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The impact of rural out-migration on land use transition in China: Past, present and trend

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ABSTRACT

Although rural out-migration has significantly transformed land use at the local to regional scale, the links between rural out-migration and land use change are not well understood. This paper connects Zelinsky's mobility transition model to land use transition theory and identifies the impacts of rural out-migration on land use transition. It then explores the significant influences of rural out-migration on land use transition in China. Since the introduction of economic reforms in 1978, China has undergone rapid and significant changes. Extensive rural out-migration has transformed China from a land-attached agricultural society to an urban and industrial society. This has produced several contrasting land use trends: increased land demand in urban areas at the expense of high-quality cultivated land, increased number of total settlement areas and emerging "hollowed villages" in the countryside. China's policies addressing these problems could benefit to other developing countries, such as restricting frontier clearing through land zoning and other ecological protection policies; encouraging nonmigrants to adjust their agricultural land holdings; protecting nonmigrants' interest through subsidizing agricultural land, and improving rural infrastructure and farmers' living conditions. Rural out-migration is thus a critical element in addressing the fundamental question of land use—how to balance the land demand for economic development, food security and conservation. This article explores the impacts of rural out-migration on land use change, analyzes the process of migration and land use transition and then examines how rural out-migration affects land use transition in China. This paper also explores future land use change in China, by considering the trend of rural–urban migration and the dynamics of population transition. In so doing, we try to link current rural out-migration dynamics and land use change to facilitate future research and policy considerations. We propose that in order to facilitate policymaking, further research should take a multiscale perspective: cross-country research should be based on an understanding of the dynamics and issues of rural out-migration and land use change in developing countries with different characteristics; country-level research should focus on land use change and problems caused by rural out-migration and its spatial characteristics; and community and household-level research should examine the effects of out-migration of household or household members on agricultural and other land use change.

Introduction

Rural out-migration is an important driver of local land use and land cover change (Kates and Parris, 2003; GLP, 2005; Lambin and Meyfroidt, 2011; Seto et al., 2012). However, the relationship between them is not yet fully understood. The migration literature has largely overlooked land use and land cover change (LUCC) as an outcome of rural out-migration. Similarly, LUCC research has not yet fully addressed the key links of land use change to migration processes (Carr, 2009). Migration has often been considered the step-child of demography and has been neglected in land use

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and food (in)security research (Teller and Hailemariam, 2011). The impact of migration on LUCC is one of the major research frontiers in the Global Land Project (GLP), especially in relation to globalization and urbanization (GLP, 2005). While considerable progress has been made in LUCC research, few studies have directly examined the links between migration and LUCC. Understanding the dynamics of LUCC still faces a number of significant challenges (GLP, 2005; Rounsevell et al., 2012). Empirical analysis on the relationship between migration and LUCC can provide critical insights into the dynamics of land use transitions.

Since the 16th century, migration in Europe has functioned as a driving force behind land use change (Antrop, 2005). Urban areas in the United States grew quickly due to population movement from the countryside to the cities during the transition from the 19th to the 20th centuries (Brown et al., 2005; Bell et al., 2010). Following the decade of the 1960s, countries in Latin America experienced rapid urbanization, with more than 70% of the population moving into urban areas in 2000s (Aide and Grau, 2004; Grau and Aide, 2008). The population and land use change dynamics in developing countries are similar to what has occurred in Europe and North America: when national or regional economies shift from agriculture to industry, cities grow, consumption increases and meanwhile, rural settlements decline and forests recover (Aide and Grau, 2004; Grau and Aide, 2007, 2008). However, case studies on migration and land use transition in Latin America have been either concerned with rural–urban migration and forest transition (Rudel, 1998; Rudel et al., 2002; Hecht and Saatchi, 2007), or focused on rural–rural migration and deforestation (Carr et al., 2005; Carr, 2009). Those authors analyzed only the relationship at local or regional scales, but a wholistic approach is needed to integrate these different landscape dynamics over time. Bell et al. (2010) reviewed migration and land use change in Europe, but they mostly focused on migration change, and the dynamic relationship between migration and land use transition was not well addressed. Migration will continue to be a major influence on land use change in this century, and studies which consider migration and land use change as discrete subjects of inquiry are likely to miss important connections (Bell et al., 2010).

China is the largest developing country in the world. Since its economic reforms were initiated in 1978, it has changed rapidly and significantly (Fan, 2008). Massive rural out-migration has transformed China from an agricultural society to an urban and industrial society (Long et al., 2012). With rapid urbanization and rural transformation, China faces a number of challenges in urban and rural development, such as expanding urban areas, emerging "hollowed villages," and settlement abandonment. The most highlighted issue of current Chinese land use is how to balance the land demand for economy development, food security and conservation. The so-called food–environment-development trilemma is a great challenge to the rural and urban sustainable development.

This article explores the impacts of rural out-migration on land use change. We analyze the process of migration and land use transition and then examine how rural out-migration affects land use transition in China. We also explore future land use change in China, in consideration of the trends of rural–urban migration and the dynamics of population transition. In so doing, we examine links between current rural out-migration dynamics and land use change, in order to facilitate future research and policy consideration.

Theory on the relationship between rural out-migration and land use transition

There is a general consensus that rural out-migration plays a significant role in many aspects of land use change. But there are questions concerning how they relate to each other and how firm the links are in various circumstances. Land use change is a nonlinear process and is associated with population change through a series of transitions. The concept of land use transition refers to a process of land use change in which the structural character of the system transforms. It is a change in land morphology within a certain region driven by socio-economic change and innovation (Lambin and Meyfroidt, 2010; Long and Li, 2012). The links between out-migration and land use transition are complex and differentiated by a wide variety of social, economic and ecological factors.

