**PhD Dissertation Proposal**

Determinants, consequences and feedbacks of land-cover/land-use changes: Human-environment interactions in Tianma Natural Reserve, China

Qi Zhang

# **Introduction**

Land-cover/land-use changes (LCLUC) is a complex result of multiple interactions between human and environment with nonlinear processes and feedbacks across various scales. It has profound impacts on the environment in provision of terrestrial goods and service (Millennium Ecosystem Assessment, 2005; Sieber et al., 2013). The causes of land use/cover change can range from the global forces by economic opportunities through national market and policies to local land management by landholders at farm level (Lambin et al., 2001). The occurring land use change at local scale can be of crucial importance in studying the causes and consequences of global climate change (Manfredo et al., 2014). Farm household has been deemed the key decision-maker on managing land use practices and subsequently modifying land cover at local scale. Evidence has been accumulated that the land use decisions of small agricultural parcels made by the landholders are determined by various factors, such as changing ownership with division of household (Walsh and Welsh, 2003), renting-in/-out due to the distance to the household (Rindfuss et al., 2004), abandoning due to poor labor availability (Sikor et al., 2008), planting trees in response to forest policy (Song et al., 2014). Exploring the underlying causes of land use decisions by local land managers from case studies will facilitate a better understanding of principal pathways of land cover change worldwide.

Many recent research projects are endeavoring to derive the environmental and socioeconomic impacts from the simulated land use pattern based on driving factors (Reidsma et al., 2006). However, the assumption of one-directional process from the human causes to environmental consequences cannot be held in reality because such consequences have feedbacks on the driving forces which may further modify the land use patterns (Verburg, 2006). As Bossel (1999) pointed out that to distinguish the driving factors and impacts on the processes of land use is one of the major challenges in the study of human-environmental interactions. The feedbacks can be divided into two types: positive and negative. The positive feedbacks amplify the changes through time. For example, off-farm work opportunities attract out-migration causing cropland abandonment and the surplus of labor may further turn to migrants (Massey, 1990). The negative feedbacks act as attenuating effects, such as land degradation due to deforestation may lead to logging ban through policy intervention (Zhang et al., 2000). To uncover the myths of feedback mechanisms through human decision making on land use over space and time, more comprehensive approaches that incorporate interdisciplinary knowledge for social-ecological analysis is needed (Ostrom and Cox, 2010).

Tianma Natural Reserve in China is a living area for the study of human-environment interactions. This region has experienced major shift of forest policy triggered by the back-to-back historical droughts and floods in 1997 and 1998. Following natural forest protection program, the Chinese government adopted Sloping Land Conversion Program (SLCP) which encourages farmers to voluntarily convert their cropland at steep slopes to forests or grasslands (Song et al., 2014). The CLSP, also known as the “Grain-For-Green” (GFG) program, is regarded as one of the biggest policies offering payment for ecosystem services (Liu et al., 2008). Since the initiation of the program, substantial changes of land use have taken place resulting from the diverse behaviors by the local households. For some participating households, the household members may seek off-farm employment or start local business stimulated by the financial support from the central government, leaving agricultural land to fallow (Dong et al., 2011). Such fallow behavior can cause the abandonment of farmland and this land may subsequently experience successional change to grassland or shrub land. For other participating households, the compensation received by household may be far lower than the opportunity cost of logging and cultivating cropland, triggering land use change elsewhere, such as land reclamation for commercial crops rather than subsistence (Zhang et al., 2008). How the farmers make use of their pieces of land attracted great interests as the underlying determinants to be examined.

Leaving cropland to fallow by local famers has been observed as one of the major land-use changes in Tianma Natural Reserve since the initiation of new forest policies. High rates of cropland abandonment have taken place particularly in area characterized by rugged terrain in Tiantangzhai Township as part of the protected region. Historically, China is short of farmland to produce enough food due to its large population. A national wide movement was fostered by the central government in the 1950s (Ye et al., 2009) to reclaim waste land to become cropland. Cropland abandonment in the rural area is a new phenomenon which is not well understood. Cropland abandonment in China has profound implication to both the natural (e.g. wildlife habitat range changes) and human (e.g. food security) systems.

One behavior in relation to land use decision by household is out-migration from rural to urban area. Intuitively, rural-urban out-migration is directly associated with the change of household size and composition, which affects the land use decision-making via household labor allocation on farm (Carr et al., 2006b). To explain how the migration decisions are made has attracted great interest to scholars from various disciplines for many decades (Bilsborrow et al., 1984). However, the behavior of migrants in China should be treated uniquely due to the Chinese household registration institution: *hukou* system, which specify an individual with both type (agricultural or non-agricultural resident) and location (permanent residence place) of residence (Fan, 2008). This central-planed regulation was posed in late 1950s as a constraint for changing social and economic status (e.g. employment) of migrants in urban place where is different from the origin. Despite of the tendency of rural peasant who confront an uncertain future in agricultural activities seeking off-farm employment opportunities (Fan and Wang, 2008), a large number of migrants with less skill and lower education have joined temporary migration streams or become return migrants under the policy of hukou system (Sun and Fan, 2011). The operation in coordination with hukou system may have relevance to such areal or structural influences on migration at macro-level as size of local labor market in urban which is also an important factor (Bilsborrow et al., 1987). Given the complexity of population distribution process over the nation, it is not surprising that there is scarcity of empirical studies with adequate data collection on individual migration decision making influenced by multiple factors within a nested scale (Zhu, 1998). To carry out a research in China on exploring driving factors at multiple level that influence out-migration is desired to better understand the distribution and pattern of people moving.

