

## Research Article

### Effects of Impoundment on Land Resources, Population, Agricultural Production and Immigrants Living Environment in the Three Gorges Reservoir, China

Li Ma<sup>1\*</sup>, Li-zhong Xia<sup>1</sup>, Lin-zhang Yang<sup>1,2</sup>, Yun-dong Li<sup>1</sup>

<sup>1</sup>State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences, Nanjing 210008, China

<sup>2</sup>Institute of Agricultural Resources and Environmental Sciences, Jiangsu Academy of Agricultural Sciences, Nanjing 210014, China

\*Corresponding author: Dr. Li Ma, Institute of Soil Science, Chinese Academy of Sciences (CAS), 71 Beijing East Road, Nanjing, 210008, Jiangsu Province, P. R. China, Tel: 86-25-86881329; Email: lma@issas.ac.cn

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## Abstract

Little information on the influences of impoundment and resettlement on population, agricultural production and farmers living environment in rural areas is available after of the Three Gorges Project (TGP) was built for ten years. Based on the investigation to immigrant households in the areas of head part of the Three Gorges Reservoir (TGR) including Zigui, Xingshan, Badong County and Yiling District, the effects of impoundment on cultivated land resources, population, agricultural production and ecological environment were analyzed in this paper. The results showed that total population of the selected counties and towns in study areas were reduced during the resettlement of immigrants; The immigrants influenced by impoundment were generally resettled properly, and decrease of labor resources in rural area were not significant; During construction and impoundment of the TGP, cultivated lands in the low altitudes area were submerged, total land resources in reservoir area were significant declined and thus further intensify the human-land conflict; Under the decrease of cultivated land and the per capita cultivated land, cultivated areas and yield of grain, citrus and vegetable in Zigui County maintained growth trends. After impoundment and resettlement, the residential environment, housing, living and traffic conditions were improved, and resettlement policies were well implemented; In the area of head part of the TGR, most of the immigrants were filled with confidence for the future and supported the construction of the TGP; The residential environment, housing, living and traffic conditions were improved after resettlement, but the ecological environment in rural areas were significant affected. An increase in the natural disasters, plant diseases and insect pests were observed. The waste disposal facilities in rural areas were also deficiency.

**Keywords:** Three Gorges Reservoir; TGR; Impoundment; Resettlement; Population; Land resources; Living environment; Satisfaction level

## Introduction

The Three Gorges Project (TGP) has a huge comprehensive benefit of the flood control, power generation, navigation, and plays an important role in the economic and social sus-

tainable development in China [1]. The Three Gorges Reservoir (TGR) refers to a specific area involves 19 cities and counties of Hubei Province and Chongqing City that submerged by the impoundment scheme of 175m water level. The total area of the TGR is about 52000 km<sup>2</sup>. The area of the

head part of the TGR located in front of the TGR area including Zigui County, Xingshan County, Badong County and Yiling District of Yichang City. This area is the firstly submerged region during the impoundment of the TGP [2,3]. For a long time, the impacts of the TGP on the ecological environment had been widely concerned [4]. In June 2003, the TGP impounded the water level to 135 m, then impounded the water level to 150 m in September 2006; in 2009, the TGP was fully completed, and impound the water level to 175 m in stable operation. In recent years, the problem of involuntary resettlement caused by the large water conservancy project had being generally concerned. The TGP normal operating water level is 175m, which involving many problems such as population resettlement, cultivated land submerging, movement of cities and towns and resettlement of immigrants and so on [5,6]. The total immigrant population is about more than 1.2 million [7-9]. Since the beginning of the towns move and resettlement work, the immigration has made remarkable achievements. But more research is still required for the long-term impacts of impoundment and immigration on population, land resources and ecological environment in the area of TGR area [10-13].

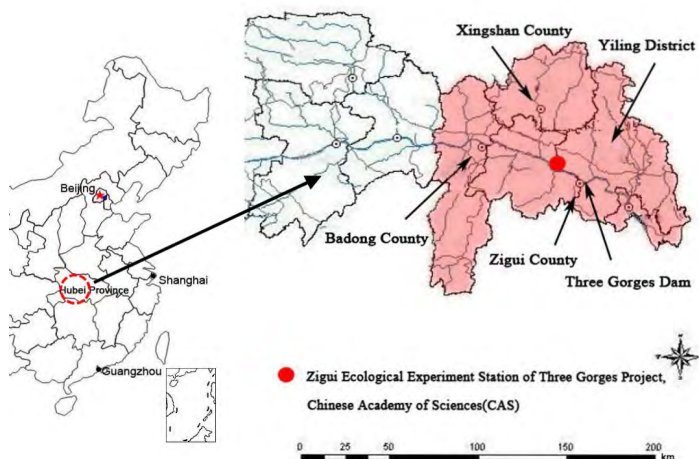
To study the long-term effects of impoundment of TGP and resettlement on the land carrying capacity, agro-ecological system and ecological environment in the TGR area, the population and labor resource, cultivated land resource, agricultural productivity in resettlement area of TGR were statistics analyzed in this study. We also carried out a questionnaire survey of satisfaction levels of local immigrants on natural conditions and ecological environment after impoundment in typical areas of the head part of the TGR. The findings in this paper are expected to yield a rational basis for future development of agriculture, ecological environment protection and improvement of peoples' living conditions in the TGR area.