In Boserup's "induced intensification theory," population is the prime engine of technology innovation and land use intensification, and out-migration is the final resort to alleviating population pressure (Boserup, 1965; Turner and Fischer-Kowalski, 2010). Zelinsky provided a hypothesis of the mobility transition model focusing on migration, identifying five stages in the transition of a society, from one that depends on subsistence agriculture to one that is super-advanced (post-industrial), in which migration flows are absorbed by modern telecommunication systems (Zelinsky, 1971). In this mobility transition model, the links between migration and land use change were not examined. Foley et al. (2005) pointed out that land use transition co-evolves with demographic transition. But how migration affects land use change has not been clearly interpreted. Bilsborrow and Geores (1992) observe that rural out-migration causes human capital gain in destination areas, while origin areas lose it. In the classical Lewis world, where rural migrant-sending areas are characterized by a surplus of labor force, the loss of labor through migration does not induce a production decline (Lewis, 1954; Ranis and Fei, 1961). However, if migrants take capital with them, it may increase the size of the redundant labor force and cause new rounds of rural out-migration. Even when migrants do not take capital with them, in leaving a rural area, human capital attached to these migrants also leaves the rural sector. This results in lowered productivity (Taylor and Martin, 2001). On the other hand, returned migrant brings new technology which can lead to land use intensification in rural migrant-sending areas. Lambin and Meyfroidt (2011) noted the remittance effect of rural out-migration can accelerate land conversion. Recently, a proposed concept of urban land teleconnections applied a process-based framework to understand how flows of capital, people, materials, energy, and waste connects multiple urban and rural systems (Seto et al., 2012). In this framework, local land use transition is shaped by a network of rural–urban connections. In consideration of the process of rural out-migration in east China, Long et al. (2012) presented a four-stage evolution model to illustrate the development of "hollowed villages"—a phenomenon of de-population leading to abandonment of houses throughout the rural settlements in China. The basic idea of the model is to represent the process of land use change in rural China and its interaction with rural out-migration. The model is consistent with McLeman's settlement abandonment model, which depicts a process of settlement abandonment caused by out-migration (McLeman, 2011). Despite great progress in this field, challenges to understanding the impact of migration on land use transition still exist.

Here we connect Zelinsky's hypothesis of mobility transition with the land use transition model (Fig. 1). The pre-modern traditional society in Zelinsky's model is characterized by "little genuine residential migration and only such limited circulation as is sanctioned by customary practice in land utilization, social visits, commerce, warfare, or religious observances" (Zelinsky, 1971). At this stage, rural population is attached to land with limited mobility, and livelihoods are dominated by small-scale subsistence agriculture. To feed the increasing population, agricultural land extensification takes place at the expense of forest and other natural land clearing (stage 1 in Fig. 1). At the second stage, rural areas become a transitional society, which is characterized by "massive

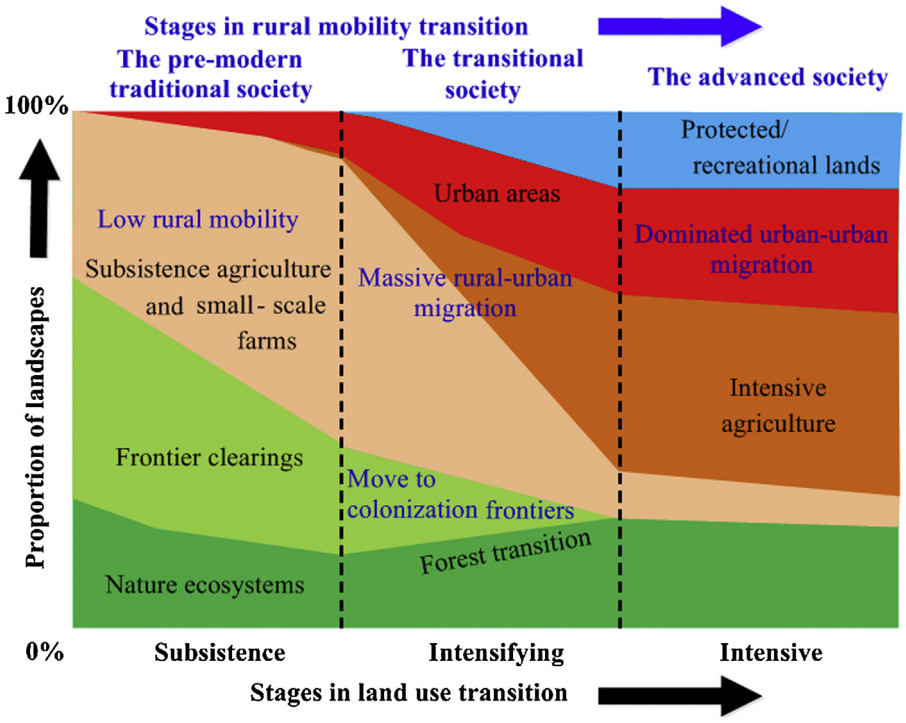

Fig. 1. Stages in land use and mobility transition.