# **Scientific Questions and Hypotheses**

The objective of the study is to explore the underlying determinants of land use/cover changes associated with individual migration under forest protection and restoration programs. A further goal is to better understanding the feedback mechanisms between human causes and land use dynamics through household decision making under forest policy intervention. In this research, the scientific questions and the corresponding hypotheses are:

1. What are the determinants of household decision making on the cropland abandonment under the forest protection and restoration programs?

* A farmer’s decision on whether to abandon a parcel of land for farming is a complex process driven by both biophysical and socioeconomic factors. Biophysical factors may include topographic characteristics (e.g. elevation, slope position where parcel located, and its accessibility). Socioeconomic factors may include household labor availability and migration.
* The abandonment rates by households for paddy-land and dryland is different over the recent decade. The abandoning rates by households participated GFG program differs from those did not during the implementation of forest policy

1. What are the driving factors that influence the out-migration decision by household members during the implementation of forest policies?

* Migration decision making is affected by factors at multiple levels with the ultimate goal of better net economic gain for the household.

1. What are the emergent phenomena on land-cover/land-use from the individual household land use decision making in the study area?

* Land-cover/land-use in the study area is the complex result from the decision making primarily by household on cropland abandonment and by individual on out-migration. It may follow nonlinear trend through time as a result of feedbacks from the changes in the natural system in response to land use decisions.

# **Theoretical Framework**

## Human Causes of Land Use Changes

Five high-level drivers were summarized by Lambin et al. (2003) in terms of human activities on land use changes: 1) increasing pressure of production due to resource scarcity, 2) globally market-oriented opportunities, 3) policy and project intervention, 4) lacking adaptive capacity while increasing vulnerability, and 5) social organization in resource access and attributes. The land use change as a dependent variable can be regarded as a function these five fundamental but strongly interacting factors, which contains various sub-level elements within each category. Each of these fundamental drivers include numerous variables which are, in most cases, interwoven in operating human-natural systems where land managers can learn and adapt to the changing environment. The functional equation and the table of sub-level elements (Table 1) are illustrated as follow:

**Table 1** fundamental causes and Sub-level variables of land use changes (Lambin et al., 2003)

|  |  |
| --- | --- |
| High level factors | Sub-level elements |
| Pressures | Population of resource users, labor availability, quantity of resources, and sensitivity of resources… |
| Opportunities | Market prices, production costs, transportation costs, and technology… |
| Policies | Subsidies, taxes, property rights, infrastructure, and governance… |
| Vulnerability | Exposure to external perturbations, sensitivity, and coping capacity… |
| Social organization | Resource access, income distribution, household features, and urban-rural interactions… |

By applying the theorized causes of land use changes to the cropland abandonment at local scale, many empirical studies have been conducted on exploring the multiple determinants of decision-making on turning land to fallow by households. Various results showed that cropland abandonment not only have strong correlation with environmental conditions such as topographic properties, but also be driven by socioeconomic activities as well as demographic development. Kuemmerle et al. (2008) found that the abandonment rates are higher in area with steeper slopes and higher elevations and widely spread due to declining returns from farming and demographic change in Southern Romania. By using logistic regression, Lake et al. (2009) also detected the increase of abandonment risk as the altitude and slope degree increase, but more neighboring cultivated cropland and livestock units decreased the likelihood of abandonment. Muller et al. (2009) attribute the phenomenon of abandonment to both unfavorable topography and adverse market access. Contradictory results in terms of topographic factors were found in Southeastern Albania by Sikor et al. (2009) that the cropland abandonment are more likely to appear in villages located at lower elevation but with smaller number of parcels for each household. The outcomes indicated that occurrence of abandoning cropland was driven by non-farm opportunities especially from migration. Studies in different region revealed that geographic variables at landscape scale such as patch fragmentation and physical accessibility are critical to cropland abandonment, particularly for those isolated patches (Muller and Munroe, 2008; Muller et al., 2013). Dong et al. (2011) examined the pattern and rationality of both land reclamation and abandonment with regard to land suitability under the “Grain for Green” project in mid-eastern Inner Mongolia of China. Despite the fact that the influential factors vary across regions, few research experiments designed to incorporate variables from both environmental conditions of land patch and socioeconomic factors of household in examination land use process, particularly cropland abandonment by local farmers.

## Theories on Population and Migration

The social theories on population and demographics are believed to have great contribution to study human decision-making on land use. One of the most influential theories was put forward by Malthus’s population theory in 1798, which concerned that geometrically growing population would be constrained by the arithmetical growth of agricultural productivity. However, Boserup (1965, 1981, 1983 and 1990) challenged the Malthusian assumption of constant technology by regarding inversely the growth rates of land subsistence as dependent variable stimulated by growing population pressure through technology innovation and agricultural intensification. Furthermore, the combined theory of life cycle household (Goody, 1958) and demographic characteristics (Chayanov, 1966) provided an idea of modeling land use as a function of stage in household life cycle limited by consumers and labors. A framework of four major theories for population change and environment was discussed by Jolly (1994) who highlighted the effects of demography on land use in developing countries. The key point to distinguish these notions is how to regard the role population growth plays in exploring the influences of land degradation. To reveal the agricultural response to the population pressure, Bilsborrow (1987) developed a conceptual approach to explore the consequences of rural population increase in developing countries. Out-migration is one of the demographic-economic response resulting from population pressure.

