Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)
ISSN 1673-565X (Print); ISSN 1862-1775 (Online)
www.jzus.zju.edu.cn; www.springerlink.com
E-mail: jzus@zju.edu.cn

Environmental impact assessment of ecological migration in China: a survey of immigrant resettlement regions*

Ye-cui HU[†1], Wei ZHOU[1,2], Tao YUAN[1,2]
[1]*School of Land Science and Technology, China University of Geosciences, Beijing 100083, China*
[2]*Key Lab of Land Consolidation and Rehabilitation, Ministry of Land and Resources, Beijing 100035, China*
[†]E-mail: huyc@163.com

Received Oct. 8, 2016; Revision accepted May 23, 2017; Crosschecked Jan. 31, 2018

Abstract: Implementation of ecological migration (eco-migration) policies may improve the fragile ecological environment of emigration areas; however, it also places enormous pressure on the human-environment systems in immigrant resettlement regions. Via the application of participatory rural appraisal (PRA) methods, ecological footprint (EF), and stochastic impacts by regression on population, affluence, and technology (STIRPAT) models, 21 villages of Huanjiang County in Guangxi Zhuang Autonomous Region, China were used in this research as a case study area for the environmental appraisal of eco-migration policies in immigrant resettlement regions. Results show: (1) In the past 20 years of implementing eco-migration policies, the EF per capita constantly increased, the biocapacity (BC) per capita constantly decreased, and the ecological deficit gradually increased, indicating an extremely negative impact of eco-migration projects on the ecological environment in the immigration areas. (2) Cropland and forest land are the most important components of the per-capita EF. The per-capita EF of cropland experienced overall a first increasing and then decreasing trend, and the per-capita EF of forest land constantly increased and showed the most rapid increase among all types of EF in the last two decades. (3) The proportion of per-capita EF of different types of productive land is in the order of forest land > cropland > carbon uptake land > built-up land > grazing land from high to low, and this is a significant change from the original order of cropland > forest land > carbon uptake land > grazing land > built-up land. (4) Because of unequal possession of ecologically productive resources, the overall per-capita EF, overall per-capita BC, overall per-capita ecological deficit of productive land use by migrants, and their component values of different types of productive land use are all lower than the corresponding values of the natives. The ecological deficit of natives is more severe than that of migrants. (5) Whereas population growth and overexploitation of resources lead directly to the increased pressure on the ecological environment in the immigration areas, increasing nonagricultural income and improving the consumption structure can reduce the dependence of farmers on the land, thus inhibiting the increase of EF.

Key words: Ecological migration; Environmental impact; Ecological footprint (EF); Immigration area; China
https://doi.org/10.1631/jzus.A1600669 **CLC number:** Q14

1 Introduction

Poverty and ecological migration (eco-migration) caused by climate change, drought, and desertification have become global problems (Myers, 2002). Migrants' livelihood and ecological problems have subsequently become core issues of global poverty reduction and human-environment sustainability (Duraiappah, 1998; Ferrol-Schulte et al., 2013). Eco-migration can reduce the continuing destruction of already weak ecological environments caused by human activities. It is conducive to the recovery and rebuilding of the ecological system in emigration regions and reduces the loss of water and soil

* Project supported by the National Natural Science Foundation of China (Nos. 70903061 and 41171440) and the Fundamental Research Funds for the Central Universities (No. 2652015175), China
ORCID: Ye-cui HU, https://orcid.org/0000-0002-6747-2163

resources, thus carrying great significance for the improvement of regional ecological environments (Myers, 1997; Barbier, 2010; Raleigh, 2011; Morrissey, 2013). However, large-scale immigration will inevitably cause a reshaping of human-environment systems in the immigration area. In particular, in less developed regions where land resources are limited and employment opportunities are lacking, the competitive relationship between immigrants and local population natives will be more marked (Huang et al., 2001; Trier and Turashvili, 2007; Fox et al., 2009).

An eco-migration program is a complex phenomenon, with the effects of eco-migration influenced by the natural, social, economic, political, and cultural factors of a region. The effects of eco-migration have subsequently become core issues of global poverty reduction and human-environment sustainability (Duraiappah, 1998; Ferrol-Schulte et al., 2013). A fair amount of scholarship has tried to characterize and describe the impact of migration. However, no consensus has been reached by previous studies regarding the effectuation of the immigration program (Ocello et al., 2014). One perspective suggests that migration can indeed be seen as a coping mechanism or as a last-resort solution, which improves the ecological environment on emigration. It is generally believed that there is a close relationship between poverty, eco-migration, and fragile ecological environments (Cavendish, 2000; Bates, 2002; Ezra, 2003; Morrissey, 2013). Another perspective takes a negative view. According to this second perspective, large-scale eco-migration will inevitably cause tremendous impact and pressure on the natural-social-economic system in immigration regions; furthermore, eco-migration and environmental degradation will be trapped in a vicious circle (Becchetti et al., 2010). For example, as Nepal's eco-migration program shows that limited cropland land with resources under competition leads to the further deterioration of the regional ecological environment, control of the population is far more important than the implementation of the eco-migration program (Hrabovszky and Miyan, 1987; Bachour and Dong, 2006; Thornton et al., 2012).

Ecological footprint (EF), from the perspective of the land area used for production, indicates the effect and impact of human consumption activities on the natural environment and reflects the environmental pressure and crisis in the investigated region (Wackernagel et al., 1999; Mostafa, 2010). EF analysis serves as an effective tool for measuring the impact of human activities on the ecological environment, and its use can be expanded to investigations at global, national, regional, and individual levels and in various fields such as agriculture, national land resources, energy, and tourism (Li et al., 2007; Rice, 2007; González-Vallejo et al., 2015; Xi et al., 2015; Guo and Yan, 2016; Ozturk et al., 2016). Moreover, research using this indicator has developed from static research to long-term time-series dynamic research. The EF method is easily understood and can be easily combined with the use of other indicators. This method is mainly combined with the input-output method, energy value analysis, and geographic information system (GIS) methods to analyze the processes and causes of regional environmental changes (Chang and Xiong, 2005; Ferng, 2009; Wu et al., 2013). Because of drastic changes in land use and regional environments, ecologically fragile regions have gradually become research focuses in EF-related research. For example, Xiao et al. (2015) established an ecological assessment model based on the EF model and applied the model to resettlement compensation management for migration action in the Three Gorges Reservoir Project. Fu et al. (2013) and Li et al. (2015) employed the EF method for ecological safety assessment in northwest China and Tibet, China, which are ecologically fragile plateau regions. In addition, a large number of researchers have analyzed the influential factors of environmental pressure in ecologically fragile regions based on assessment using EF models. Alix-Garcia et al. (2010), based on EF analysis of ecologically deteriorated areas, stated that an increase of income increases the ecological environmental pressure, particularly in areas with poor basic infrastructure. Moreover, they concluded that convenient transportation can ease environmental pressure. Hou et al. (2015), based on research data from Zhangye City in the northwest arid region of China, used EF as an environmental pressure indicator to analyze the environmental impact of rural farmers' consumption and concluded that means of livelihood and consumption patterns are the most important factors affecting the per-capita EF of rural households. EF analysis of the ecological functional region of the Inner Mongolia farming-pastoral belt suggested that nonagricultural employment opportunities can relieve environmental impact to a certain extent (Hao et al., 2015). Rural households are the main subjects in the social economy and land use decision-making, and thus their production and consumption behaviors have an important effect on the ecological environment (Hao et al., 2015; Liang and Zhai, 2015). Because EF models possess various advantages, such as effective reflection of environmental quality, relatively complete accounting systems, and bottom-up data collection, a number of researchers have used EF to investigate the ecological environmental impact of economic and decision-making behaviors of rural households at the micro-level (Zhao, 2013; Shen et al., 2015; Wang and Zhang, 2015). The results of these research indicated that the economic behaviors of rural households are an important factor affecting the quality of the local environment. Research on the driving mechanisms of EF changes of rural households can provide a good reference for developing policies that can effectively improve local environments.