Adapted from Foley et al. (2005).

movement from countryside to cities" (Zelinsky, 1971). This stage includes the second and third stages of Zelinsky's mobility transition model, where the interaction between urban and rural is growing and rural areas are integrated into regional or national networks. Rural livelihoods are diversified and rural peasants' mobility is increasing. The rural–urban migration shifts economies from agricultural to urban and industrial, which gives rise to rapid urban expansion and abandonment of rural areas. This takes place in parallel with land intensification and forest transition. When remittances from migrants are invested in infrastructure and technology, agricultural intensification is widely adopted, including high-yield seed varieties, synthetic fertilizer and other chemical inputs, irrigation, mechanization, multiple cropping, and shorter fallow periods (DeFries and Rosenzweig, 2010). These intensifications can spare land for nature (Rudel et al., 2009). Remittances can also be invested in buying food and fuel, and food imports can reduce pressure on agricultural land. The increasing use of electricity, coal and other fuel and decreasing use of firewood can spare land for forest (Lambin and Meyfroidt, 2011). Meanwhile, as the increasing urban population needs more recreational land, the need for protected and resort areas also increases. These factors contribute to forest transition from net deforestation to net reforestation and the recovery of natural ecosystems (Rudel et al., 2009; Lambin and Meyfroidt, 2010; Ellis, 2011; Lambin and Meyfroidt, 2011). However, as Zelinsky noted, there is still a number of rural–rural migrants who move to colonization frontiers in this period, creating new agricultural land (Carr et al., 2005; Carr, 2009) (stage 2 in Fig. 1).

The third stage of Zelinsky's model is characterized by "reduced movement from countryside to city and vigorous movement of migrants from city to city and within individual urban agglomerations" (Zelinsky, 1971). It is an urban society with a slight change in rural population. At this stage, intensive agriculture dominates agriculture, and other kinds of land use level off (stage 3 in Fig. 1).

Currently most developing countries are in the transitional society and land-intensifying stage. Experiences in Latin America show that rural out-migration not only contributes to land sparing and agricultural intensification, but also to land extensification and deforestation in some frontiers (Aide and Grau, 2004; Carr, 2009; Macedo et al., 2012). Vietnam is one country that experienced a trend similar to Latin America. Beginning in the 1980s, Vietnam has been marked by increased migration from rural to both rural and urban destinations. Its rural–rural migration was characterized by movement from more highly populated areas to "frontier" regions, often in the uplands (Adger et al., 2002).

From 1978, rapid urbanization and rural out-migration have transformed China from a pre-modern traditional society to a transitional society, a transformation some other developing countries are also undergoing. The impact has given rise to a large land use transition.

Understanding the coupled process in China

The process of rural out-migration

Migration has a great impact on national economic development, rural transformation and land use transition (Long et al., 2012). It has transformed China from an agricultural based society to an urban and industrial society (Peng, 2011; Siciliano, 2012). Extensive rural out-migration in China started in 1978. According to official statistics, the number of rural–urban migrants was 2 million in 1983 (Han et al., 2010), and by 2010 had reached 253 million (NPFPC, 2012). The rural population decreased from 841.38 million to 656.56 million between 1990 and 2011, while the urban population increased from 301.95 million to 690.79 million, respectively (Fig. 2). The urbanization rate changed from 17.91% in 1978 to 51.27% in 2011 (NBSC, 2012). Currently, China is still in Zelinsky's second stage of "mobility transition," characterized by massive movement of the rural population from the countryside to cities and to frontiers (Zelinsky, 1971; Grötzbach, 1984; Carr, 2009). For example, China's urban population increased by 21 million in

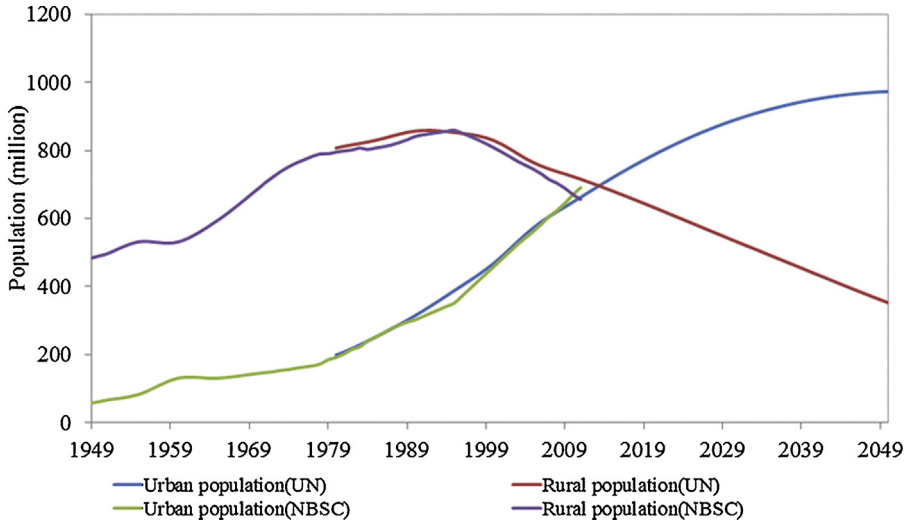

Fig. 2. The change in rural and urban population in China from 1949 to 2050.
Data from NBSC and UN FAO statistics http://faostat.fao.org/.

2011, and the rural population decreased more quickly than the UN projection (Fig. 2).

Rural–urban migrants not only contribute a lot to urban development, but also cause great transformation of rural areas (Murphy, 2002; Fan, 2008; Long et al., 2012). Owing to massive rural out-migration, the number of villages in China decreased from 3.77 million in 1990 to 2.66 million in 2008 (NBSC, 2011). The rural out-migration is usually in a form of chain migration: at first the head of the family or a young, educated family member moves to a city to find an off-farm job, followed by other adults in the family, and finally the entire family moves out. Family migration in China represents nearly 66% of the total migrants in 2010 (Xu, 2011). Because of the dual-track structure of socio-economic development, migrants may still have relationships with their areas of origin after they move to cities, via ownership of the house and farmland or having family members in the origin area, having "left the soil but not separated from their village." Some of them plan to return when economic dispersion occurs or when they become too aged to work in cities, a factor which contributed to the emerging of the so-called hollowed villages (Long et al., 2012). Most rural inhabitants born in the 1970s and 1980s are performing off-farm work now. Of the total number of migrants in 2010, nearly 45% are born after the 1980s (NPFPC, 2012). The young and educated rural residents like to move to cities because of the cultural and economic attraction of urban life; once they move out, they become reluctant to return to the rural area. In 2010, 40% of farmers in China were older than 50; it is estimated that the percentage will increase to 50% by 2016 (Li et al., 2011). As laborers on farmland age over the next twenty years, the Chinese countryside will face the question of who will cultivate the farmland.