Numerous approaches had been developed since early 1980s aiming at explanations of out-migration from rural area to urban in developing countries. Lee (1966) divided the factors influencing migrant perception into “push” and “pull” forces. The “push” factors are associated with negative conditions in origin areas of migrants while the “pull” factors are attractions from destination areas. Though ideal analysis concerns about information from both origin and destination (Bilsborrow et al., 1984; Skeldon, 1990), the former of more importance is sufficient to this study based on the research question on finding determinants of migration. Recent theory in an economic view (the New Economic of Labor Migration) attributed the migration strategies to the household decision making by minimizing the risk in living conditions such as crop failure (Stark and Bloom, 1985; Stark and Taylor, 1989, 1991). Not only can a household with migrants expect additional source of income with remittance by migrants (i.e. income diversification), allocating one or more members to migration also alleviate the pressure of consuming resources by changing household age structure (Barbieri et al., 2009).

## Complexity Theory on Social-Ecological Systems

Land-cover and land-use changes is the manifestation of the dynamics of the coupled human-natural systems (Turner II et al., 2004) characterized by multiple interactions between human and the environment across scales. The complexity theory has been advocated by a growing number of researchers as a means of solving the problems in systems where components and the environment are interacting (Manson, 2001; Crawford et al., 2005). From ecological perspective, Levin (1998) proposed a definition of the complex adaptive system which is considered as a system created not only based on the environmental conditions but also influenced by self-organization due to closely interplaying components. By involving the human systems, a framework of coupled human and natural systems (CHANS) was proposed by Liu et al. (2007) with regard to the complex processes between human and environment with organizational and spatiotemporal couplings. One of the key terms in the complexity theory is emergence that system dynamics exhibit several characteristics: reciprocal effects, feedback loops, nonlinearity, thresholds, resilience, time lags, and heterogeneity (Liu et al., 2007).

Untangling the complexity of CHANS become the major task in field of study how people interact with natural components as it offers ideas of deriving variables as indicators of sustainable development both ecologically and socioeconomically. Ostrom (2009) provided a framework of the sustainable Social-Ecological Systems (SESs) by systematically identifying 10 subsystem variables (Table 2) affecting self-organizations (Also see Ostrom, 2007). This construction of variables makes it possible to collect data for quantitative analysis, though remains one of the challenges due to strong interdependence among all the variables. With these conceptualized framework, it is believed that empirical experiment designed at household level, particularly based on rural household demographics, is of critical importance to description and explanation of the complex coupled human-natural systems (Sherbinin et al., 2008).

**Table 2** Core subsystems in a framework for analyzing social-ecological systems (Ostrom, 2009)

|  |  |
| --- | --- |
| First-level systems | Illustration of second-level variables |
| Social, economic, political settings (S) | Economic development, market incentives, political stability… |
| Resource systems (RS) | Size of resource system, location, sector… |
| Resource units (RU) | Number of units, spatial and temporal distribution… |
| Governance system (GS) | Network structure, monitoring process… |
| Users (U) | Number of users, location, history of use… |
| Interactions (I) | Harvesting levels, conflicts among users… |
| Outcomes (O) | Social performance, ecological performance… |
| Related ecosystems (ECO) | Climate patterns, pollution patterns… |

# **Study Area**

## Study Site

The Tiantangzhai Township in Jinzhai County of Anhui Province locates in the eastern Dabieshan mountainous region of China, with elevation ranging from 300 to 1700 meters above sea level. This mean annual precipitation of this region is 1350 mm with mean air temperature 16.4℃ (Song et al., 2014). The mild weather condition make it an optimal environment for vegetation growth and thus natural forests is the dominant land cover in this region. It was also designated as part region of Tianma Nature Reserve, protecting forests from wood harvest by local residents.

The Township, isolated from metropolitan area, covers an area of 206.6 km2 with population of 17,000. There are more than 4300 households with ~700 participated in the Grain-For-Green program which was initiated in 2002. The participated household may pant tress in cropland by selecting between two types: ecological trees (e.g. fir, maple) and economic trees (e.g. walnut, pecan). Because of the requirement by the central government that 80% of the land was assigned to plant ecological trees while 20% economic trees (Uchiba et al., 2005), the economic forests are quite limited and the main tree species by the program is Maple.

## Data Acquisition

### *Remotely sensed imagery and digital elevation model*

A time series of Landsat images with 30 m resolution were acquired from USGS Global Visualization Viewer (<http://glovis.usgs.gov/>). One scene of WorldView-2 image on July 13 of 2013 with high spatial resolution (2m) was also obtained. Topographic indices (e.g. elevation, slope, aspect, moisture index) were derived from digital elevation model (DEM) in 30 meter resolution. The WorldView-2 image with high spatial resolution was georeferenced using 33 ground control points. The most recent Landsat image was classified using a machine learning algorithm called random forest (RF) classifier. Adaptive automatic signature generalization (AASG) was then applied to parse out the training sites to create land cover maps of previous Landsat images.

### *Ancillary data*

Topographic map with identification of GFG parcels with their geographic location and area was obtained from the local forestry station. The parcels were manually delineated and imported in ArcGIS as a vector layer based on the WorldView-2 image. There are 226 GFG parcels in total. Ground control points (GCPs) and points of training sites were collected by Global Positioning System (GPS) in the field work during the summer in 2013 for georeference and classification of the remotely sensed images.

