys produced data about land use at the plot, household, and village levels (Table 2 and Figure 4). Data on land-use type, production, and biophysical properties were collected at the plot level. Demographic information, farmland endowment, education, social connections (in terms of government contacts), and income sources were collected or summarized at the household level. Households with incomplete data were excluded from the analysis. All continuous variables were mean-centered for statistical analyses.

Interviews

We (the first author and a local assistant) revisited all eight surveyed villages in July 2008 and conducted formal and informal interviews of forty-nine farmer households, ten village leaders, and ten local government officials (five at the county level and five at the township level; Table 1). We stayed with a household

Table 1. Basic characteristics of the surveyed villages

Village descriptors	ZJ	TJK	FJ	SZT	ZJYM	ZJQ	DWP	HXL
No. households surveyed	23	20	23	19	21	19	35	33
No. households interviewed	13(3)	15 (2)	2	3	5 (1)	3(1)	3(1)	15(2)
Distance to closest county capital (km)	44.3	23.9	37.2	4.0	4.4	1.5	6.2	19.7
Irrigation system	Y	N	N	N	N	N	Low capacity	Low capacity
No. private pumps	2	0	2	0	1	13	0	1
Average area per capita (mu)	2.9	0.6	1.4	1.9	1.7	1.2	0.9	0.6
Average plot size	1.2	0.9	0.8	0.8	0.6	1	0.7	0.5
% hilly area	0	17	0	0	24	0	0	33
No. off-farm jobs per household	0.57	1.38	1.49	1.72	1.50	0.90	1.37	2.20
% off-farm income	47.62	89.58	72.42	51.37	82.83	48.84	57.72	76.58

Note: 1 mu = 0.067 hectares. Abbreviations listed in column headings represent village names; these have not been identified for privacy.

Table 2. Description of variables used in the multilevel regression analysis

Variable name	Description	Min	Max	M	*SD*	Frequency
Dependent variable at the plot level ($N = 1{,}117$)						
One-season rice	1: One-season rice					464
	0: Not one-season rice					653
Cotton	1: Cotton					343
	0: Not cotton					774
Independent variables at the plot level ($N = 1{,}117$)						
Plot size (mu)	The size of the plot	0.02	7.00	0.67	0.59	
Fertility	1: Good					131
	2: Average					676
	3: Bad					310
Slope	1: Flat					916
	2: Hilly					201
Distance (minutes)	Minutes to walk to the plot from the house	0	90	14.56	11.04	
Independent variables at the household level ($N = 123$)						
HouseholdType	1: No children					88
	2: With children and elderly					10
	3: With children but no elderly					25
DependenceRatio (%)	Percentage of children and elderly in the household	0	66.67	14.46	17.37	
PctFemaleLabor (%)	Percentage of female labor in the household	0	100	47.70	16.25	
NumClgStudents	Number of people who are in college	0	2	0.07	0.29	
TotalArea (mu)	Total area of farmland	0.1	19.30	6.347	4.12	
PctFlat	1: > 85% flat farm land					88
	0 < 85% flat farm land					35
AvgPlotSize (mu)	Average size of all the plots	0.05	2.35	0.69	0.34	
HaveLoans	1: Has loans					55
	0: Has no loans					68
HaveGovContact	1: Has government contact(s)					23
	0: Has no government contact(s)					100
Education	1: Highest education level is high school or above					49
	0: Highest education level is below high school					74
SqrtOfffarmIncome (CNY)	The square root of the amount of off-farm income	0	320.90	109.40	71.26	
Independent variable at the village level ($N = 6$)						
DistanceToCity	The distance to the closet county capital calculated using ArcGIS	Values are shown in Table 1				

Note: 1 mu = 0.067 hectares.