There are still many rural–rural migrations besides rural–urban migration in China, including government-sponsored, poverty-alleviating migration, mostly from vulnerable mountainous and other environmentally degraded areas. In addition, there is voluntary migration through land purchases by rural–urban migrants. The mountainous and environmentally degraded areas in China are the poorest areas, which are characterized by marginality, inaccessibility, and fragility. Chinese governments from county to national levels all consider resettlement as a tool to alleviate poverty and rehabilitate the environment. This kind of migration is found mainly in three stages from 1980: western poverty-alleviating migration of the 1980s; "aid the poor" and "development-oriented migration" of the 1990s; environmental conservation and poverty-alleviating migration of the decade from 2000. Beginning in 2010, many provinces in China relocated people from mountainous areas to other areas, such as Guizhou (1.5 million), Shaanxi (2.8 million) and Ningxia (0.35 million) (Economist, 2012). Rural out-migration in these areas will reduce the social capital and resilience of nonmigrants, and drive the evolution of settlement abandonment (McLeman, 2011).

The process of land use transition

Cultivated land use change

Fig. 3 shows a continuous decrease in cultivated land from 1980, due to ecological and settlement land occupation altogether (Wang et al., 2012). After 2000, the widely implemented "Grain-for-Green" policy in China converted many cultivated lands with slopes more than 25° into forest and grassland, which contributed to a quick drop in the amount of cultivated land.

The use of cultivated land was intensifying. Irrigated land increased steadily from 1980 (Fig. 3), partly due to changes in technology and in improving infrastructure by exploiting underground water and building reservoirs and water cannels. The multiple cropping index and the amount of fertilizer both increased rapidly from 1980 (Fig. 4).

Construction land change

Construction land in China includes settlement and industrial land, transportation land, and land for water conservancy facilities. Construction land grew rapidly from 23.71×10^6 hm^2 in 1996 to 33.06×10^6 hm^2 in 2008 (Table 1). The increase in construction land was at the expense of high-quality cultivated land (Wang et al., 2012). In China, by 2011 there were 30 cities with more than 8 million people and 13 cities with more than 10 million people (NBSC, 2012). The urban area increased from 9.39×10^5 hm^2

Table 1
Construction land change in selected years since 1996 ($\times 10^4$ hm^2).

Types of construction land use	1996	2003	2008
Settlement and industry land	2186.93	2535.42	2691.60
Transportation land	60.70	214.52	249.60
Land for water conservancy facilities	123.33	356.53	364.50
Total	2370.96	3106.47	3305.7

Source: National Bureau of Statistics of China.

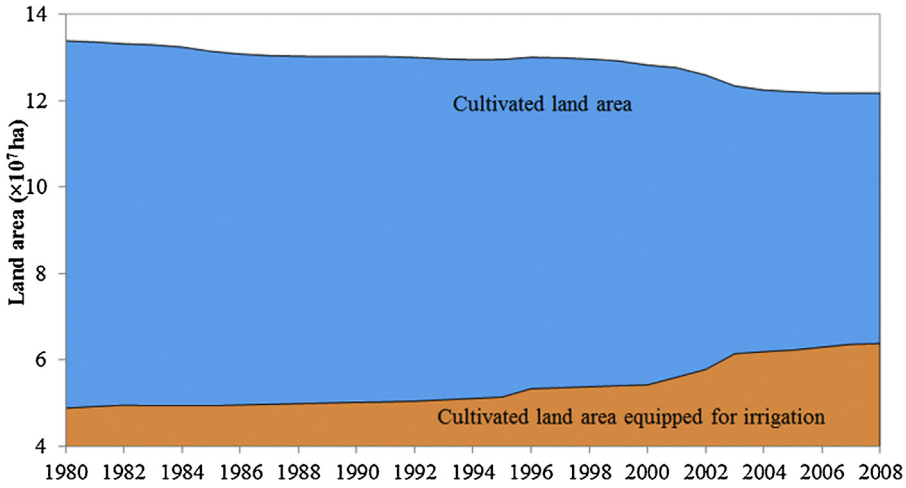

Fig. 3. The change of cultivated land area in China. The data of cultivated land area are reconstructed from Chinese statistics yearbook and China land and resources almanac (Cai et al., 2009).
The data of irrigated land area come from FAO statistics (http://faostat.fao.org/).

in 1985 to 40.06×10^5 hm^2 in 2010. Satellite remote sensing data validated that the urban number increased by 20% and the urban area increased by 270% between 1992 and 2009 (Small and Elvidge, 2013).