Research on eco-migration emerged in the 1980s–1990s in China. Different from the general situation in other countries, China's eco-migration was developed along with national poverty alleviation and development projects. The government planned and organized eco-migration in China, with the aim of protecting fragile ecological environments and improving the living situation of local residents and the development of emigration regions. From 1983 to 1999, China's western provinces (autonomous regions) began to explore the ecological migration policy for poverty relief. Since 2000, the government has arranged for central investment to implement ecological migration for poor people living in ecologically fragile areas (CPAD, 2011). The scope of implementation extended from the initial four provinces to 17 provinces. By the end of 2015, the state has accumulated a total of 36.3 billion CNY as the compensation investment, relocated more than 6.8 million people, and adopted a combination of ecological immigration and poverty alleviation projects, returning farmland to forests and other policies (Chen and Ge, 2015). According to China's 13th Five-Year Plan, more than 10 million people will emigrate from the ecologically fragile regions in northwest and southwest China, with the hope of solving the increasingly severe ecological and poverty issues in the areas. Implementation of eco-migration projects will inevitably lead to significant changes of the population-resource-environment structure in both emigration and immigration areas. Whereas eco-migration improves the resource environment in the emigration areas, it also raises a new question: will it bring a large amount of pressure to the natural and environmental systems in immigrant resettlement areas, causing new environmental resource issues in these areas? In a number of developing countries, including Indonesia, Brazil, and Ethiopia, previous eco-migration projects commonly caused environmental disasters and worsened the poverty issue in the immigrant resettlement areas (Finco, 2009; Morrissey, 2013). In China, eco-migration is an important strategy for improving ecological environments and alleviating poverty, and as a result, its success in relieving human-environment conflicts is critical for the further promotion of state strategies at the regional level. Therefore, timely research concerning the ecological environmental impact of eco-migration projects on immigrant resettlement areas can provide a good reference for the implementation of eco-migration projects during the poverty alleviation and development programs in China, or even worldwide.

Guangxi Zhuang Autonomous Region, China is an area with typical karst landform development and the co-existence of economic poverty and an ecologically fragile environment. Karst formations occupy 97 700 km^2 of land area in this region, accounting for approximately 41% of the total land area. Because of the fragility of the ecological environment and the long-existing impact of human activities, the region has experienced severe land degradation and serious rocky desertification. Approximately 400 000 people live in karst mountain regions with an insufficient per-capita cropland land area of 0.02 hm^2. Because of poor objective conditions, directly investing a large amount of resources does not necessarily solve the poverty issue nor improve the ecological environment in these regions fundamentally. Since the 1980s, an eco-migration project has been implemented in these regions, through which rural residents move from the karst regions, where they lack basic living conditions, to the hilly regions, where land resources are relatively abundant. Guangxi became a model for China's eco-migration project, where nearly 230 000 farmers were resettled from 1994 to 2000, and more than 1 million people will emigrate from the ecologically fragile regions in 2016–2020.

In this study, Huanjiang County in Guangxi Zhuang Autonomous Region was used as a case study to explore the ecological environmental change in eco-migrant resettlement regions. The EF method served as a research tool to investigate the ecological environmental impact of the production and consumption behaviors of rural households in immigrant resettlement areas. In addition, a stochastic impacts by regression on population, affluence, and technology (STIRPAT) model was used to analyze the socioeconomic factors that affect the ecological environmental change at the rural household level. The aims of this study were to provide a basis for decision-making related to sustainable production and decision-making behaviors of rural households in eco-migrant resettlement areas, as well as to develop strategies and suggestions to mitigate EF increase and ecological deficit in such areas.

2 Research area

Huanjiang County is located in the northwestern part of the Guangxi Zhuang Autonomous Region. It has a total land area of 4572 km^2. There is a gradual reduction in terrain from north to south, and the section south of the center is hilly land with a small basin. The highest altitude in the county is 1693 m and the lowest is 149 m. Located in the subtropical monsoon zone, it has a moderate climate with plenty of rain and is warm in winter and cool in summer. Given the county's barren hill slopes and the significant concentration of young forests, there is a large contiguous area with considerable potential for agricultural development. Therefore, conditions in the county have been favorable for scaling up development relating to the eco-migration project. Since the early 1990s, the county has received 70 000 eco-migrants, distributed on 290 resettlement sites. Huanjiang has become the largest and most representative eco-migrant resettlement county of the southwestern karst region.

Based on the findings of a comprehensive exploratory study and the views of relevant public departments, including the Huanjiang County Land Resources Bureau, Agriculture Bureau, Forestry Bureau, and Poverty Alleviation Office, as well as those of local people, 21 resettlement sites were selected in this study as survey points. The selected resettlement sites, which are located in Jinqiao Village, Daan Township, share similar features in terms of natural and socioeconomic conditions, resource-use patterns, and concentration of resettlement farmers, and thus the selected sites are representative.

3 Data sources and methods

3.1 Data sources

The research was carried out using a participatory rural appraisal (PRA) method for the period June–July 2015. The research data were obtained through face-to-face interviews. The interviews included not only the relevant information on farmers in 2014, but also the information about farmers before the ecological migration in 1995 and at the ecological resettlement midterm in 2005. Because of the small number of households in each of the selected survey sites described earlier, we conducted a comprehensive household survey, excluding only those households that were empty during the survey period. Interviews were conducted in 140 households, with the household heads as the respondents. The final number of questionnaires found to be satisfactorily completed was 131, of which 95 were completed by migrants and 36 by native residents. Although the survey sample is small, because the natural resources of the resettlement area and the socioeconomic conditions are highly similar in Guangxi, this survey well represents the general situation of the Guangxi resettlement area. The questionnaire was divided into three parts: (1) basic characteristics of respondents, including individual age, gender, education level, and current occupation; (2) information related to EF accounts, including resource-related account information (e.g. crop production and the quantity of livestock owned), carbon footprint account information (besides fossil fuel consumption amount), and biomass fuel consumption amounts; (3) land use/land cover change information.