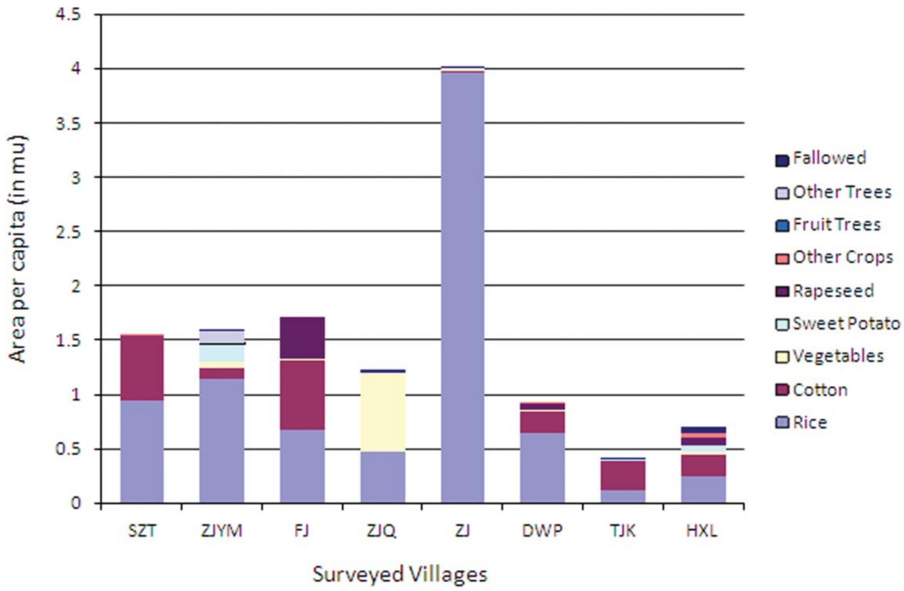

Figure 4. Major land-use types and areas in the surveyed villages. *Note:* 1 mu = 0.067 hectares. (Color figure available online.)

in each of three villages (ZJ, TJK, and HXL), spending five to seven days in each, observing the daily life of villagers and engaging in informal conversations with them. When opportunities arose, we also interviewed some households that had not been surveyed. We spent a half to full day in each of the other five villages. Initially, we planned to stay in ZJQ, a village near its county capital with a significant income from growing vegetables, but their farmland was acquired by the county government for industrial development. Instead we spent one day in ZJYM, which is also close to its county capital with some vegetable production. In each village, we visited the fields, if possible in the company of a farmer or village leader, to familiarize ourselves with the quality of farmland resources.

Following Holstein and Gubrium's (1995) approach of active interviewing, we worked with the respondent to construct a narrative together and interpret its meaning. For the formal interviews, we designed a set of questions on land-use practices, land-use changes, other livelihood strategies, decision making, crop cultivation, flood risk, and living standard expectation but were not limited by these questions. Preliminary analysis of the survey data before the interviews revealed that some factors (e.g., education and government contacts) were associated with the income of households and we asked farmers about the impacts of these factors on their livelihoods and those of other households. To seek in-depth understanding, we sometimes asked different questions to different farmers based on their answers and the characteristics of the households. All of the interviews were digitally recorded. Because we used qualitative analysis to complement interpretation of the quantitative analysis, we did not adopt a highly formalized approach (Lincoln and Guba 1985; Strauss and Corbin 1998) but rather used qualitative information from observations and interviews to develop in-depth understanding of relevant quantitative information.

Multilevel Modeling

The regression models were fitted using the R software package with the Laplace method. We represent each land-use choice as a binary variable observed at the plot level and used a three-level logistic model generally specified (Snijders and Bosker 1999) as

$$\log\left(\frac{p_{ijk}}{1-p_{ijk}}\right) = \gamma_{000} + \gamma_{100}X_{1ijk} + \cdots + \gamma_{q00}X_{qijk} + \gamma_{010}Z_{1jk} + \cdots + \gamma_{0r0}Z_{rjk} + \gamma_{001}a_{1k} + \cdots + \gamma_{00s}a_{sk} + R_{0jk} + U_{00k} + e_{ijk} \quad (1)$$

The model is essentially composed of two parts: the fixed effects and the random effects. In Equation 1, the fixed effects are represented collectively as follows: At Level 1, x_{qijk}, γ_{q00}, q are the variables, regression coefficients, and total number of variables, respectively; at Level 2, the corresponding components are z_{rjk}, γ_{0r0}, r;

and at Level 3, they are a_{sk}, γ_{00s}, and s. R_{0jk} represents the random effect of Level 2 groups, and U_{00k} represents the random effect of Level 3 groups. The random effects can be regarded as error terms at group levels and, with these random effects, the variances between groups are modeled explicitly. Such a model reveals what Level 1 variables are related to the within-group variance and what group-level variables are associated with the between-group variations in intercepts (Bliese 2006). We only modeled the variations of the intercept, but not regression coefficients, between groups.