The change in rural settlement displays several contrasting trajectories. First, total rural settlement area increased at national level (Fig. 5). Even though the rural population has decreased since 1996, the rural settlement area is increasing (Long et al., 2012). Second, the abandonment of houses and property in inner settlement and the expansion of new settlement areas on the outskirts of the old settlement created many hollowed villages. The total area of hollowed villages is at least 6.7×10^6 hm^2 in 2010 (Long et al., 2012). In order to reduce the area occupied by rural settlements, Chinese government adopted a policy of "linkage between urban land taking and rural land giving" (LUTRG) in 2009. This innovation involves occupying farmland and converting it to built-up areas, while reclaiming the same amount of farmland obtained by adjusting parts of the rural settlements (Andersen, 2010; Tan and Beckmann, 2010). It reduces the land area used for housing in a village by moving farm households to newly built, multiple-storey buildings. This policy can partly solve the problem of the hollowed villages. Finally, settlement abandonment increased in some areas. Settlement abandonment mostly happens in marginal areas, especially in west China. Marginal areas include three categories: mountainous areas and severely arid area; hazard-prone areas (earthquake-, landslide- and mud stone flow-prone areas), and degradation areas (soil erosion, desertification areas). Ecological migration, poverty alleviating migration, and economic-induced migration were tangled in these areas.

China's rapid economic development and urbanization has created intense demand for construction land. But conversion of agricultural land or rural settlement land to construction land is very sensitive in China because it always directly relates to tradeoffs between government, farmers, and developers.

Land for nature

Land for nature is the total land area minus cultivated and construction land (Lambin and Meyfroidt, 2011). Because of increasing

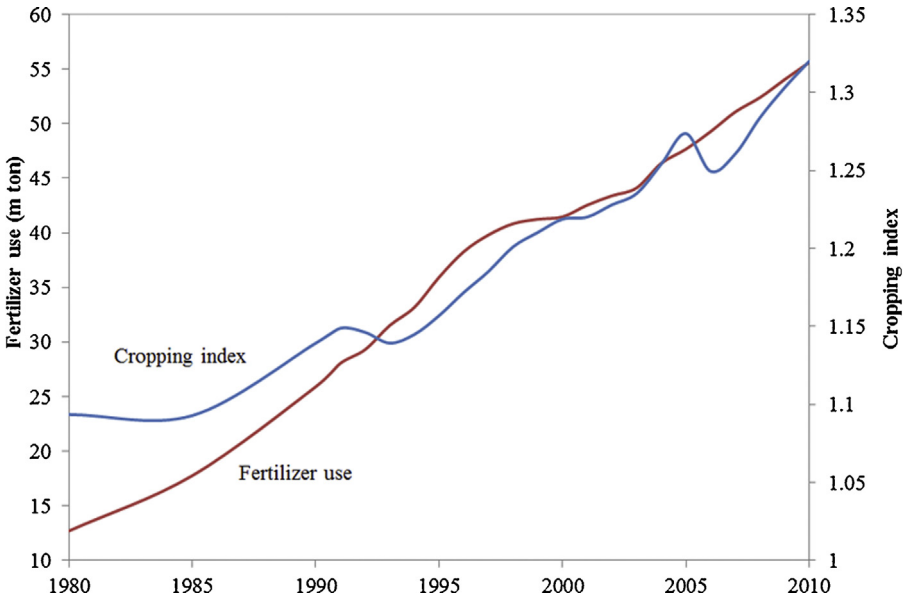

Fig. 4. Fertilizer use and cropping index change during 1980–2010. The cropping index = crops area/cultivated land area × 100%.
Data from NBSC.

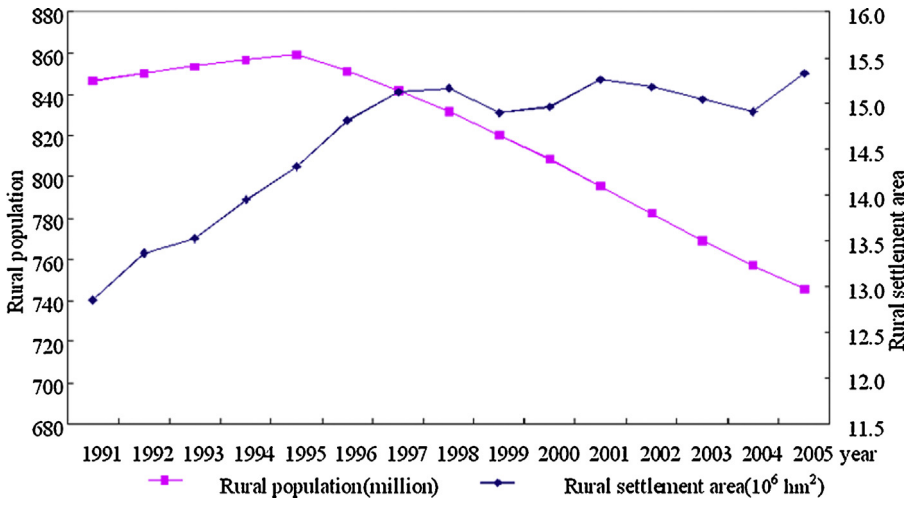

Fig. 5. The change in rural settlement area in the 1991–2005 period.
Data from China Land & Resources Almanac.

land degradation and decreasing ecosystem goods and services, environmental protection is of great concern in China. Chinese central government initiated a series of policies to increase the forest area, such as the Three North Shelterbelt Construction Program in 1978, the Natural Forest Protecting Program in 1998, and the Grain-for-Green policy in 1999 (Wang et al., 2004). The Three North Shelterbelt Construction Program aimed to build a forest shelterbelt system across north China to solve problems with dust storms and desertification in arid and semi-arid China (Wang et al., 2010a,b). Owing to this policy, forest area in North China increased 2.65×10^7 hm^2 between 1978 and 2012 (Chen and Yu, 2012). The Natural Forest Protecting Program was designed to protect remaining natural forests around headwaters and sensitive ecological regions; it increased 1.0×10^7 hm^2 forest area in ten years (Liu, 2010). The Grain-for-Green policy targeted returning steep, cultivated land with a slope of more than 25° to forest and pasture. With these great efforts, forest in China has been in transition (Lambin and Meyfroidt, 2011) and the total forest land area increased from 9.6×10^7 hm^2 in 1977–1981 to 19.55×10^7 hm^2 in 2004–2008 (Xu et al., 2007). Between 1978 and 2011, the number of protected areas increased from 106 to 2640, and the total area increased from 12.6×10^5 hm^2 to 14.97×10^7 hm^2 (Jiang, 2005; NBSC, 2012).