### *Survey for data collection*

The major source of demographic and socioeconomic data comes from two survey conducted in 2013 and 2014, with 250 and 482 households respectively sampled in the township. Households with GFG participation and those not participated were included in both surveys. Apart from the social data, the geographic coordinates of central point for each cropland parcel were also measured during the field work. The parcel points were stored in ArcGIS associated with attributes such as parcel. The categories of overall information gathered include:

* Household demographics
* Agricultural products and farming cost
* Land parcel and crop raiding
* NFCP and GFG
* Socio-economic activities (business, off-farm work)
* Income and expenditure

For the 2013 survey, 125 households were randomly sample both from who participated GFG program and 125 did not. If a household selected was unable to be interviewed due to various reason (e.g. no household member was at home), its nearest neighbor was selected as a substitute to stave off small sample size. Finally, it resulted in 250 valid interviews with 139 (55.6%) for GFG households and 111 (44.4) for households who did not participate. The geographic locations for both cropland parcels and GFG forest parcels in sampled households were also measured using Global Positioning System (GPS) tools during the field work.

For the 2014 survey, two-phase stratified sampling methods with disproportionate allocation (Groenewold and Bilsborrow, 2008; Bilsborrow and Lomaia, 2011) was used for sampling considering the low proportion of GFG households (~16%) in the study area. At resident group level, all the groups were firstly categorized into 5 strata based on the proportion of GFG households. The groups in strata with high proportion of GFG households were oversampled due to its small number of groups. Then at household level, households were sampled separately from GFG households and those without participation of GFG. This methods was designed to oversample the GFG household category which is the minority of the total population. The variables derived from the sample data should be assigned weights based on sample size in order to represent the population. 482 households were interviewed including 263 (54.6%) GFG households.

### *A second survey for data collection*

Another survey will be conducted in one of the 7 villages (Huanghe Village) in the Township. By interviewing the village leader and resident group leader, the information of each household to be obtained include: household demographic data, overall income, agricultural product, migration information, fuel wood collection and consumption, geo-locations of household and land parcels associated with their properties. This data to be collected provides the major information for designing an agent-based model.

# **Research Methods**

## Determinants of Cropland Abandonment

Kaplan-Meier survival analysis and log-rank test statistic were employed to measure the survival rates of each patch of cropland (i.e. cropland being not abandoned) to understand whether household participation in the “Grain-For-Green” (GFG) program played a role. The Kaplan-Meier estimator is widely used in measuring the proportion of subjects living for a period after intervention of treatment (Goel et al., 2010). In the case, as the abandoning year were recorded for each piece of fallow land, the parcel under cultivation were marked as survived land. The log-rank method tests the significance of different survival rates change through time between two groups. In this study, the “treatment” dividing the two groups was participation of GFG program by a household that parcel belongs to or whether a parcel was used as paddy land or dryland.

Logistic regression model (Hosmer and Lemeshow, 1989) was applied to identify the determinants of cropland abandonment. The data were organized into two levels: households based table and land parcels based table. Within household level, the demographic and socio-economic data were included as covariates that influence the probability of abandoning a certain amount of cropland by a household. Within the parcel level, the dependent variable is whether the cropland patch be abandoned in binary choice while the independent variable include topographic and geographic properties of that parcel. The outcome shows relative odds of abandonment to the non-abandonment which will be used to model the decision making by farmer to abandon their pieces of land.

## Migration Behavior Modeling with Multilevel Approach

Substantial work has been done on out-migration from rural to urban area, putting much effort on examining impacts of various factors at individual, household and community levels (Bilsborrow, 1987; Guo and Yang, 1999; Ezra et al., 2001; Kulu and Billari, 2006; Barbieri et al., 2009). The variables at individual level may include each person’s properties, such as age, gender, education, marital status, and occupation. The household variables may include the information about household size, member structure, and land ownership. The community (village) level variables may include geographic distance measured from the household to center of capital city, nearest main road, middle school. In the Township, there is one more level between household and village called resident group. Each resident group consists of ~20 households, which have strong connection to each other and share information and knowledge. As a result, the household decision can be particularly influenced by the characteristics of resident groups. In this study, multilevel mixed-effects logistic regression (Hedeker, 2003) was proposed to explore the fixed and random effects of driving factors at above-mentioned level that impact the individual out-migration decisions as represented by equation (1). The i, j, k, l indicate variables at particular individual, household, resident group and village level, respectively.

Under the Chinese household registration institution, the behavior of out-migrants from rural are to urban is complicated. The majority of migrants may not become permanent residents in cities either due to the hukou system or concerns with their land security in origins. Therefore, clear definitions in terms of migration should be articulated before analysis. Since the time period of the study is during the forest policy, migrants who left after 2000 are of the greatest interest. An individual defined as an *out-migrant* should satisfied the conditions that 1) at least 16 years old; 2) who lives and eats most of the time away from the house for at least 6 continuous months; 3) who lives outside of the country; and 4) who left since 2000 at age 16+ and are still living away, whether to work, study, accompany another family member, etc. A *local migrant* is an individual who left his/her previous household but is still living within the county. A *return migrant* is someone who became an out-migrant, then return and live again in his/her previous household before the interview. A *non-migrant* is someone who never left household as a migrant.