The off-farm income variable was used to evaluate the influence of urban job markets and other independent variables (Table 2) were chosen to represent the biophysical properties of plots (Level 1), the characteristics of households (Level 2), and the location of a village (Level 3) based on existing theoretical understandings of land-use decisions as we discussed in the Background section. In addition to including demographic variables associated with labor availability, we categorized households into three types: (1) without children, (2) with children and elderly, and (3) with children but no elderly. We included information on elderly in the household structure variable because our fieldwork suggested that elderly in rural China perform an important function in taking care of young children.

Although we incorporated their qualitative data into our overall analysis of household land-use decisions, we excluded ZJ and ZJQ for the multilevel regression because they were outliers in terms of land-use practices. Whereas two-season rice is practiced village-wide in ZJ, the dominant land-use practice in ZJQ is vegetable cultivation. There is no cotton production in either village. Within the remaining six villages, there were a total of 1,117 plots and 123 households.

We generated a series of models for both one-season rice and cotton. Initially, an empty model without group random effects was fitted, followed by an empty model with group random effects. Model M1 includes only Level 1 variables. Four groups of Level 2 variables were then added sequentially to generate M2.1, M2.2, M2.3, and M2.4. Model M3 was generated by adding the Level 3 variable.

In addition to reporting coefficient values, we calculated the area under the receiver operating characteristic (ROC) curve (AUC) for each model as a measure of the goodness of fit. The ROC curve describes the relationship between the proportions of true-positive and false-positive predicting from a logistic regression model based on an infinite number of probability cutoff values. AUC can be interpreted as the probability that a classifier will assign a higher score to the positive case than to the negative case, if we randomly draw pairs, one from a positive group and one from a negative group (Fawcett 2006). It can be used to compare the performance of different models (Overmars and Verburg 2006). The value of AUC ranges from 0.5 to 1.0, with 0.5 indicating no better than random prediction and 1.0 a perfect discrimination.

Results

Results from Multilevel Models

Overall, our modeling results suggest that factors at multiple scales from the biophysical environment to household characteristics, village location, and urban job markets affect crop choices of rural households. Because the choices of cultivating one-season rice and cotton are interrelated, we interpret the results of two series of multilevel models together (Tables 3 and 4).

The prediction accuracy of the model for one-season rice was improved by adding biophysical variables at the plot level. This suggests that the likelihood of growing rice varies among plots of a given household. A household is more likely to grow rice on larger and flatter plots and plots of average fertility. This is consistent with our field observation that rice is grown on flat and large plots where water is available from rain or made accessible by irrigation. Growing rice on large plots also facilitates harvesting by machines, which are widely used. Harvesting machines are rented and usually run through the rice fields of an entire village. That adding plot-level variables reduced the random component of variance between villages indicates that variations in the biophysical properties of farmland partially contribute to the differences between villages in the likelihood of choosing rice.

The prediction accuracy of the cotton model was not improved substantially by adding biophysical variables at the plot level (Table 4). This suggests that the variations in the likelihood of growing cotton between the plots of a given household are small, although the significance and directions of the coefficients indicate that cotton is more likely to be found on smaller plots and plots further away from the house. Cotton can grow almost anywhere except on low-lying, flood-prone plots. When large plots are used to grow rice, it follows naturally that cotton is planted on smaller

Table 3. Multilevel models for one-season rice

One-season rice		Variables	With no variables: Without random effects	With no variables: With random effects	M1 Add plot variables	M2.1 Add household structure variables	M2.2 Add land resource variables	M2.3 Add financial variables	M2.4 Add social variables	M3 Add village location
Fixed effects										
		Intercept	−0.34***	−0.65	−0.68	−0.52	−0.43	−0.50	−0.63	0.50
Plot level		Plot Size			1.81***	1.81***	1.84***	1.83***	1.82***	1.82***
		Fertility 2			0.66*	0.61*	0.59*	0.56*	0.60*	0.58*
		Fertility 3			−0.14	−0.18	−0.14	−0.15	−0.09	−0.09
		Slope 2			−2.88***	−2.92***	−3.26***	−3.27***	−3.28***	−3.27***
		Distance			−0.02†	−0.02†	−0.01	−0.01	−0.01	−0.01
Household level	Household structure	Household Type 2				−1.56*	−1.66*	−1.70*	−1.45*	−1.25†
		Household Type 3				0.34	0.34	0.33	0.19	0.15
		Dependence Ratio				0.00	0.00	0.00	0.00	0.00
		PctFemaleLabor				0.00	0.00	0.00	−0.01	−0.01
		NumClgStudents				0.13	0.06	0.06	−0.03	−0.10
	Land resources	Total Area					0.05	0.04	0.03	0.01
		PctFlat					−0.02*	−0.02*	−0.02*	−0.02**
		AvgPlotSize					−0.54	−0.52	−0.56	−0.56
	Financial variables	Have Loans 1						0.17	0.25	0.18
	SocialConn &education	HaveGovContact 1							1.02**	1.10**
		Education 1							−0.39	−0.40
Village level	DistanceToCity									−0.11*
Urban job markets		SqrtOffarmIncome						0.00	0.00	0.00
Random effects	Household level			0.5248	1.4989	1.3702	1.3565	1.3449	1.1359	1.0617
	Village level			0.9884	0.6587	0.5215	0.5476	0.6091	0.8910	0.6358
AUC			0.5	0.7813	0.8838	0.8834	0.8839	0.8841	0.8810	0.8814