The impact of rural out-migration on land use transition

Before 1978, China was a poor, agriculture-dominated, closed society with low population mobility. It shares the migration and land use change characteristic of stage 1 in Fig. 1, with more than 80% of the population trapped in rural areas characterized by subsistence agriculture. In order to feed the increasing population, natural ecosystems all over the country were cleared for agricultural extensification. The relaxing of restrictions on rural out-migration by the economic reforms of 1978 gave rise to rapid urbanization, and China fell into a transitional stage from then on (stage 2 in Fig. 1).

The impacts of rural out-migration on land use transition conforms to the general trends of the stage 2 of Fig. 1, but it also has unique characteristics. Extensive rural out-migration in China has reduced labor forces in rural areas and increased population in urban areas. The former causes rural settlement and agricultural land change, and the latter increases urban land and per capita consumption, occupies rural cultivated land, and fosters land intensification (Fig. 6). Compared to other developing countries, the rapid rate of urbanization and the number of rural out-migrations in China is unique. Rapid urbanization and rural out-migration not only created abandonment of large amounts of settlements and cultivated land in remote areas, but also increased total rural settlement area. Rural out-migration also accelerated population transition: the average family size decreased from 4.41 in 1982 to 3.10 in 2010, and the number of households increased from 2.21×10^8 to 4.18×10^8 in the same period in China (NBSC, 1983, 2011). The per capita house area increased from 17.83 m^2 in 1990 to 34.1 m^2 in 2010 (NBSC, 2011), factors leading to settlement land expansion in urban and rural areas (Liu et al., 2003; Yu and Liu, 2007). Owing to the incomplete social security system and "dual-track" household responsibility system, numerous rural–urban migrants still own their houses in rural areas, and even built new houses for security reasons, producing large numbers of hollowed villages (Long et al., 2012).

Land intensification in China is influenced by rural out-migration, but it is also heavily affected by policies. An increasing urban population and corresponding increased food consumption requires more production of vegetables, which leads to rapid expansion of plastic greenhouses (Chang et al., 2013). Rural livelihoods are diversified when migration becomes a livelihood strategy. National investigation indicates that more than 50% of peasants' annual income was from off-farm sources in 2011 (Zhou and Liu, 2012). Off-farm sources stimulate technology application on farmland, which in turn can save time on agriculture and allow the acquisition of more non-farm incomes. With improved transportation and marketization, agriculture is gradually transformed from subsistence agriculture to commercial agriculture. However, policies also greatly influence agriculture intensification. China sets a numerical target for food self-sufficiency and maintains quite a high self-sufficiency rate, which improves agricultural infrastructures all over the country and intensifies agricultural land-use.

Land sparing from agriculture to forest or grassland is partly caused by migration and land intensification, as with other countries. (Rudel et al., 2009). Rural out-migration facilitates vegetation recovery in several ways. First, rural out-migration may reduce fuelwood consumption and collection with labor reduction effects (Chen et al., 2006; Shi et al., 2011). Second, if remittances from migrants is invested in energy purchases, such as coal and electricity use, it will decrease the demand for firewood and contribute to natural conservation. Third, an increasing urban population needs more tourist areas, which give rise to an increase in protected areas (Phalan et al., 2011). State

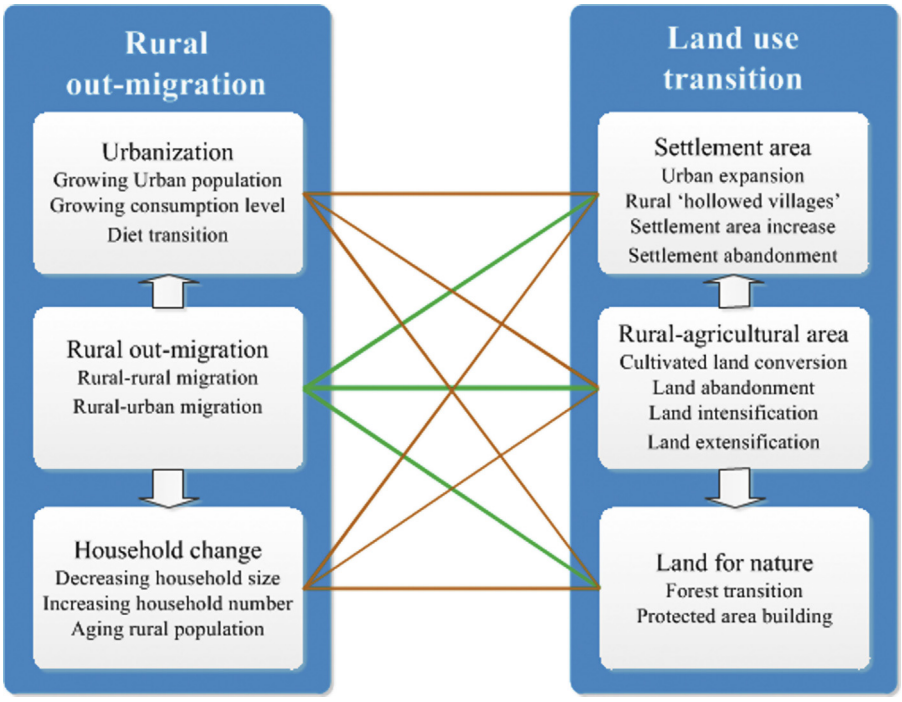

Fig. 6. The interaction between rural out-migration and land use transition in China.