## Materials and Methods

### Study area descriptions

This research was carried out at the Zigui Ecological Experiment Station of the TGP, one of the key stations of the TGP Ecology and Environment Monitoring Network. It is located at Shuitianba Town (31°3.53' N, 110°40.55' E), Zigui County, Hubei province, China, approximately 50 km up-stream of the Three Gorges Dam. A long-term work of investigation monitoring and analysis was carried out around the area of the head part of the TGR which affected by the impoundment of the TGP and resettlement (Fig. 1). The areas of head part of the TGR includes Zigui County, Xingshan County, Badong County, and Yiling District of Yichang City, Hubei Province, which the firstly submerged area of impoundment of the TGP. This area belongs to the humid subtropical monsoon climate. Over 90% of total land area is classified as hilly. The mean annual temperature ranges from 17 to 19°C; the mean annual sunshine duration

ranges from 1216 to 1884 h; the mean annual precipitation is 940.3 mm, with about 80% falling between April and October. The local soil (purple soil) is developed from purple sandstone and silt loam in texture and is classified as an Inceptisol based on the USDA soil classification system. Slope land is accounting for about 75% of the total cultivate land areas [1,2,14].



**Figure 1.** Study area of immigrant investigation in the head part of the TGR.

### Immigrants investigation and data analyses

To accurately obtain the actual situations of land resources, population, agricultural production and immigrant satisfaction in the head part of the TGR, files of agricultural statistics in each county and district from 1996 to 2007 were collected, and typical villages and towns were also selected for major investigation. Shuitianba, Guizhou, Maoping, Quyuan, Guojiaba and Shazhenxi Towns of Zigui County, Xiakou Town of Xingshan County, Taipingxi Town of Yiling District, and Yanduhe Town of Badong County were selected as the typical area. Based on the different conditions of man-land relationship and social economics in different areas, typical farm household and control household were determined during the investigation. Through field visit and questionnaire survey, 202 copies of the complete survey data was collected (Fig. 2a). Investigated immigrant households from different towns in Zigui County were accounting for 64% of all typical households (Fig. 2b). Based on the population and areas in different investigated regions, the immigrant households were divided into four types (see Table.1), of which 156 households in type A, 31 households in type B, 4 households in type C and 11 households in type D. SPSS16.0 software package was used to process the investigation data. Graphs prepared using Excel 2010 software system.

Results and discussion

Effects of impoundment on land resources in the head part of the TGR

The TGP had impounded to the water level of 175m and most of the cultivated land in low altitude area was submerged. Total area and per capita area of cultivated land in different regions of the TGR were showed in Fig.3 and Fig.4. With progress of the impoundment and resettlement, the total areas of cultivated land in Shuitianba, Guizhou and Shazhenxi Town of Zigui County were gradually decreased, especially after May, 2003 which the start time of impoundment of the TGP. The decline of the total cultivated land areas were found in Zigui County and Xinsha County. Through field investigation, a part of local villages were merged or moved during that period, a large area of slope land was reclaimed and citrus orchards in some regions were expanded. So the increasing of total cultivated land areas were found in Guojiaba and Maoping town of Zigui County and Badong County. With the reduce in total population in the head part of the TGR, per capita land area in Guizhou and Shazhenxi Town of Zigui County increased to some extent, but it was an inevitable trend that the total available land resources decline for the impoundment of the TGP.