If there is one or more household member who was identified as out-migrant(s), the household is recognized as *migrant household*, otherwise as *non-migrant household*. Individual information both out-migrant and non-migrant was also collected for comparison analysis. For migrant household, a non-migrant was randomly selected if his/her age is 16+ at the time the individual out-migrant left. For non-migrant household, a non-migrant whose age is 16+ five years ago (i.e. 2009) was randomly selected.

## Agent-Based Model of Land Use/Cover Changes

An increasing number of studies endeavored to understand the land use/cover changes using agent-based model (ABM), which is operated to simulate the process-pattern interactions in high-level system by designing a set of rules to control the component behavior at micro-level (Crawford, 2005; Entwisle et al., 2008; Heppenstall et al., 2012; Walsh et al., 2013). Such agent-based model of land use/cover change (ABM/LUCC) was characterized by integrating two parts: a model representing the landscape where components interact and an agent-based model composed of autonomous decision-making entities as well as rules defining relationship between agents and environment (d’Aquino et al., 2002; Parker et al., 2003; Manferdo et al., 2014). This study proposed to use agent-based approach to simulate the emergent phenomenon of land-cover/land-use changes by incorporating land use decisions by households and individual migration behavior. The model will be described under the ODD protocol: overview, design concept, and details (Grim et al., 2006, 2010; Chen et al., 2012).

### *Purpose*

The model will be developed to simulate the effects of land use decision by households and individual migration behavior on the dynamics of land-cover and land-use over time.

### *Agents, state variables, and scales*

The entities in the model include active agents and passive agents (Walsh et al., 2013). The active agents include individual, household, resident group and village, while the passive agents include pixels representing continuous landscape with grids and parcels for pieces of land patches. The variables describing the properties of agents are summarized in Table 3. The pixel scale is based on the Landsat images with 30 meter resolution and the parcel can be overlaid with grids for extraction of the pixel information. The socioeconomic variables derived from interview at household level were linked to the land parcels through household ID.

**Table 3** State variables for agents in the model

|  |  |
| --- | --- |
| Agent | State variables |
| Individual | Person ID, household ID, RG\_ID, village ID, age, gender, education, marital status |
| Household | Household ID, RG\_ID, village ID, XY coordinates, knowledge from other households in the same RG, roster, assets, land area |
| Resident group (RG) | RG\_ID, village ID, whether has GFG households, minute distance to village center |
| Village | Village ID, minute distance to township center, whether has primary/middle school, whether has health facility |
| Pixel | Pixel ID, parcel ID, land cover type, elevation, slope, aspect |
| Parcel | Parcel ID, household ID, RG\_ID, village ID, XY coordinates, area, land use type (crop, GFG forest, or fallow), distance to household, parcel yield if growing crop |

### *Design concepts*

Emergence: The land-use/land-cover changes is a result of nonlinear effects of land use decision by households and individual out-migration.

Adaptation: active agents adapt to the land cover changes by changing their land use decisions as well as migration decisions.

Interaction: household agents change their knowledge by interacting with other households in the same resident group.

### *Initialization*

The properties of the active agents were initialized with the data collected from the second survey. The pixel and parcel agents were initialized from classification of satellite images and GPS measurements during field work.

### *Submodels*

The details of rural design for agent interactions should be based on both literatures and regression outcome from the previous work.

# **Expected Results**

## Cropland Abandonment

1. During the implementation of forest policy, the survival rates of parcels from being abandoned by households are decreasing over the township as household were leaving cropland into fallow. The temporal trajectories of abandonment rates for paddy land and dryland are different. The abandonment rates by GFG households also differs from those by not-participated households.
2. At land parcel level, such unfavorable topographic characteristics as high elevation and steep slope are major stimuli to abandonment certain pieces of land. At household level, the economic and social status (e.g. income from non-agricultural off-farm work) influence whether abandonment occurred within a household.

## Migration

1. The decision making of individual migration within a household is influenced by factors at individual, resident group and village level.

## ABM

1. The agent-based model of land use/cover change captures the nonlinearities and feedbacks of the interactions between human and environment through the process of land use/cover changes.

# **Some Preliminary Results**

## Cropland Abandonment

### *Description of cropland abandonment*

The description is based on the data collected in 2013. Over all the 1206 cropland parcels, 233 parcels were abandoned by households. In 2013, the abandonment rates of paddy land and dryland are 0.239 and 0.138 respectively. The rates of abandoned parcels belonging to GFG households and not-GFG households are 0.194 and 0.238 respectively (Table 4).

**Table 4 a) Description of cropland abandonment rates for paddy land and dryland**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Paddy land (rates) | Dryland (rates) | Total (rates) |
| Abandoned | 158 (0.239) | 75 (0.138) | 233 (0.193) |
| Cultivated | 503 | 470 | 973 |
| Total | 661 | 545 | 1206 |

**Table 4 b) Description of cropland abandonment rates for GFG and not-GFG households**

|  |  |  |  |
| --- | --- | --- | --- |
|  | GFG (rates) | Not-GFG (rates) | Total (rates) |
| Abandoned | 126 (0.194) | 107 (0.238) | 233 (0.193) |
| Cultivated | 523 | 450 | 973 |
| Total | 649 | 557 | 1206 |