3.2 Methods

3.2.1 Ecological footprint of production (EFp)

Following the approach developed by Borucke et al. (2013), we calculated EFp by summarizing the footprints of renewable resources, carbon uptake land, and built-up land. Footprints of renewable resources estimated the area of bioproductive land occupied by humanity (e.g. cropland, grazing land, forest land, and fishing ground). Carbon uptake land is the only land use type for which biocapacity (BC) is currently not explicitly defined. Carbon uptake land is assumed to be forest land associated with biomass and fossil fuel use. The built-up land footprint is calculated based on the area of land covered by human settlements and infrastructure. EFp can be calculated based on the following equation (Borucke et al., 2013):

$$\mathrm{EFp}=\sum P_i/Y_{\mathrm{N},j}\cdot \mathrm{YF}_{\mathrm{N},j}\cdot \mathrm{EQF}_i=\sum P_i/Y_{\mathrm{W},j}\cdot \mathrm{EQF}_i,\quad (1)$$

where P_i is the amount of each primary product i that is harvested (or carbon dioxide emitted) in the nation; $Y_{\mathrm{N},j}$ is the annual national average yield for the production of commodity j (or its carbon uptake capacity in cases where P is CO_2); $\mathrm{YF}_{\mathrm{N},j}$ is the country-specific yield factor for the production of each product j; $Y_{\mathrm{W},j}$ is the average world yield for commodity j; EQF_i is the equivalence factor for the land use type producing product i.

To ensure the continuity of EFp across different years and the comparability between our results and findings in the relevant literature, we obtained the constant factors of $Y_{\mathrm{N},i}$, $\mathrm{YF}_{\mathrm{N},i}$, and EQF_i from the calculations of Xie et al. (2001) and the National Footprint Accounts (NFA) (Lin et al., 2016).

3.2.2 Quantifying biocapacity

BC refers to the total biologically productive land in the study area under given environmental and socioeconomic conditions and was calculated by

$$\mathrm{BC}=\sum A_{\mathrm{N},j}\cdot \mathrm{YF}_{\mathrm{N},j}\cdot \mathrm{EQF}_i,\quad (2)$$

where $A_{\mathrm{N},j}$ is the bioproductive area that is available for the production of each product j at the country level, $\mathrm{YF}_{\mathrm{N},j}$ is the country-specific yield factor for the land producing products j, and EQF_i is the equivalence factor for each land type producing each product i.

3.2.3 Measuring ecological reserve/deficit

After subtracting BC from EF, a positive difference is called an ecological deficit (ED) and indicates that the per-capita natural resource use exceeds the BC in the area, whereas a negative difference is called an ecological reserve (ER) and indicates that per-capita resource use is within the allowable range below the BC. This difference reflects the ecological pressure in the research area and can be calculated using the following equations:

$$\mathrm{ED}=\mathrm{EF}-\mathrm{BC}\ (\mathrm{EF}>\mathrm{BC}),\quad (3)$$

$$\mathrm{ER}=\mathrm{BC}-\mathrm{EF}\ (\mathrm{BC}>\mathrm{EF}).\quad (4)$$

3.2.4 Driver analysis methods

Ehrlich and Holdrens (1971) proposed the classical IPAT model, which describes the effects of socioeconomic driving factors, such as population (P), affluence (A), and technology (T), on environmental pressure (I) to indicate the relationship between economic growth and natural resource environments. However, the IPAT model has some limitations, e.g. it can only examine a limited number of variables and can only determine the proportional impact of independent variables on dependent variables (Yuan et al., 2013). To overcome these shortcomings, York et al. (2002) proposed the STIRPAT model based on the traditional IPAT model. The STIRPAT model can add social and other controlling factors as variables into the analysis of environmental impact, but these variables must be conceptually consistent with the form established in Eq. (5). Because of its satisfactory performance in analyzing the environmental impacts of human factors, this model has been widely applied. In the current study, the EF was used as an indicator of environmental pressure. To explore the effect of the socioeconomic activities of rural households on the per-capita EF in eco-migrant resettlement areas, with a consideration of the availability of research data, population (P), affluence (A), consumption modes (C), and livelihood (L) were used as explanatory variables to establish the STIRPAT model, as shown in the equation below:

$$I = \alpha_0 P^{\alpha_1} A^{\alpha_2} C^{\alpha_3} L^{\alpha_4} \varepsilon, \tag{5}$$

where I represents the EFp; α_0 is the model constant; α_1, α_2, α_3, and α_4 represent the changes in the exponential term caused by P, A, C, and L, respectively; ε is a random error term. To reduce heteroscedasticity among the variables, both sides of the expanded model are logarithmized.

4 Results and discussion

4.1 Changes in per-capita EFp

Because migration policies were implemented in the research area mostly during 1997–1998, the EFp per capita in the resettlement area at one pre-migration time point, 1995, and two post-migration time points, 2005 and 2014, were determined (Fig. 1) to investigate the ecological environmental impact of livelihood-related behaviors of rural households before and after migration.

4.1.1 Early stage (1995–2005)

In the early stage of implementing migration policies (1995–2005), the per-capita EFp of migrants, natives, and residents as a whole all showed an increasing trend but varied in the degree of increase. The per-capita EFp of the natives increased rapidly, reaching 3.82 gha in 2005, which is considerably higher than the average level of the migrants in the same period and exceeds the global per-capita EFp threshold of 2.6 hm^2 (Lin et al., 2016).

As for the component composition of the per-capita EFp, cropland and forest land were the major components of the per-capita EFp of rural households in Jinqiao Village, together accounting for more than 80% of the total per-capita EFp of different productive land use types. The contributions of different productive land use types to the per-capita EFp of migrants, natives, and residents as a whole, were ordered as cropland > forest land > carbon uptake land > grazing land > built-up land.

With the increase of living standards and the requirements of living conditions, the per-capita EFp of built-up land for migrants, natives, and residents as a whole all showed an increasing trend. Because of differences in income, consumption, and ownership of land resources, the component EFp of natives was generally higher than that of migrants.

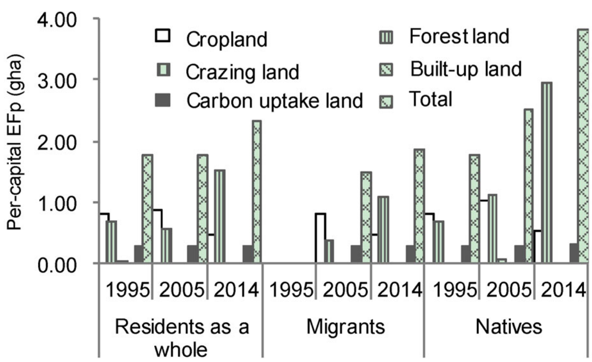

Fig. 1 Per-capita EFp of rural households

4.1.2 Middle and late stages (2005–2014)

In the middle and late stages of migration policy implementation (2005–2014), the per-capita EFp of migrants, natives, and residents as a whole constantly grew. Between 2005 and 2014, the per-capita EFp of Jinqiao Village residents as a whole increased by 0.56 gha, whereas that of the migrants and natives increased by 0.36 gha and 1.30 gha, respectively. Compared to the early stage of migration policy implementation, the overall growth rate increased rapidly in this period.