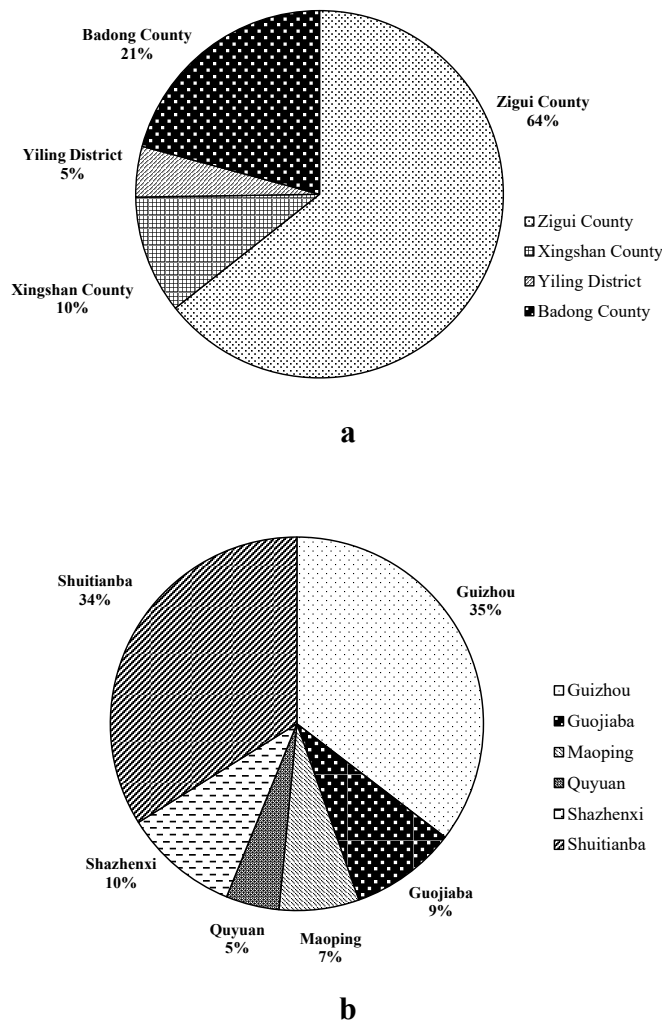


Figure 2. Distribution of investigated immigrant households in the head part of the TGR.

Table 1. Four types of investigated immigrant households in area of head part of the TGR.

Types	A	B	C	D
Status	Non-immigrants (Control)	House and field were both submerged during impoundment of the TGP	Only field were submerged during impoundment of the TGP	Only house were submerged during impoundment of the TGP

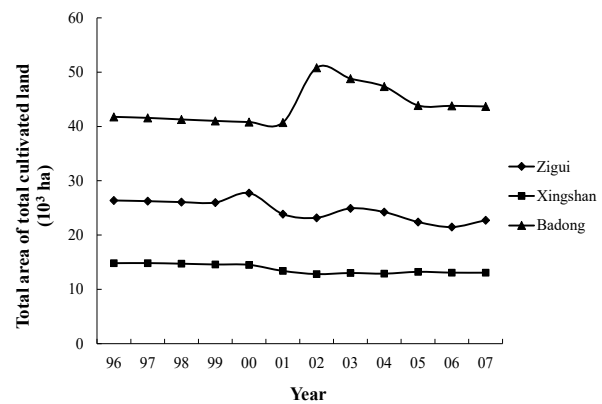
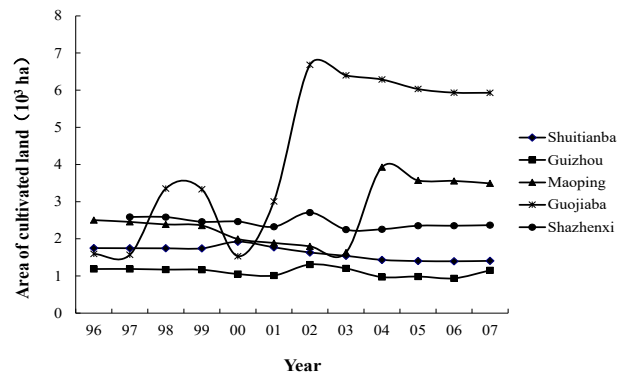
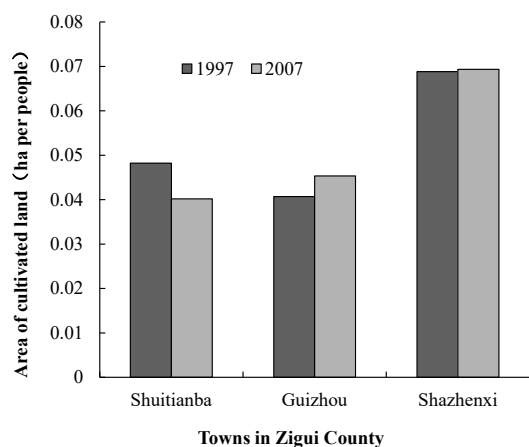
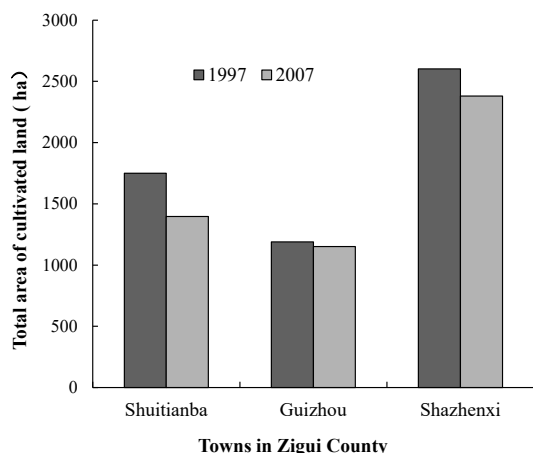
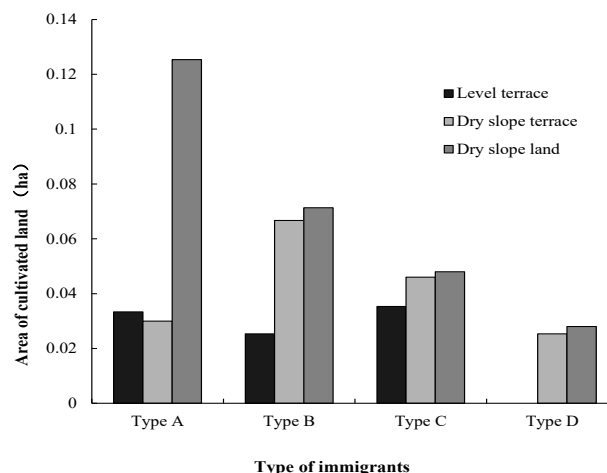
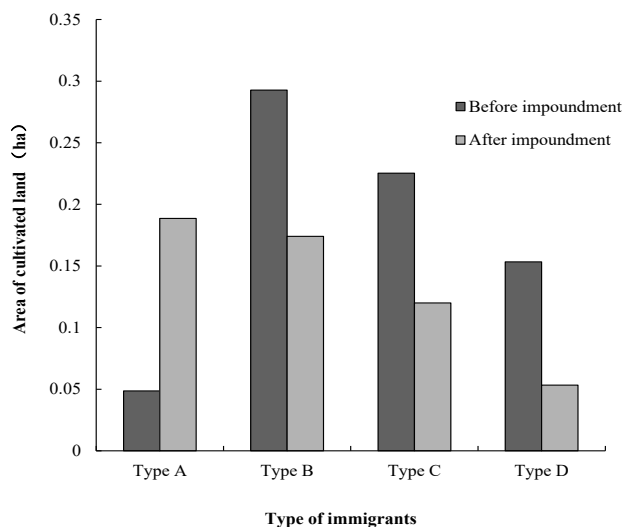