### *Survival Analysis*

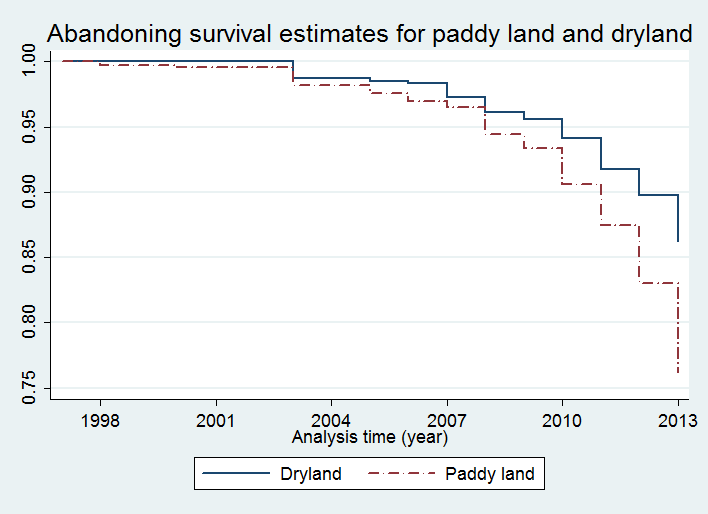
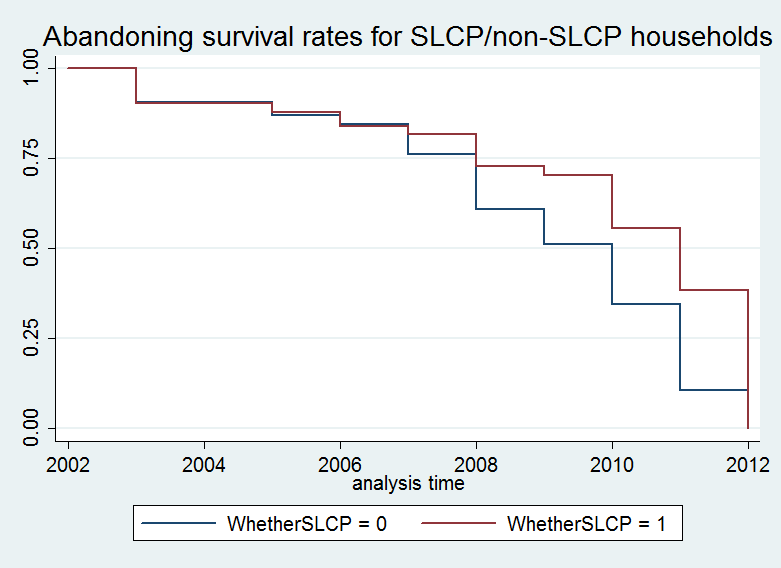
 

Fig 1. The figure on the left shows the abandonment rates of parcels for paddy land and dryland from 1998 to 2013. The overall survival (under cultivation) rates for paddy land is significantly lower with log-rank test chi2=18.67 (p-value: 0.0000). The figure on the right shows the abandonment rates of parcels for GFG households and not-GFG households since 2002 when the GFG program was initiated. The parcels belonging to GFG households have higher survival rates with chi2=13.82 (p-value: 0.0002).

### *Comparison of variables between parcels abandoned and those under cultivation (t-test)*

**Table 5 Comparison of variables between abandoned parcels (1) and cultivated parcels (0)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Mean difference** | **p-value for all parcels** | | **p-value for paddy land** | | **p-value for dryland** | |
| *Variables* | *Diff<0* | *Diff>0* | *Diff<0* | *Diff>0* | *Diff<0* | *Diff>0* |
| Elevation | 0.0188\* | - | 0.1152 | - | 0.0037\*\* | - |
| Parcel area | 0.0285\* | - | 0.7243 | - | 0.1701 | - |
| Minute distance | 0.0000\*\*\* | - | 0.0000\*\*\* | - | 0.2825 | - |
| Geographic distance | 0.0018\*\* | - | 0.0024\*\* | - | 0.3939 | - |
| Slope | 0.0077\*\* | - | 0.0071\*\* | - | 0.0355\* | - |
| TWI | - | 0.0000\*\*\* | - | 0.0000\*\*\* | - | 0.0011\*\* |

\* p<0.05

\*\* p<0.01

\*\*\* P<0.001

1. The abandoned cropland has higher elevation, steeper slope, larger area, longer distance/minute distance; lower topographic wetness index (TMI).
2. The abandoned paddy land has longer minute distance, and longer geographic distance, steeper slope; and lower TWI.
3. The abandoned dryland has higher elevation, steeper slope; and lower TWI.

### *Exploring determinants of cropland abandonment (logistic regression)*

**Table 6 Coefficients for logistic regression with dependent variable “whether a parcel abandoned or not (1/0)”**

|  |  |  |  |
| --- | --- | --- | --- |
| *Variables* | *All parcels* | *Paddy land* | *Dryland* |
| Elevation (100m) | 0.11388 | 0.06393 | 0.27231\* |
| Parcel area | 0.16881\*\* | -0.02024 | 0.16364 |
| Minute distance | 0.03054\*\*\* | 0.04568\*\*\* | -0.0002 |
| TWI | -0.188302\*\*\* | -0.27447\*\*\* | -0.20490\* |
| *\_Constant* | -0.761895 | 0.91491 | -1.72157 |

\* p<0.05

\*\* p<0.01

\*\*\* P<0.001

1. The. The log odds of abandonment increase by 0.169 with 1-mu increase of patch area; increase by 0.0305 with 1-minute increase of walking distance; and decrease by 0.188 with one-unit increase of moisture index.
2. The log odds of paddy abandonment increase by 0.0457 with 1-minute increase of walking distance; and decrease by 0.274 with one-unit increase of moisture index.
3. The log odds of dryland abandonment increase by 0.272 with 100-meter increase of walking distance; and decrease by 0.205 with one-unit increase of moisture index.