Note: AUC = area under the curve.
†Significant at 0.1.
*Significant at 0.05.
**Significant at 0.01.
***Significant at 0.001.

Table 4. Multilevel models for cotton

			With no variables		M1	M2.1	M2.2	M2.3	M2.4	M3
Cotton		Variables	Without random effects	With random effects	Add plot variables	Add household structure variables	Add land resource variables	Add financial variables	Add social variables	Add village location
Fixed effects										
		Intercept	–0.81***	–0.72†	–0.83†	–0.78	–0.74	–0.68	–0.64	–1.24†
Plot level		PlotSize			–0.60***	–0.57***	–0.64***	–0.64***	–0.65***	–0.65***
		Fertility 2			–0.02	0.01	0.00	0.00	–0.01	0.00
		Fertility 3			0.32	0.35	0.34	0.27	0.26	0.27
		Slope 2			0.32	0.33	0.33	0.35	0.36	0.35
		Distance			0.01†	0.02*	0.02*	0.02*	0.02*	0.02*
Household level	Household structure	Household Type 2				–0.38	–0.45	–0.47	–0.48	–0.52
		HouseholdType 3				–0.08	0.00	0.03	0.02	0.03
		DependenceRatio				0.01	0.01	0.01	0.01	0.01
		PctFemaleLabor				0.02***	0.02***	0.02***	0.02***	0.02***
		NumClgStudents				–0.51	–0.43	–0.48	–0.44	–0.43
	Land resources	TotalArea					0.05†	0.06*	0.06*	0.06*
		PctFlat					0.00	0.00	0.00	0.00
		AvgPlotSize					0.00	–0.11	–0.11	–0.12
	Financial variables	HaveLoans 1						–0.09	–0.09	–0.09
	SocialConn & education	HaveGovContact 1							0.00	–0.01
		Education 1							–0.07	–0.06
Village level		DistanceToCity								0.06
Urban job markets		SqrtOfffarmIncome						–0.002†	–0.002†	–0.002†
Random effects	Household level			0.3095	0.2800	0.0913	0.0396	0.0272	0.0286	0.0589
Village level			0.9959	1.0797	1.1188	1.1497	1.2456	1.2470	1.0386	
AUC			0.5	0.8008	0.8023	0.7840	0.7775	0.7779	0.7786	0.7778

Note: AUC = area under the curve.
†Significant at 0.1.
*Significant at 0.05.
**Significant at 0.01.
***Significant at 0.001.

plots. In the field, we also observed that cotton is usually grown on higher and drier sites where water is not easily accessible. Growing cotton on plots further away from the house is consistent with the notion that cotton is a cash crop, and rice is a subsistence crop. Overall, the impacts of biophysical properties of plots on the choice of cotton are not as important as on the choice of rice.

Household-level variables of household type, percentage of flat area, and government contacts were found to be significantly associated with the between-household variations in the choice of rice (Table 3). A household with children and elderly is less likely to grow rice on a given plot because parents usually do migratory work. As a result, rice consumption and labor availability are both lower in these households, and off-farm income is usually sufficient to purchase rice for food. Because rice is usually planted on flat plots and because households have limited subsistence needs for rice cultivation, a household with a greater percentage of farmland that is flat is less likely to grow rice on a given plot when controlling for the effect of the slope of plots. They are more likely to meet their rice-growing needs and grow something else on additional available land. Whether a household has government contacts is positively associated with the choice of rice. Our interviews and observations in the field indicate that households with government contacts are more likely to have income sources other than crop cultivation near villages. Because they do not have much labor for crop cultivation, and rice cultivation is less labor intensive, they choose to grow more rice. This also points to an informal means by which institutions influence land-use choices, through social interactions that can create differential opportunities among households.