With the increase of off-village employment and the large-scale expansion of economic plant forests promoted by the "Conversion of Farmland to Forest

Program" (CFFP), the per-capita EFp of cropland showed a decreasing trend and that of forest land maintained an increasing trend for migrants, natives, and residents as a whole. The per-capita EFp of cropland for residents as a whole, migrants, and natives decreased by 0.41 gha, 0.36 gha, and 0.51 gha, respectively, whereas the per-capita EFp of forest land increased by 0.96 gha, 0.71 gha, and 1.83 gha, respectively.

The per-capita EFp of built-up land showed an increasing trend during this stage, whereas the per-capita EFp of carbon uptake land remained generally stable. With the exception of grazing land, the component per-capita EFp of the natives exceeded the corresponding values for migrants and residents as a whole.

From the perspective of the component composition of the per-capita EFp, cropland and forest land remained the key components of the per-capita EFp for rural households. However, the per-capita EFp values of different productive land use types of migrants, natives, and residents as a whole, experienced certain changes, in descending order: forest land > cropland > carbon uptake land > built-up land > grazing land.

In general, during the past 20 years of eco-migration policy implementation, the per-capita EFp of Jinqiao Village residents as a whole, migrants, and natives, all showed an increasing trend. The direct cause is a significant change in the per-capita forest footprint; the root causes are: (1) changes in the structure of land use and (2) changes in the intensity of land use. In the early period of implementation of immigration policy, the land of the farming household in the study area was used mainly as farmland. In the later period, under the guidance of returning farmland to forest and the land reclamation policy, there was a gradual increase in the proportion of the forest area, and especially the fast-growing forest area, leading to an increase in wood, fruits, and other forest products. In the early stage of the implementation of immigration policy, only a few farmers were willing to increase manpower and economic investment in land (fertilizers, pesticides, etc.). However, in the later period, it was discovered through research that almost all farming households increased the use of chemical fertilizers and pesticides, and increased the frequency of mechanized farming to increase production. Some households used more fertilizers and pesticides in the woodland than in the farmland. The households acting as "economic man" are the main sector of economic activity, and their microeconomic behaviors are the key factors affecting the ecological environment. In the middle and late periods of the implementation of immigration policy, there was a significant improvement in the level of consumption in the households of the study area compared with the initial stage. Therefore, farmers' demands for an ecological environment were increasing.

Among different types of productive land use, the per-capita EFp of grazing land and fossil energy land remained generally stable, whereas that of built-up land, woodland, and cropland experienced great changes. The per-capita EFp of built-up land and forest land showed a constantly increasing trend and that of cropland experienced a general trend of first increasing and then decreasing. In the middle and late stages of migration policy implementation, the contributions of different productive land use types to the per-capita EFp of migrants, natives, and residents as a whole were in the order of forest land > cropland > carbon uptake land > built-up land > grazing land, differing from the original order of cropland > forest land > carbon uptake land > grazing land > built-up land, at the early stage. This indicates the beginning of the impact of migration policies on the composition of the per-capita EFp among rural households.

4.2 Changes in per-capita BC

4.2.1 Early stage (1995–2005)

In the first 10 years of migration policy implementation, for the population of Jinqiao Village as a whole and the natives, the per-capita BC decreased by 35.53% and 31.20%, respectively. The overall per-capita BC for Jinqiao Village decreased from 1.25 gha in 1995 to 0.80 gha in 2005. For natives, this figure decreased from 1.25 gha in 1995 to 0.86 gha in 2005 (Fig. 2).

The implementation of migration projects directly resulted in a change in the composition of

Jinqiao Village's per-capita BC. The contributions of each land use type to per-capita BC were, in descending order, forest land > cropland in 1995, which later changed to an order of cropland > forest land by 2005. The per-capita BC compositional structure was consistent for migrants, natives, and Jinqiao Village as a whole in 2005.

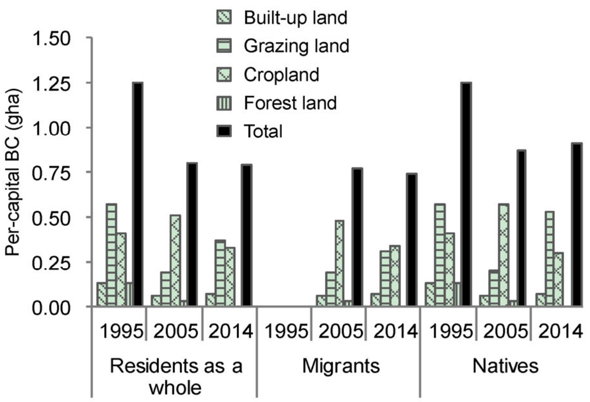

Fig. 2 Per-capita BC of rural households

Cropland gradually became the most important contributor to per-capita BC for rural households in Jinqiao Village. In the context of wasteland reclamation and immigrant resettlement, the per-capita BC of cropland for Jinqiao Village as a whole and natives increased by 24.39% and 39.02%, respectively. Because of drastic increases in population and demand for wood fuel caused by massive immigration, the per-capita BC of forest land and grazing land in the studied immigration area showed a rapid decline, decreasing by 66.67% and 76.92%, respectively.

4.2.2 Middle and late stages (2005–2014)

In the middle and late stages of migration policy implementation (2005–2014), the per-capita BC for residents as a whole and migrants mostly remained stable. However, the per-capita BC for natives increased from 0.86 gha to 0.91 gha, which was caused mainly by the increase in the per-capita BC of forest land.

The compositional structures of per-capita BC for Jinqiao Village as a whole and for the migrants showed similar change trends, and the contribution of each land use type was in a descending order of cropland > forest land > grazing land > built-up land. Cropland was still the most important component of the per-capita BC, whereas the contribution of forest land increased considerably. For the natives, the contribution of each land use type to the per-capita BC was in a descending order of forest land > cropland > grazing land > built-up land, with forest land contributing more than cropland, becoming the major component in the BC composition.

With the increase of off-village employment and the large-scale expansion of economic plant forests promoted by the "CFFP", the per-capita BC of cropland showed a significant decline and that of forest land increased. The per-capita BC of forest land for the village residents as a whole, migrants, and natives increased by 48.39%, 38.84%, and 61.72%, respectively.