environmental protection policies such as the Grain-for-Green and the Three-North Shelterbelt Construction Program policy also have a great impact on forest transition in China (Lambin and Meyfroidt, 2010). Rural–rural migration also causes land extensification in some places (Fig. 1), as has occurred in other developing countries. For example, the government-sponsored migration in Xinjiang province and in the west Hexi corridor of Gansu Province transformed the desert area into cultivated land by using underground water and by transporting surface water from yellow river.

Future land use in China

Rural out-migration is transforming China from a land-attached society to a "moving" society. The transformation has had great impacts on land use transition in China, and it may continue for a long time. By 2050 China's population is expected to reach 1.4 billion, with nearly 75% living in urban areas (Peng, 2011). Thus, the urban area will continue expanding with the increasing urban population until 2050 (Cai et al., 2009; Li et al., 2011).

The central Chinese government has initiated strict policies to control the loss of cultivated land. The "1.8 billion mu (120 million hectares) red line of cultivated land" was initiated in 2006 to ensure food security. With respect to the policy dimension of land use change, the decline of cultivated land will be restricted; and as regards the potential of consolidating and rehabilitating the hollowed villages, there are hopeful prospects for cultivated land protection (Long et al., 2012). However, the amount of cultivated land will still decrease in the light of land abandonment in large-scale out-migration areas (He et al., 2009; Tian et al., 2010; Gao, 2011). The Chinese Communist Party's Central Committee issued 10 consecutive No. 1 Policy Documents from 2004 to 2013. All of these documents focused on agricultural infrastructure, water conservation, and grain production. The No. 1 Policy Document of 2013 emphasizes the need for scale enlargement of agricultural land holdings, encouraging agricultural land transfer to professional farms, family farms, and farmer cooperatives in an effort to develop large-scale farming. Farmers are encouraged to exchange their plots with others in order to resolve the land fragmentation problem. But implementation of this policy should be very cautious and ensure it does not hurt farmers' interests, not change land use, and not cause decline in agricultural production. This policy will further intensify agricultural land use in China.

The continuing agricultural intensification will decrease the percentage of subsistence agriculture. In turn, it will spare some land for ecological restoration (Fig. 1). In 2011, the central Chinese government initiated major function-oriented zoning (MFOZ), in which land development in China is divided into four kinds of major function zones: optimal development region, key development region, restrictive development region, and prohibited development region (Fan and Li, 2009). This plan will be implemented on the national to county scales, which casts strict restriction on land use in China. Along with the strictest policy on "construction land saving and intensive use," the rate of land conversion from cultivated land to construction land will decrease. It is estimated that the increase in construction land will stop after 2050 (Cai et al., 2009).

China will transition to an advanced society when its urbanization rate reaches 75%, which it is expected to do around 2050 (Cai et al., 2009; Li et al., 2011). Then, population movement will be characterized by vigorous movement of migrants from city to city. Land use change will tend to stabilize and cultivated land will be dominated by intensified agriculture, with subsistence agriculture greatly reduced. Therefore, natural ecosystems will be improved, with increasing forest and protected areas.

Discussion

General implications of rural out-migration on land use transition

Rural out-migration connects rural transition, population transition, diet transition, and land use transition; this is key to understanding the interaction between socio-economic change and land use change. Urban and rural land use change is teleconnected through rural–urban migration (Seto et al., 2012). In fact, policies on rural out-migration can impose a great impact on rural and urban land use change, as in China and Vietnam before

and after 1980. The policy of migration restriction kept rural inhabitants attached to the land, which resulted in the expansion of small-scale subsistence agriculture. The policy reform on relaxing migration restrictions afterwards created rapid rural and urban transformation. For this reason, Chinese experience can shed light on understanding the relationship between migration and land use transition in other developing countries.

Currently most developing countries are in stage 2 in Fig. 1. Migration is characterized by massive rural–urban migration and movements to colonization frontiers (Carr, 2009). Rural–urban migration results in an increase in urban settlement areas and occupation of cultivated land. Movements to colonize frontiers lead to deforestation and other environmental issues (López-Carr and Burgdorfer, 2013). There is a need to better integrate migration into overall national planning, and to treat agriculture more seriously. Land zoning and other ecological protection policies in China restrict development in ecologically sensitive areas, which contributes greatly to environment security. Rural development policies in other developing countries should also recognize the long-term effects of migration on land use change and encourage related rural adjustments, such as scale enlargement of agricultural land holdings in China. In the process of massive rural out-migration, nonmigrants' interest should be protected by the government, including agricultural infrastructure improvement, farmer subsidies, and rural living conditions improvement.

China's unique characteristics and policy implications

Urbanization and rural out-migration in China have a great impact on land use change, and shares some trends of developed countries, such as marginal settlement abandonment, forest transition, and urban sprawl. But China also has unique characteristics. First, the top-down political system and policies greatly affect land use transition in China (Long and Woods, 2011), not only in terms of the rapid rate of transition but also in the large scale. The household registration system (Hukou) and the "dual-track" policy of rural–urban development in China increased the total rural settlement area and created numerous hollow villages (Long et al., 2012). Because of the land tenure system, large-scale cultivated land was quickly transformed into urban and industrial land, resulting in many conflicts between farmers, governments, and land developers. On the other hand, conversion of cultivated land is strictly restricted by national policies, resulting in the strongest growth in house sale prices. Meanwhile, forest area saw a dramatic increase because of the national forest policy. Large-scale "ecological migrants" were displaced from marginal areas, which significantly changed land use and land cover in origin and destination regions (Tan and Wang, 2004; Wang et al., 2010a,b).