The household-level variables percentage of female labor and total area of farmland were both significantly associated with the between-household variations in the choice of cotton on a plot (Table 4). Across the villages, we observed that most males engage in migratory work and some females stay at home. Women and the elderly are the major source of farm labor, and the elderly tend to take care of children. Because cotton cultivation generates more income than rice but is more labor intensive, those households with female labor on the farm are more likely to choose cotton over rice on a plot. That a household with larger farmland area is more likely to grow cotton on a plot is consistent with cotton as a cash crop. Extra plots are used to grow cotton and increase income after subsistence needs are met.

Adding variables at the household level significantly reduced the random part of variance between households in cotton choices, although they did not improve the prediction of the choice of cotton on a plot (Table 4). Specifically, household type accounted for the most variation between households in cotton choice, and farmland resources accounted for additional variation. Demographic structure is particularly important because it often determines feasible livelihood options and the amount of labor on the farm. For example, if young parents do not have elderly relatives to take care of their children, they have to stay on the farm.

Adding variables at the household level reduced some household-level random variation in rice choice (Table 3), although the large remaining variation among households could not be explained well by these variables. Household type and government contacts explained between-household variations in rice choice more than other variables. Compared to other livelihood options, one-season rice cultivation is least profitable but also less labor intensive. As part of the overall livelihood strategies, rice production is a result of balancing labor, farmland resources, and food demand to increase overall economic benefit, and the variations between households in the choice of rice have no simple explanation.

Village location in terms of distance to the closest county capital was significantly associated with between-village variations in rice choice but not cotton (Tables 3 and 4). Adding village location also reduced the village-level random variation in rice and, to a lesser extent, cotton choice. In the villages near a county capital, households were found more likely to grow rice on an individual plot. Our interviews and field observations suggest that urban centers offer off-farm job opportunities for households that live within the distance accessible by motorcycle and bus. Because rice cultivation is less labor intensive than cotton, households in villages closer to markets choose to grow more rice so they can allocate their labor more productively in off-farm work.

With other factors controlled, off-farm income was negatively associated with the choice of cotton, although the association was not very strong (Table 4). As cash sources, cotton production and off-farm activities compete for labor, with cotton cultivation being less profitable than off-farm activities. And when people have a lot of off-farm income, they do not need to grow cotton. This demonstrates one way in which urban job markets interact with labor to influence land-use decisions of rural households.

Household Land-Use Decisions and Cross-Scale Processes

In this section we further integrate qualitative interviews and field observations with the modeling results to examine the cross-scale processes and discuss how macrolevel forces associated with national policy changes (i.e., off-farm income earned in urban job markets and price changes in agricultural markets) and regional government interventions affect household land-use decisions through their interactions with local factors.

Because off-farm work in general generates higher economic return than crop cultivation, households usually put off-farm activities as top priorities when considering livelihood choices, and urban job markets have a strong influence over household land-use decisions through affecting labor availability on the farm. The modeling results have demonstrated that off-farm activities compete for labor with cotton production. Through interviews and field observations, we found another important way in which urban job markets interact with labor to affect crop choices of rice. Our conversations with village leaders revealed that before economic reforms started in the late 1970s, rice was cultivated twice a year where the biophysical environment allowed across all surveyed villages. In seven out of eight surveyed villages, two-season rice was converted to one-season rice at the time of survey, mainly due to the availability of urban labor markets and, related to it, the failure of collective irrigation systems. Based on our interviews, off-farm jobs in the county capital yielded 60 CNY to 100 CNY per day in 2007. Long-term migratory work in cities brought an income between 10,000 CNY and 30,000 CNY per person in a year. Off-farm work reduces labor available on the farm and makes labor-intensive farming activities difficult. Many of the farmer households that we talked to performed the following calculation, with some variations in yields among plots and households. One mu of farmland can produce 300 kg to 400 kg of cotton, which sold for about 5.6 CNY per kilogram in 2007, with a net income of at least 1,000 CNY after deducting costs. If used for one-season rice production, the same land area could produce about 500 kg of rice, which sold for about 1.6 CNY per kilogram in 2007 and only brought a net income of about 600 CNY. The failure of collective irrigation systems further exacerbates the condition for rice production. In the surveyed villages where households switched two-season rice to one-season rice, the collective irrigation systems (built in Mao's time) have been destroyed or are operating in a very limited capacity (Table 1). In these villages, total rice production in two seasons would only yield about 150 kg more grain on average than in one season. The extra cost in fertilizer (prices of which have increased in recent years), seeds, pesticides, and rented machinery for harvest, along with the labor costs, however, would result in very little net gain. Although we cannot separate the causal relationship between availability of urban jobs and the failure of collective irrigation systems, relatively high returns from off-farm work make crop cultivation unattractive, especially in villages where farmland is not rich, and reduce the efforts rural households invest in crop-cultivation-related activities, including maintenance of collective irrigation systems.