In general, from 1995–2014, the per-capita BC for Jinqiao Village decreased rapidly in the early migration period (1995–2005) and declined at an abated rate in the middle and late stages (2005–2014). The compositional structure of per-capita BC for the village as a whole, migrants, and natives changed drastically before and after implementation of migration policies. The contribution of forest land to the per-capita BC was higher than that of cropland in 1995. However, an opposite trend was observed in 2005, with the contribution of cropland being higher than that of forest land. In 2014, this order changed to cropland > forest land for the village as a whole and migrants and to forest land > cropland for the natives. In 1995, forest land was the dominant contributor to the per-capita BC, accounting for approximately 50%. After 2005, cropland gradually became the most important contributor. By 2014, the total contributions of cropland and forest land exceeded 75% of the per-capita BC. The contribution of forest land in the per-capita BC showed a decline in the early stage and an increase in the middle and late stages of migration policy implementation. Because of unequal land allocation, the per-capita BC and each of its components for migrants were lower than the corresponding values for the natives.

4.3 Changes in per-capita ecological reserve/deficit

Prior to the implementation of migration policies (1995), the ecological environment in Jinqiao Village had an ecological deficit of 0.52 gha. The ecological deficits for cropland, carbon uptake land, and forest land were, at per-capita deficit levels, 0.39 gha, 0.26 gha, and 0.12 gha, respectively. Grazing land and built-up land did not have deficits (Fig. 3).

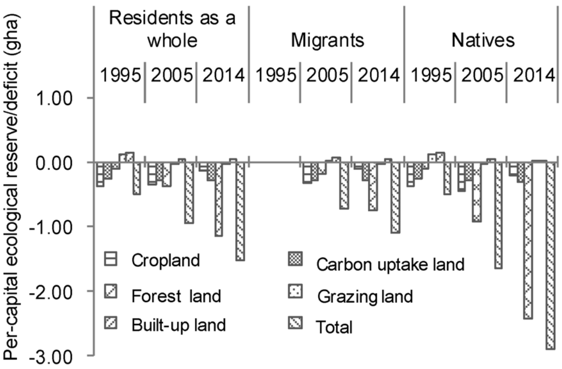

Fig. 3 Changes of per-capita ecological reserve/deficit for rural households

Massive immigration significantly deteriorated the ecological deficit of Jinqiao Village. In 2005, the per-capita ecological deficit of Jinqiao Village reached −0.96 gha. Compared to the pre-migration levels, the ecological deficit of forest land decreased sharply; the ecological reserve of grazing land decreased to ecological deficit; the ecological deficits of cropland, carbon uptake land, and built-up land remained mostly unchanged. In 2005, for migrants, the overall per-capita ecological deficit reached −0.73 gha; the ecological reserves of grazing land and built-up land were 0.01 gha and 0.05 gha, respectively; the ecological deficits of cropland and forest land were 0.33 gha and 0.18 gha, respectively. The natives had the most severe ecological deficit, with a per-capita ecological deficit of 1.65 gha. In particular, the deficit of forest land reached 0.93 gha and that of cropland continued to worsen, increasing to 0.45 gha. The ecological reserves of grazing land and built-up land also decreased by 0.14 gha and 0.08 gha, respectively.

By 2014, the per-capita ecological deficits of Jinqiao Village as a whole, migrants, and natives continued to increase, reaching −1.54 gha, −1.12 gha, and −2.91 gha, respectively. The implementation of the CFFP led to a rapid increase of the EFp of forest land, further worsening the per-capita ecological deficit of woodland. The per-capita forest land ecological deficits of Jinqiao Village as a whole, migrants, and natives reached −1.15 gha, −0.77 gha, and −2.43 gha, respectively. For cropland, compared to the situation in 2005, the per-capita ecological deficit was abated, as evidenced by the data showing that the per-capita deficits decreased by 0.22 gha, 0.22 gha, and 0.25 gha for Jinqiao Village as a whole, migrants, and natives, respectively.

Overall, the ecological environmental pressure increased constantly with the resettlement of a massive number of immigrants in the research area, as indicated by the fact that the per-capita ecological deficit increased from −0.52 gha and turned into a deficit of −1.54 gha. The per-capita ecological deficit for cropland demonstrated a trend that first increased and then decreased, whereas the per-capita deficit of forest land constantly increased. The surpluses of grazing land and built-up land rapidly declined in 1995–2005, slowly declined in 2005–2014, and are currently at a surplus threshold level. Despite the greater per-capita BC for natives than for migrants, the excessively higher per-capita EFp of natives directly resulted in a per-capita ecological deficit more severe than that of migrants.

4.4 Analysis of influential factors

4.4.1 Selection of variables

Based on the reasoning behind the STIRPAT model, the influential factors of environmental pressure include population, economic activity, technology, political and economic regulations, attitude, and religion (Waggoner and Ausubel, 2002; Xu et al., 2005). Related studies have concluded that consumption modes and means of livelihood can be used to characterize economic activity, and social assets can be used to characterize political and economic regulations, attitudes, and religions (Zhao et al., 2012). Combined with the above conclusions, the EF of rural households was used to measure environmental pressure in this study. In addition, population, affluence, consumption modes, and means of livelihood were used as explanatory variables to establish a STIRPAT model. Family size was selected to represent the population factor. Per-capita agricultural income, per-capita nonagricultural income, and per-capita cropland area were selected to represent the affluence factor. Per-capita consumption levels and the household Engel coefficient were used to represent the consumption level and consumption structure. The proportion of household labor engaged in nonfarm activities represented the means of livelihood of a household. The causes of ecological environmental pressure generated by rural households were analyzed to seek countermeasures for sustainable development of different types of rural household. Descriptions of various indicators are presented in Table 1.

4.4.2 Causes of ecological environmental impact of rural households

Using the STIRPAT model to analyze the mechanisms of environmental pressures exerted by rural households, we calculated the *F*-statistic of the model as 17.18 and the degree of fit was 0.65 for Jinqiao Village as a whole, the *F*-statistic for the migrants was 14.31 and the degree of fit was 0.70, and the *F*-statistic for the natives was 8.53, with the degree of fit as 0.82 (Table 2). The equations of all three models had a satisfactory fit.