### *Statistics and logistic regression results at household level*

**Table 7 Comparison of variables between households who abandoned land parcels (1) and households who never abandoned land parcels (0)**

|  |  |  |
| --- | --- | --- |
| *Variables* | *p-value for diff < 0* | *p-value for diff < 0* |
| Household elevation (m) | 0.0344\* | - |
| Male percentage (%) | - | 0.0215 |
| Male age 15-60 percentage (%) |  | 0.0126\* |
| Whether sold GE+ | 0.0401\* | - |

+ GE means Gastrodia Elata, a fungus can be sold as an alternative income source.

**Table 7 Coefficients for logistic regression with dependent variable “whether abandonment occurred in a household (1-occurred, 0-never occurred)”**

|  |  |  |  |
| --- | --- | --- | --- |
| *Variables* | *All parcels* | *Paddy land* | *Dryland* |
| Male percentage (100%) | - | -0.021477\* | - |
| Minute distance on average | - | 0.041532\*\* | - |
| Fuel wood consumption (1000 jin) | - | 0.25614\* | - |
| Whether has pig | - | - | -0.75650\* |
| NFPP area (100 mu)+ | - | - | 0.71539\* |

+ NFPP denotes natural forest protection program, which is a logging ban for forest conservation. Almost every household participated in this program.

1. The households who has cropland abandonment have: a) higher elevation; b) less percentage of male / male age 15-60; c) more likely to plant / sell GE.
2. The log odds of abandoning paddy land by households a) decrease by 0.0215 with 1% increase of male member over household size; b) increase by 0.0415 with 1-minute increase of average walking distance of paddy parcels; c) increase by 0.256 with 10000-jin increase of fuel wood consumption.
3. The log odds of abandoning dryland by households a) decrease by 0.756 if the household raises pig; b) increase by 0.715 with 100-mu increase of natural forest area owned.

# **References**

Bilsborrow, R.E. 1987. Population pressures and agricultural development in developing countries: a conceptual framework and recent evidence. *World Development*, 15(2):183-203.

Bilsborrow, R.E. 1987. The impact of origin community characteristics on rural-urban out-migration in a developing country. *Demography*, 24: 191-210.

Bilsborrow, R.E. and Lomaia, M. 2011. International migration and remittances in developing countries: Using household surveys to improve data collection in Eastern Europe and Central Asia. Working Paper, Poverty Department, World Bank, Washington DC, pp. 73 (on website).

Bilsborrow, R.E., Oberai, A.S., and Standing, G. 1984. Migration surveys in low income countries: Guidelines for survey and questionnaire design. London: Croom Helm.

Boserup, E. 1965. The condition of agricultural growth. Chicago, Aldine.

Boserup, E. 1981. Population and technological change: a study of long-term trends. Chicago, *University of Chicago Press*.

Boserup, E. 1983. The impact of scarcity and plenty on development. *Journal of Interdisciplinary History* 14: 383-407.

Boserup, E. 1990. Economic and demographic relationships in development. *Baltimore: John Hopkins University Press*.

Bossel, H., 1999. Indicators for sustainable development: theory, method, applications. *International Institute for Sustainable Development*, Winnipeg, Manitoba

Chayanov, A.V., 1966. The theory of peasant economy. Homewood, III: Richard D. Irwin.

Chen, X. et al., 2012. Agent-based modeling of the effects of social norms on enrollment in payments for ecosystem services. *Ecological Modelling*, 229(24): 16-24.

d’ Aquini, P. et al., 2001. Agent-based models of land-use and land-cover change. Paper presented at the International Workshop in Irvine, California, USA.

Dong et al., 2011. Spatio-temporal pattern and rationality of land reclamation and cropland abandonment in mid-eastern Inner Mongolia of China in 1900-2005. *Environmental Monitoring and Assessment*, 179: 137-153.

Carr, D. L., Pan, W. K., and Bilsborrow, R. E. 2006b. Declining fertility on the frontier: The Ecuadorian Amazon. *Population and Environment*, 28(1): 17-39.

Grimm, V. et al. 2006. A standard protocol for describing individual-based and agent-based models. *Ecological Modelling*, 198: 115-126.

Grimm, V. et al. 2010. The ODD protocol: a review and first update. *Ecological Modelling*, 221: 2760-2768.

Groenewold, G. and Bilsborrow, R.E. (2008). Design of samples for international migration surveys: Methodological considerations and lessons learned from a multi-country study in Africa and Europe. In: Bonifazi, C., Okólski, M., Schoorl, J., and Simon, P. (eds.). International migration in Europe; new trends and new methods of analysis. Amsterdam: Amsterdam University Press: 293-312.

Geoghegan J et al., 1998. Socializing the pixel and pixelizing the social in land-use and land-cover change. In: Liverman D, Moran EF, Rindfuss RR, Stern PC (eds) People and pixels: linking remote sensing and social science. National Academy Press, Washington DC, pp 51-69.

Goel, M.K. et al., 2010. Understanding survival analysis: Kaplan-Meier estimator. *International Journal of Ayurveda Research*, 1: 274-278.