Second, China has a very large population size. The significant bottom-up out-migration of younger and more skilled residents has given rise to brain drain, aging rural labor forces, and countryside stagnation (Long et al., 2012). This is similar to the rural transformation in Europe and North America during the early-to-mid twentieth century, but the scale is much larger than in those countries, resulting in a lot of issues in a short time. With this in mind, China should take steps to raise farmers' livelihoods, improve the rural infrastructure (Long et al., 2010), pay more attention to the people staying behind in the countryside, and protect them from becoming "trapped populations" with low social, economic, and environmental capital (Black et al., 2011). Due to the migration of labor forces, people staying behind in the rural areas are old people, women, sick and disabled men, and children, and because of this some highly productive farmlands were abandoned (He et al., 2009; Long and Zou, 2010; Tian et al., 2010; Gao, 2011). In addition to protecting cultivated land, China should also be concerned with who will cultivate the land in future. Research results suggest that the central Chinese government should invest in rural infrastructure to develop modern agriculture and scale management, decrease the income gap between urban and rural dwellers and train future farm workers (Long and Woods, 2011; Long et al., 2012). The contemporary European and North America rural restructuring can also shed light on sustainable rural development in China, such as the rural community regeneration (Long and Woods, 2011), multifunctional land use (Wilson, 2010) and community support agriculture (CSA) (Lamb, 1994).

Finally, the central Chinese government takes food security very seriously. The area of cultivated land is strictly controlled so it does not fall below 1.8 billion mu (12.0×10^7 hm^2) (Lichtenberg and Ding, 2008). China also has a 95% grain self-sufficiency policy and limits its food trade with other countries. For the most part, these policies protected cultivated land from decreasing. But it should be noted that construction land converted from cultivated land is high-quality in most cases (Wang et al., 2012), so it is even more important to protect high-quality land. Intensified use of high-quality land can spare the land in mountainous and other vulnerable areas. It brings hope for ecosystem and biodiversity restoration (Aide and Grau, 2004). But land intensification also brings problems (Matson et al., 1997); for example, exploiting groundwater for irrigation will cause a decline in the groundwater table (Zhang et al., 2008), and massive use of fertilizer results in water pollution and affects soil quality (Siciliano, 2012). These negative factors should also be considered.

Research gaps and priorities for further research

Rural out-migration is an important driving force behind land use transition. For this reason, there is a need to give more priority to rural out-migration on the part of both government and researchers in developing countries. Land use policies should be based upon a better understanding of the impacts of rural out-migration on land use transition. To draw lessons for policymaking, this will require comprehensive research at the cross-country level, country level, and rural community and household level.

Cross-country research should compare the dynamics of rural out-migration among countries with different urbanization levels, drawing lessons from other countries' experiences. There is also a need to collect population census data and land use data on developing countries, examining the impact of rural out-migration on the change of agriculture, forest, and settlement land use.

Country-level research should consider land issues caused by rural out-migration, balancing the need of land for food security, urban development and ecosystem protection. Other questions of concern are, how much land is needed to feed the increasing urban population and its consumption, what area characteristics influence the decision to migrate, where are the places with net in-migration and out-migration, and what are the impact of out-migration on land use change.

Rural community level research should focus on the question of why population in some rural communities tends to decrease but in others, not. A related question would investigate the subsequent effects of having a long-term out-migration on rural origin-area land use. Household level research should investigate the effect of out-migration of household members on agricultural and other land use; and it should also examine nonmigrants' future plan on migration and land use.

Conclusion

Human mobility transition is closely related to land use transition. The three stages of rural mobility transition, the pre-modern traditional society, the transitional society, and the advanced

society are corresponding to three stages of land use transition: subsistence, intensifying, and intensive, respectively. Different stages of mobility transition have different land use structure and dynamics.

Currently most developing countries are in the second stage. Migration is characterized by massive movements from rural to urban areas and the colonization of rural frontiers. Land use transition is characterized by an increase in urban areas and in intensive agriculture; forest transition; and new frontier clearings. Rural out-migration at this stage brings opportunities as well as challenges to urban and rural sustainable development. To balance the demand of land for food security, ecological restoration, and economic development, a systematic approach is needed to understand the coupled process of rural out-migration and land use transition. Chinese experience can shed light on the rural development policy of other developing countries. For example, frontier clearing should be restricted by land zoning and other ecological protection policies. In the process of massive out-migration in rural areas, nonmigrants should be encouraged to adjust their agricultural land holdings; their interest should also be protected by the government. For China's part, it needs to be more responsive to the dynamics of rural out-migration and land use transition, to raise the nonmigrants' livelihood conditions for reducing poverty, to rehabilitate the ecosystem from land sparing, and to satisfy food demands from sustainable land intensification.

Future research about the impacts of rural out-migration on land use transition should take a multiscale perspective. To draw lessons for policymaking, cross-country research should examine qualitative and quantitative analysis for the dynamics of rural out-migration among countries with different urbanization levels; country level research should focus on land issues caused by rural out-migration, and on the spatial characteristic of rural out-migration and land use transition; research at community and household level should explore the subsequent effects of a long-term out-migration on rural origin-area land use change, and the effect of out-migration of household members on agricultural and other land use change.

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