In terms of consumption-related factors, the nonstandardized coefficients for the family sizes of Jinqiao Village as a whole, as well as migrants and natives were 0.73, 0.97, and 0.14, respectively. This indicates that the larger the family size was, the more severe the environmental degradation was. Pretty and

Table 1 Indicators used for analysis of per-capita EF (influential factors)

Indicator	Metric description
Family size, FS (person)	Number of people permanently living in a rural household
Per-capita agricultural income, PCAI (CNY/year)	Mainly includes income sources such as crops and economic plants, poultry and livestock, and forestry
Per-capita nonagricultural income, PCNAI (CNY/year)	Mainly includes income sources such as off-village employment, nonagricultural business, and government stipends
Per-capita cropland area, PCALA (hm^2/year)	Area of cropland possessed by a rural household per family member
Per-capita consumption, PCC (CNY/year)	Reflects the living consumption level of rural households
Household Engel coefficient, HEC (%)	Proportion of a rural household's expenditure for food
Proportion of nonagricultural employment, PNAE (%)	Proportion of family members employed in secondary or tertiary industries in a household

Table 2 Mechanisms of environmental pressures exerted by rural households

Indicator	Jinqiao Village as a whole		Migrants		Natives	
	Nonstandardized coefficient	*T*-test value	Nonstandardized coefficient	*T*-test value	Nonstandardized coefficient	*T*-test value
Constant term	−6.98	−6.44***	−5.72	−5.17***	−8.12	−1.57*
FS	0.73	3.65***	0.97	4.82***	0.14	0.20
PCAI	0.01	0.29	0.01	0.31	0.21	1.65*
PCNAI	−0.01	−0.02	−0.06	−0.70	−0.10	−1.00
PCALA	0.17	2.31**	0.22	3.12***	0.04	−0.14
PCC	0.84	8.34***	0.70	7.26***	1.37	3.13***
HEC	−0.15	−1.38*	−0.18	−1.53*	−0.07	−0.23
PNAE	−0.04	−0.36	−0.02	−0.17	−0.03	−0.15
R^2	0.65		0.70		0.82	
F-statistic	17.18		14.31		8.53	

* significance level of 0.1; ** significance level of 0.05; *** significance level of 0.01

Ward (2001), Xu et al. (2005), and Long et al. (2006) pointed out that population is the main factor driving change in EF. Zhao et al. (2012) revealed a positive correlation between family size and environmental pressure. This correlation can be attributed to the fact that larger populations result in a greater demand for land use and a greater consumption of goods, thus causing an increase of ecological pressure. In the research area of this study, large-scale migrant resettlement was the major factor causing continued deterioration of the ecological environment in Jinqiao Village. Population control and reasonable estimation of suitable population-carrying capacities of resettlement zones might be effective approaches to alleviate environmental pressure and maintain sustainable development of immigration areas.

From the perspective of the affluence factor, per-capita agricultural income and cropland resource possession both showed a positive correlation with environmental pressure, whereas nonagricultural income had a negative correlation with environmental pressure. These results can be explained from two aspects. On the one hand, if rural household income mainly comes from agriculture activities, the increase of household income would indicate an increased rate of land use and reclamation, which results in increased intensity of land use and inevitably increases the pressure on the ecological environment. On the other hand, nonagricultural income reduces the dependence of rural households on the land and decreases land use and reclamation rate. Thus, an increase of nonagricultural income would impede the growth of EF. The per-capita cropland deficits for Jinqiao Village as a whole, as well as for migrants and natives, showed a remarkable increase because of large-scale land reclamation in the early stages of migration policy implementation (1995–2005). In the middle and late stages, the livelihood means of rural families changed, and an increasing number of residents chose to leave the village for work, instead of farming on their own land. In addition, with the implementation of CFFP in China, farmers chose to give up a portion of their sloped farmland to receive more state subsidies, leading to a decrease of cropland and a constant increase of forest land in the research area. This directly resulted in the reduction of the per-capita EF for cropland and an increase for forest land correspondingly. In addition, the per-capita ecological deficit of cropland changed from an increasing trend to a decreasing trend, whereas the per-capita forest land deficit constantly increased.

In terms of consumption-related factors, for each unit of increase in per-capita consumption, the per-capita EF of the Jinqiao Village residents as a whole, migrants, and natives increased by 0.84, 0.70, and 1.37, respectively, and the results are statistically significant. Per-capita consumption is an important influential factor of the per-capita EF. An increase in per-capita consumption indicates increased demands for food, residence, and travel, along with greater consumption and pollutant emission. The increased per-capita household consumption has generated the greatest pressure and challenge in sustainable family development. Our survey data showed that in 2014, natives' per-capita consumption level was 1.75 times that of migrants, which might be the primary reason for the overall higher EF of natives. The Engel coefficients for Jinqiao Village as a whole, migrants, and natives all showed a statistically significant negative correlation with environmental pressure. The Engel coefficient represents the structure of household consumption; the smaller the coefficient, the smaller the proportion of income spent on food. The change in the consumption structure of residents also contributed to a greater pressure on the environment.

From the perspective of means of livelihood, the environmental pressure decreased by 0.04, 0.02, and 0.03 units, respectively, with every 1-unit increase in the proportion of family members engaged in nonagricultural employment for Jinqiao Village as a whole, migrants, and natives. This indicates that the diversified nonagricultural means of livelihood of rural households not only reduced the fragility of livelihood and reduced the threat posed by natural disasters, but also allowed rural residents to search for living consumption modes that were more suitable, thus increasing their responsiveness to ecological environmental changes and effectively reducing the environmental pressure (Shackleton et al., 2007). Yan et al. (2006) and Hao et al. (2015) stated that means of livelihood is a key factor affecting the ecological environment. Increasing nonagricultural employment opportunities can relieve the environmental impact. In Jinqiao Village, with the development of the economic market in China, rural residents have more opportunities to work outside the village, directly reducing their degree of dependence on land resources and reducing the impact of the increasing population on the local environment. Therefore, changing the means of livelihood is an effective way to avoid the high ecological environmental pressure that might be exerted by the uniform agricultural means of livelihood.

5 Conclusions

Using the survey data of the three naturally formed resident groups, Jinqiao Village residents as a whole, migrants, and natives, in the research area, a production-based EF model was applied in this study to measure the per-capita EF, per-capita BC, and per-capita ecological reserve/deficit values in 1995, 2005, and 2014. In addition, quantitative analyses of the EF, BC, and ecological reserve/deficits were conducted for each type of biologically productive land. The results show that in the past 20 years of eco-migration policy implementation, regardless of whether referring to Jinqiao Village as a whole, migrants, or natives, the EF constantly increased, BC decreased, and the ecological environmental pressure increased. These findings indicate that large-scale migration exerted a negative impact on the local ecological environment.

Among different types of biologically productive land, cropland and forest land are the most important components of per-capita EF, together accounting for more than 80% of the total per-capita EF. In the last 20 years of migration policy implementation, the per-capita EF, per-capita BC, and per-capita ecological deficit of cropland demonstrated basic trends of increase, at first, followed by decrease. For forest land, the per-capita EF and per-capita ecological deficit constantly increased, whereas the per-capita BC first decreased and then increased. The per-capita EF for grazing land remained relatively stable, but the constant decrease in per-capita BC resulted in the ecological reserve of grazing land currently reaching its threshold. The per-capita EF of built-up land constantly increased, but a constant decline in BC resulted in the ecological reserve of built-up land currently being at its threshold level. Since the implementation of migration policies, the compositional structures of the per-capita EF and the per-capita BC of Jinqiao Village residents as a whole, migrants, and natives, have changed drastically. The contribution of each land use type to the per-capita EF changed from an order of cropland > forest land > fossil fuel land > grazing land > built-up land to an order of forest land > cropland > fossil fuel land > built-up land > grazing land. Because of unequal allocation of biologically productive land resources, the overall per-capita EF, overall per-capita BC, overall per-capita ecological deficit, and the EF components of migrants were lower than those of the natives, indicating that the per-capita ecological deficit of natives is more severe than that of migrants.