Off-farm work offered by urban job markets and market prices of agricultural products also interact with location and ultimately labor to affect household land-use decisions. Both the modeling results and our field observations suggest that households near urban centers are more likely to grow rice on an individual plot. This is because urban centers offer off-farm work opportunities, and cultivating less labor-intensive crops allows them to spend labor on and earn more income from off-farm work. Through our interviews, we also found an increase in cotton production especially in villages far away from urban centers. Some households in HXL and TJK (both villages are far from urban centers) told us that they were growing more cotton than before because market prices for cotton went up. Transportation cost is not a major factor in these differences in rice relative to cotton production because across surveyed villages, rice and cotton are collected by some commercial entities, and their prices based on farmers' reports are similar across surveyed villages. Rather, this suggests that location affects crop choices indirectly by affecting local off-farm options, which then affect labor availability on the farm and consequently labor allocation. Urban centers in the PLR serve as local off-farm employment centers, and this appears different from other rural areas in China where commercial agriculture dominated rural livelihoods, and villages were found to serve as important labor centers to affect land rent and agricultural land use (S. Liu 1999, 2000).

Off-farm work also interacts with household characteristics other than labor to affect household land-use decisions. Again, because off-farm work in general generates higher economic return than crop cultivation, households usually make off-farm activities top priorities when considering livelihood choices, and household characteristics, especially government contacts and demographic structure, can affect its land-use choices indirectly by determining off-farm options. Our modeling results and field interviews suggest that those households with better government connections often have access to high-return livelihood options, such as doing business, purchasing and operating machines, and finding salary-based jobs. When a household has better off-farm options, it usually allocates less labor to farming activities and tends to grow more rice, if it still cultivates crops. The majority of households have only migratory work and crop cultivation as their feasible options. Demographic structure affects whether they can do migratory work away from home and labor availability on the farm, which then determines their land-use choices. For example, when a household has young kids but no elderly people to take care of their kids, adults might have to stay on the farm, and when both adults are present on the farm, a household might rent and cultivate more farmland to increase income.

Our interviews also revealed differential government interventions in the region that affect household land-use decisions and demonstrate an interaction with the biophysical environment. Cotton cultivation was introduced to households in some areas in the PLR by the government in the 1990s. The government, however, never introduced cotton in ZJ because ZJ and its surrounding area is a major rice production base where farmland is rich, fertile, and suitable for rice production. The government puts extra effort into maintaining the irrigation systems in ZJ and its surrounding areas. There the township government manages the collective irrigation system for the entire township and charges each household a monthly fee. With its large farmland area and productive rice paddies supported by a fully operational irrigation system and government subsidies for rice cultivation (about 100 CNY per mu for two-season rice and 50 CNY for one-season rice in 2007), one mu of two-season rice generates an income in ZJ not much lower than cotton would. That is why households in ZJ still cultivate two-season rice. Therefore, regional government interventions partially had the effect of reinforcing and enhancing the effect of natural variability (i.e., productive rice regions were maintained) on household crop choices in the PLR.

National policies, market forces, and regional government interventions interact with location and household characteristics to affect household land-use decisions in the PLR that are, however, ultimately confined by the biophysical environment. Our modeling results demonstrate that the biophysical properties of plots are important for crop choices. Additional observations in the field and conversations with farmers also confirm the role of the biophysical environment in determining the possibility for land use and land-use change. For example, in ZJ where two-season rice is cultivated village-wide, villagers plant one-season rice in low-lying areas to avoid damage during the rainy season (April–June). In HXL, peanuts, watermelon, sweet potatoes, and many other crops are cultivated on the hilly fragmented plots because the soil of these plots has low fertility. Although cotton cultivation was introduced to ZJYM in the 1990s, the villagers switched back to rice because cotton did not grow well on its flood-prone, low-lying farmland. In HXL we observed that some small marginal plots were even left fallow, and some villagers told us that all of the plots were cultivated intensively in the past.