Goody, J., 1958. The development cycle in domestic groups. *Cambridge Papers in Social Anthropology, NO. 1.* Cambridge, UK: Cambridge University Press for the Department of Archaeology and Anthropology.

Hedeker, D. 2003. A mixed-effects multinomial logistic regression model. *Statistics in Medicine*, 22: 1433-1446.

Heppenstall, A. J. et al., 2012. Agent based models of geographical systems. Berlin and New York: Springer.

Hoshino, S., 2001. Multilevel modeling on farmland distribution in Japan. *Land Use Policy*, 18: 75-90.

Hosmer D.W. and Lemeshow S. Applied Logistic Regression. New York: John Wiley & Sons, 1989.

Lambin et al. 2005. Dynamics of land use and land cover change in tropical regions. *Annual Review of Environment and Resources* 28: 205-241.

Lee, E.S. 1966. A theory of migration. *Demography*, 3(1): 47-57.

Liu et al. 2008. Ecological and socioeconomic effects of China's policies for ecosystem services. *Proceedings of the National Academy of Sciences*, 105(28): 9477-9482.

Liu et al. 2007. Coupled human and natural systems. *Ambio*, 36: 639-649.

Liu, J. et al. 2007. Complexity of coupled human and natural systems. *Science*, 317: 1513-1516.

Massey, D.S. 1990. Social Structure, Household Strategies, and the Cumulative Causation of Migration. *Population Index*, 56(1): 3-26.

Malthus, T. R. 1798. An Essay on the Principle of Population.

Manfredo, M.J., et al., 2014. Understanding Society and Natural Resources. International Association for Society and Natural Resources.

Ostrom, E. 2007. A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Science*, 104(39): 1 5181-15187

Ostrom, E. and Cox, M. 2010. Moving beyond panaceas: a multi-tiered diagnostic approach for social-ecological analysis. *Environmental Conservation*, 37: 1-13.

Overmars, K.P. and Verburg P.H., 2006. Multilevel modeling of land use from field to village level in the Philippines. *Agricultural Systems*, 89: 435-456.

Pan, W.K.Y. and Bilsborrow, R.E., 2005. The use of a multilevel statistical model to analyze factors influencing land use: a study of the Ecuadorian Amazon. *Global Planet Change*, 47: 232-252.

Parker, D.C., et al., 2003. Multi-agent systems for the simulation of land-use and land-cover change: a review. *Annuals of Association of American geographers*, 93: 314-337.

Reidsma, P., 2006. Impacts of land use change on biodiversity: an assessment of agricultural biodiversity in the European Union. *Agricultural Ecosystem Environment* 114(1): 86–102

Rindfuss, R.R. et al., 2004. Developing a Science of Land Change: Challenges and Methodological Issues. *Proceedings of the National Academy of Science* 101: 13976-13981.

Sherbinin et al., 2008. Rural household demographics, livelihoods and the Environment. Global Environmental Change, 18: 38-53.

Skeldon, R. 1990. Population mobility in developing countries: A reinterpretation. London and New York: Belhaven Press.

Stark, O., & Bloom, D. E. (1985). The new economics of labor migration. *The American Economic Review*, 75(2), 173–178.

Stark, O., and Taylor, J. E. 1989. Relative deprivation and international migration. *Demography*, 26(1), 1–14.

Stark, O., and Taylor, J. E. 1991. Migration incentives, migration types: The role of relative deprivation. *The Economic Journal*, 101(408), 1163–1178.

Song. C., Zhang, Y., Mei, Y., Liu, H., Zhang, Z., Zhang, Q., Zha, T., Zhang, K., Huang, C., Xu, X., Jagger, P., Chen, X. and Bilsborrow, R., 2013. Sustainability of forests created by china's sloping land conversion program: a comparison among three sites in Anhui, Hubei and Shanxi. *Forest Policy and Economics* 38, 161–167.

Sun, M., Fan, C.C., 2011. China's permanent and temporary migrants: differentials and changes, 1990–2000. *The Professional Geographer*, 63: 92-112.

Turner II B.L. et al., 2004. Integrated land-change science and its relevance to the human sciences. In: Gutman G et al (eds) Land change science. Observing, monitoring and understanding trajectories of change on the earth’s surface. Kluwer Academic Publishiers, Dordrecht/Boston/London, pp 431–447

Uchida E, Xu JT, Rozelle S. (2005). Grain for green: cost-effectiveness and sustainability of China’s conservation set-aside program. *Land Economics*, 81: 247-264.

Walsh, S.J. et al. 2013. Design of an Agent-Based Model to Examine Population-Environment Interactions in Nang Rong District, Thailand. *Applied Geography*, 39: 183-198.

Walsh, S.J. and Welsh, W.F., 2003. Approaches for Linking People, Place, and Environment for Human Dimensions Research. *Geocarto International* 18(3): 51-61.

Ye, Y et al., 2009. Cropland cover change in Northeast China during the past 300 years. *Science in China Series D*, 39(3): 340-350.

Zhang, P. et al. 2000. China’s forest policy for the 21st century. *Science*, 288: 2135-2136.

Zhang et al., 2008. Payment for environmental services: the sloping land conversion program in Ningxia autonomous region of China. *China & World Economy*, 16: 66-81.

Zhu, J. 1998. Rural out-migration in China: A multilevel model. In R. E. Bilsborrow (Ed.), Migration, urbanization and development: New directions and issues (pp. 157–186). New York: United Nations Population Fund, and Kluwer Academic Publishers.