The major factors resulting in increased ecological environmental pressure were: expanded population, due to large-scale migration; increased grazing land reclamation for the purpose of increasing agricultural income and cropland area; increased consumption demand. The increases of nonagricultural income and nonagricultural employment and the optimization of consumption structure can reduce the dependency of rural residents on the land, thus impeding EF growth and effectively relieving ecological environmental pressure. Thus, policy makers and implementers can relieve the environmental pressure caused by eco-migration through population control strategies and reasonable estimation of population carrying capacities of resettlement areas. Meanwhile, promoting change of the means of livelihood of rural residents from uniform agricultural means to nonagricultural means can prevent the high ecological environmental pressure exerted by the uniform agricultural means.

References

Alix-Garcia JM, Mcintosh C, Sims KRE, et al., 2010. The ecological footprint of poverty alleviation: evidence from Mexico's Oportunidades program. *Social Science Electronic Publishing*, 95(2):417-435.

Bachour B, Dong W, 2006. Socioeconomic impact of urban redevelopment in inner city of Ningbo. *Journal of Zhejiang University-SCIENCE A*, 7(8):1386-1395. https://doi.org/10.1631/jzus.2006.A1386

Barbier EB, 2010. Poverty, development, and environment. *Social Science Electronic Publishing*, 15(12):635-660.

Bates DC, 2002. Environmental refugees classifying human migrations caused by environmental change. *Population and Environment*, 23(5):465-477. https://doi.org/10.1023/A:1015186001919

Becchetti L, Rossetti F, Castriota S, 2010. Real household income and attitude toward immigrants: an empirical analysis. *The Journal of Socio-Economics*, 39(1):81-88. https://doi.org/10.1016/j.socec.2009.07.012

Borucke M, Moore D, Cranston G, et al., 2013. Accounting for demand and supply of the biosphere's regenerative capacity: the national footprint accounts' underlying methodology and framework. *Ecological Indicators*, 24: 518-533. https://doi.org/10.1016/j.ecolind.2012.08.005

Cavendish W, 2000. Empirical regularities in the poverty-environment relationship of rural households: evidence from Zimbabwe. *World Development*, 28(11):1979-2003. https://doi.org/10.1016/S0305-750X(00)00066-8

Chang B, Xiong L, 2005. Ecological footprint analysis based on RS and GIS in arid land. *Journal of Geographical Sciences*, 15(1):44-52. https://doi.org/10.1007/BF02873106

Chen Y, Ge Y, 2015. Spatial point pattern analysis on the villages in China's poverty-stricken areas. *Procedia Environmental Sciences*, 27:98-105. https://doi.org/10.1016/j.proenv.2015.07.098

CPAD (The State Council Leading Group Office of Poverty Alleviation and Development), 2011. The Outline for Development Oriented Poverty Reduction for China's Rural Areas (2011-2020). State Council, China.

Duraiappah AK, 1998. Poverty and environmental degradation: a review and analysis of the nexus. *World Development*, 26(12):2169-2179. https://doi.org/10.1016/S0305-750X(98)00100-4

Ehrlich PR, Holdrens JP, 1971. The impact of population growth. *Science*, 171(3977):1212-1217. https://doi.org/10.1126/science.171.3977.1212

Ezra M, 2003. Environmental vulnerability, rural poverty, and migration in Ethiopia: a contextual analysis. *Genus*, 59(2):63-91.

Ferng JJ, 2009. Applying input–output analysis to scenario analysis of ecological footprints. *Ecological Economics*, 69(2):345-354. https://doi.org/10.1016/j.ecolecon.2009.08.006

Ferrol-Schulte D, Wolff M, Ferse S, et al., 2013. Sustainable livelihoods approach in tropical coastal and marine social–ecological systems: a review. *Marine Policy*, 42(14):253-258. https://doi.org/10.1016/j.marpol.2013.03.007

Finco MVA, 2009. Poverty-environment trap: a non linear probit model applied to rural areas in the north of Brazil. *American-Eurasian Journal of Agricultural & Environmental Science*, 5(4):533-539.

Fox J, Vogler JB, Poffenberger M, 2009. Understanding changes in land and forest resource management systems: Ratanakiri, Cambodia. *Tonan Ajia Kenkyu*, 47(3):309-329.

Fu W, Zhao JQ, Du GZ, 2013. Ecological safety analysis of the northwest region of China based on the ecological footprint and environmental Kuznets curve. *China Population Resources and Environment*, 23(5):107-110 (in Chinese).

González-Vallejo P, Marrero M, Solis-Guzman J, 2015. The ecological footprint of dwelling construction in Spain. *Ecological Indicators*, 52:75-84. https://doi.org/10.1016/j.ecolind.2014.11.016

Guo HW, Yan LJ, 2016. The application of city development index and ecological footprint in the assessment of sustainable development of China's municipalities. *Acta Ecologica Sinica*, 36(14):1-10.

Hao HG, Zhang JP, Li XB, et al., 2015. Impact of livelihood diversification of rural households on their ecological footprint in agro-pastoral areas of northern China. *Journal of Arid Land*, 7(5):653-664. https://doi.org/10.1007/s40333-015-0049-5

Hou CX, Zhao XY, Wen Y, et al., 2015. Spatial disparities and the peasant household consumption on environment: based on the survey data of Zhangye city in 2010. *Acta Ecologica Sinica*, 35(6):2013-2019.

Hrabovszky JP, Miyan K, 1987. Population growth and land use in Nepal 'the great turnabout'. *Mountain Research & Development*, 7(3):264-270. https://doi.org/10.2307/3673203

Huang ZH, Lu BX, Chen XX, 2001. Migration of surplus agricultural labor in the process of economic transition. *Journal of Zhejiang University-SCIENCE*, 2(2):220-226. https://doi.org/10.1631/jzus.2001.0220

Li P, Sun ZB, Fang JP, et al., 2015. The sustainable development assessment in Tibet based on the dynamic analysis of ecological footprint. *Journal of Soil and Water Conservation*, 29(6):327-331 (in Chinese).

Li Z, Ju MT, Liu W, et al., 2007. Dynamic measurement of ecological footprint of energy resources and its economic efficiency in last ten years, China. *Resources Science*, 29(6):54-60 (in Chinese).

Liang LT, Zhai B, 2015. Environmental impacts of farmer households' land use behaviors via the methods of PRA and LCA. *China Land Science*, 29(5):84-92 (in Chinese).

Lin D, Hanscom L, Martindill J, et al., 2016. Working Guidebook to the National Footprint Accounts, 2016 Edition. Global Footprint Network, Oakland, USA.