These cross-scale processes behind household land-use decisions we have illustrated through the case study in the PLR are limited by our survey sample size and field experiences. To what degree they are applicable to the entire region and how they manifest in the spatial land-use patterns remain important questions for future investigation.

Discussion

Our use of multilevel modeling and qualitative methods enabled a synthesis of perspectives on the cross-scale processes behind household land-use decisions in central China and enhanced our understanding of the deferential effects of macrolevel processes (i.e., policy changes and market forces) across local social and environmental contexts. A key element in the design of our research was the construction, use, and interpretation of a quantitative model in the context of available qualitative observations. Although we do not suggest that there is a single strategy for combining these different types of information, our research demonstrates the value of combining qualitative and quantitative information through our ability to address cross-scale interactions and the ability to employ both deductive and inductive reasoning about coupled human–environmental systems.

This understanding of cross-scale processes behind household land-use decisions allows us to consider possible future land-use changes and their consequences. As urbanization in China deepens, rural households on average will earn more off-farm income, which will continue to affect agricultural land use. The regional government has been successful so far in maintaining rice production in farmland-rich areas through differentiating interventions; however, maintenance of rice production in these areas in the future can be challenged by rising off-farm income and also depends on price changes in the agricultural markets. Without new policy interventions, we expect to see further deintensification of agricultural land use in the areas with poor farmland resources. This could lead to abandonment of agricultural use on marginal land (which we already observed in the village of HXL) and facilitate sustainability from a conservation perspective. As we have demonstrated, off-farm income, price changes in agricultural markets, household characteristics, location, and the biophysical environment interact to influence and lead to differential land-use choices among rural households in the PLR. In the future, we expect to see continuous divergent development paths of rural households across social and environmental settings and policies that aim to secure food production and promote sustainable land use need to take into account and could take advantage of the heterogeneity of local contexts.

This synthesis of perspectives on the cross-scale processes allows us to understand specific ways in which location and household demographics affect rural household land-use decisions in the broader context of development that go beyond what the classic models of Chayanov and Von Thünen have suggested. In theorizing the effects of location and household life cycles on land use, the models of Von Thünen and Chayanov, as in any theoretical models, make certain (implicit) assumptions about the system that were true at their times or in their situations. We should expect deviations from their predictions where those assumptions do not hold. In fact, life cycles are found to be important mostly in places where farmer households practice relatively closed subsistence agriculture (McCracken et al. 1999; Perz and Walker 2002; Entwisle et al. 2005; Carr 2009). Some studies in the Amazon have questioned the effects of household life cycle on rural land use (Aldrich et al. 2006; Caldas et al. 2007; VanWey, D'Antona, and Brondízio 2007). Researchers have also attempted to incorporate other factors to remedy the inadequacy of the model of Von Thünen in examining land use (Jones and Krummel 1987; Kellerman 1989; S. Liu 2000; Angelsen 2007). Generally speaking, where the biophysical environment exhibits heterogeneity or urban centers also serve as important local off-farm employment center for local rural households, it is not likely that neat land rent gradients as defined by the model of Von Thünen will result. When rural households are linked to a larger economy outside their local agricultural production system, or where local labor and other markets exist, we might not expect the effects of household life cycles on land-use choices to be as strong as predicted by the model of Chayanov.