Long AH, Xu ZM, Wang XH, et al., 2006. Impacts of population, affluence and technology on water footprint in China. *Acta Ecologica Sinica*, 26(10):3358-3367.

Morrissey JW, 2013. Understanding the relationship between environmental change and migration: the development of an effects framework based on the case of northern Ethiopia. *Global Environmental Change*, 23(6):1501-1510.
https://doi.org/10.1016/j.gloenvcha.2013.07.021

Mostafa MM, 2010. A Bayesian approach to analyzing the ecological footprint of 140 nations. *Ecological Indicators*, 10(4):808-817.
https://doi.org/10.1016/j.ecolind.2010.01.002

Myers N, 1997. Environmental refugees. *Population and Environment*, 19(2):167-182.
https://doi.org/10.1023/A:1024623431924

Myers N, 2002. Environmental refugees: a growing phenomenon of the 21st century. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 357(1420):609-613.
https://doi.org/10.1098/rstb.2001.0953

Ocello C, Petrucci A, Testa MR, et al., 2014. Environmental aspects of internal migration in Tanzania. *Population & Environment*, 37(1):1-10.

Ozturk I, Al-Mulali U, Saboori B, 2016. Investigating the environmental Kuznets curve hypothesis: the role of tourism and ecological footprint. *Environmental Science and Pollution Research*, 23(2):1916-1928.
https://doi.org/10.1007/s11356-015-5447-x

Pretty J, Ward H, 2001. Social capital and the environment. *World Development*, 29(2):209-227.
https://doi.org/10.1016/S0305-750X(00)00098-X

Raleigh C, 2011. The search for safety: the effects of conflict, poverty and ecological influences on migration in the developing world. *Global Environmental Change*, 21(S1): S82-S93.
https://doi.org/10.1016/j.gloenvcha.2011.08.008

Rice J, 2007. Ecological unequal exchange: international trade and uneven utilization of environmental space in the world system. *Social Forces*, 85(3):1369-1392.
https://doi.org/10.1353/sof.2007.0054

Shackleton CM, Shackleton SE, Buiten E, et al., 2007. The importance of dry woodlands and forests in rural livelihoods and poverty alleviation in South Africa. *Forest Policy & Economics*, 9(5):558-577.
https://doi.org/10.1016/j.forpol.2006.03.004

Shen G, Chen Y, Xue C, et al., 2015. Pollutant emissions from improved coal- and wood-fuelled cookstoves in rural households. *Environmental Science & Technology*, 49(11):6590-6598.
https://doi.org/10.1021/es506343z

Thornton A, Ghimire DJ, Mitchell C, 2012. The measurement and prevalence of an ideational model of family and economic development in Nepal. *Population Studies*, 66(3):329-345.

Trier T, Turashvili M, 2007. Resettlement of Ecologically Displaced Persons Solution of a Problem or Creation of a New Eco-migration in Georgia 1981-2006. ECMI European Centre for Minority Issues, Flensburg, Germany.

Wackernagel M, Onisto L, Bello P, et al., 1999. National natural capital accounting with the ecological footprint concept. *Ecological Economics*, 29(3):375-390.

Waggoner PE, Ausubel JH, 2002. A framework for sustainability science: a renovated IPAT identity. *Proceedings of the National Academy of Sciences*, 99(12):7860-7865.
https://doi.org/10.1073/pnas.122235999

Wang W, Zhang M, 2015. Direct and indirect energy consumption of rural households in China. *Natural Hazards*, 79(3):1693-1705.
https://doi.org/10.1007/s11069-015-1921-5

Wu XT, Zheng HW, Liu YZ, 2013. Jiangsu's city-level ecological footprint variance based on energy values. *Resources & Industries*, 15(5):138-144 (in Chinese).

Xi X, Qiao YB, Wu KP, et al., 2015. The selection of metropolises or towns in urbanization in the perspective of sustainable development: based on the research of the international ecological footprint panel data. *China Population Resources and Environment*, 25(2):47-56 (in Chinese).

Xiao JH, Wang M, Yu QD, et al., 2015. The evaluation models of ecological compensation standard on the large-scale hydropower engineering construction based on ecological footprint: a case of Three Gorges Project. *Acta Ecologica Sinica*, 35(8):2726-2740.

Xie G, Lu C, Cheng S, et al., 2001. Evaluation of natural capital utilization with eco-logical footprint in China. *Resources Science*, 6:20-23 (in Chinese).

Xu ZM, Cheng GD, Qiu GY, 2005. ImPACTS identity of sustainability assessment. *Acta Geographica Sinica*, 60(2):198-208.

Yan JZ, Zhang YL, Zhu HY, et al., 2006. Residents' response to environmental degradation: case studies from three villages in the upper Dadu river watershed. *Acta Geographicl Sinica*, 61(2):146-156 (in Chinese).

York R, Rosa EA, Dietz T, 2002. Bridging environmental science with environmental policy: plasticity of population, affluence, and technology. *Social Science Quarterly*, 83(1):18-34.
https://doi.org/10.1111/1540-6237.00068

Yuan SF, Yang LX, Yang GS, et al., 2013. The spatial heterogeneity of socio-economic driving factors land conversion: a case based on STIRPAT and GWR models. *Economic Geography*, 33(5):137-143 (in Chinese).

Zhao XY, 2013. Environmental impact of different livelihood strategies of farmers: a case of the Gannan plateau. *Scientia Geographica Sinica*, 33(5):545-552.

Zhao XY, Hou CX, Lu HL, et al., 2012. Analysis of farmer's social capital characteristics in Tibetan area: a case study in Gannan Tibetan Autonomous Prefecture. *China Population Resources and Environment*, 22(12):101-107 (in Chinese).

中文概要

题　目：生态移民的环境影响研究——以广西移民迁入区为例

目　的：生态移民在改善迁出区生态环境的同时，也改变了迁入区资源环境配置格局。客观评价大量生态移民涌入给迁入区造成的生态系统压力，对生态移民政策的可持续推进及新形式下解决脱贫和生态环境保护问题有重要意义。

创新点：从微观农户尺度，采用生产性生态足迹评价移民迁入区生态移民工程的生态环境影响。

方　法：1. 基于参与式农户调查方法，获取移民迁入区移民和当地驻民的生态足迹账户、土地利用及农户家庭等基本信息；2. 采用生产性生态足迹评价移民迁入区生态移民工程的生态环境影响；3. 构建“STIRPAT”模型，分析移民迁入区生态环境变化的影响因素。

结　论：1. 大规模移民的迁入对移民安置区的生态环境造成持续压力；2. 人口规模扩大、荒草地开垦以及消费需求增长是造成移民迁入区生态环境压力的主要原因；3. 合理测算移民迁入区人口承载力、促进农户生计转型和增加农户生计多样化可以有效缓解生态移民对生态环境的巨大压力。

关键词：生态移民；生态足迹；移民迁入区；广西