The cross-scale land-use processes behind rural household land-use decisions we illustrated through our case study are not entirely unique in the PLR. Some studies on migration demonstrate a similar effect of off-farm income on rural land use in that remittances lead to agricultural deintensification and reforestation through reduced labor availability on farm and increased cash income (Reichert 1981; Zimmerer 1993; Preston, Macklin, and Warburton 1997; Rudel et al. 2005; Lopez et al. 2006; Müller and Sikor 2006; Hecht 2010; Qin 2010). But in some other areas remittances are found responsible for agricultural land-use intensification and deforestation due to enhanced ability to adopt new technologies or hire labor (De Haas 2001, 2006; Taylor, Moran-Taylor, and Ruiz 2006; Gray 2009). The emerging literature on teleconnection and telecoupling also provides some evidence on the influences of market forces on rural land use. For example, domestic and global markets are found linked to the conversion of forests in the Amazon to cattle ranches and in South America to soybean fields (Pfaff and Walker 2010; Reenberg and Fenger 2011). Global trades have facilitated reforestation in some countries but caused further deforestation in some others (Meyfroidt, Rudel, and Lambin 2010; Lambin and Meyfroidt 2011; J. Liu 2014), which suggests the important role of institutional settings and national policies and overall development on rural land use. Although the land-use types examined by these studies are not all the same, they bring a common message that across the developing world, urban–rural interactions and globalization play an important role in shaping local rural land use through the effects of off-farm income and markets (Seto et al. 2012; J. Liu et al. 2013; Verburg et al. 2013; Müller and Munroe 2014; Seto and Reenberg 2014). These varied outcomes of rural land use across locales reported in the literature are consequences of interactions between macro- and microlevel processes, and they emphasize the need for further investigation of these cross-scale processes.

Today as rural households in the developing world are increasingly engaged in urban work and integrated into the global economy, agricultural land use is affected by factors and forces at multiple scales from local communities to regional and global markets. This has significant consequences for food production and security locally and globally, as well as on sustainable land use and development in the developing world. In general, we can expect that market forces will play a stronger role in affecting rural household land-use decisions with local, regional, and national policies modifying market conditions. But their effects will manifest through interactions with local processes and differ across social, biophysical, and institutional settings. At a very basic level, the effects of biophysical properties of land will not go away, especially in areas where biophysical environments exhibit heterogeneity. Location and household demographics will still play a role, but their roles need to be considered in the context of other factors and forces. Although these factors and forces at multiple scales might not affect land use to the same degree or in the same way in each case or place, our case study in the PLR suggests that we can better understand their specific roles and particularly their interactions by examining how they affect household decisions through their effects on livelihood options and relative economic returns of livelihood options in the broader context of development and institutional and policy settings (Figure 1). By examining these cross-scale processes behind rural household land-use decisions, we can better understand the differential effects of macro and global forces across local social and environmental contexts and identify conditions under which desirable and undesirable outcomes are produced. Such understanding is important for predicting future land-use changes, possible consequences of land-use change, and potential effects of policy interventions (Turner et al. 1995; GLP 2005; Lambin and Geist 2006; Turner, Lambin, and Reenberg 2008; Ostrom 2009; Moran 2010; Seto et al. 2012; J. Liu et al. 2013).

Conclusions

We combined multilevel modeling and qualitative analysis to investigate how macrolevel forces associated with policy reforms in China (i.e., urban job markets and agricultural markets) interact with microlevel factors (i.e., the biophysical environment, location, and household demographics) to shape land-use decisions of rural households in the PLR. We found several interesting cross-scale interactions. Because urban centers offer local off-farm work and because rice cultivation, although less profitable, is less labor intensive than cotton cultivation, households near urban centers are more likely to grow rice than cotton. Households far away from urban centers do not have local off-farm opportunities and are more likely to increase cotton production (relative to rice) responding to increases in cotton prices, should labor on the farm permit, for example, when women are present on the farm. Furthermore, off-farm work also interacts with other household characteristics, specifically government contacts and household structure, to affect household land-use decisions by determining off-farm options. We also found differential government interventions in the region that mostly reinforce preexisting biophysical conditions, contributing to maintenance of intensive two-season rice production in select agricultural bases. Ultimately, all of these factors and forces have to interact with the biophysical environment that allows or prohibits certain land-use choices.

Essentially, rural households in the PLR, situated in different social and environmental settings, try to allocate labor among their feasible livelihood options to increase total income by giving higher priorities to higher return options. Although market prices of agricultural products directly affect economic returns from crop cultivation, many factors affect a household's land-use decisions indirectly through affecting its off-farm options, labor availability on the farm, and consequently labor allocation, because off-farm work in general generates higher returns than crop cultivation.

Today as rural households worldwide increasingly become teleconnected and telecoupled with urban economies and regional and global markets, agricultural land use is increasingly under influences of macro and global forces. Our study in the PLR demonstrates how combined use of quantitative and qualitative data and methods can be useful for acquiring a synthesis of perspectives on the cross-scale processes behind rural household land-use decisions in the broader context of development and institutional and policy settings. Such syntheses can improve our understanding of differential effects of macro and global forces across local contexts and have practical implications for securing food production and promoting sustainable land use.

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