Figure 3. Changes of cultivated land in the head part of the TGR during immigrants resettlement.



**Figure 4.** Changes of land resources in Zigui County before and after impoundment.



**Figure 5.** Changes of cultivated land of investigated immigrant households in the head part of the TGR during immigrants resettlement.

According to the statistical results of the land resources of immigrant households in study areas, the cultivated land area of immigrant households (Type A, B and C) decreased after resettlement (Fig. 5), which resulted in decrease of the agricultural productivity in rural area and reducing of farms economic income. At present, the contradiction between human and land in the head part of the TGR was more serious. For the three types of cultivated land, the largest proportion of land area was observed in arable slope land and slope terrace secondly, the area of level terrace was the minimum. The TGR was located in the mountain areas in central China and available cultivated land widely distributed on the hillside. A part of level land located in low altitude area was submerged after impoundment, which led to the lack of cultivated land resource in this area. On the whole, part of the cultivated land was submerged for the reservoir impoundment and the absolute number of land resources declined in the TGR area; the contradiction between human and land may become more serious in the future and some reasonable land exploitation measures and effective resettlement methods should be taken to further solve the problems [15].

**Effects of impoundment on the population and labor resources in the head part of the TGR**

Since the resettlement work started in 1996, the populations in three counties and four towns of Zigui County had the different degrees of decline (Fig.6 and Fig. 7). Most of the population reduction were the residents in submerged area. This part of population moved out from reservoir areas as the immigrants [16]. There were also many latter resettled immigrants moved to the high altitude areas above submerged areas. With the resettlement work carried out steadily, the population of different counties and towns steady declined. According to the

macroscopic statistics, compared with the population in 1996, the population in 2007 in Zigui, Xingshan, and Badong County was decreased by about 41,100 (11.27%), 12,900 (8.46%) and 8,400 (1.9%), respectively, but the population actual influenced by immigration and impoundment of the TGP may be larger than these numbers. Compared with the reduction of total population, decrease of the labor population (18 years old or above) was not notable, and the labor population in Shuitianba and Maoping Town of Zigui County and Badong County increased to a certain extent.

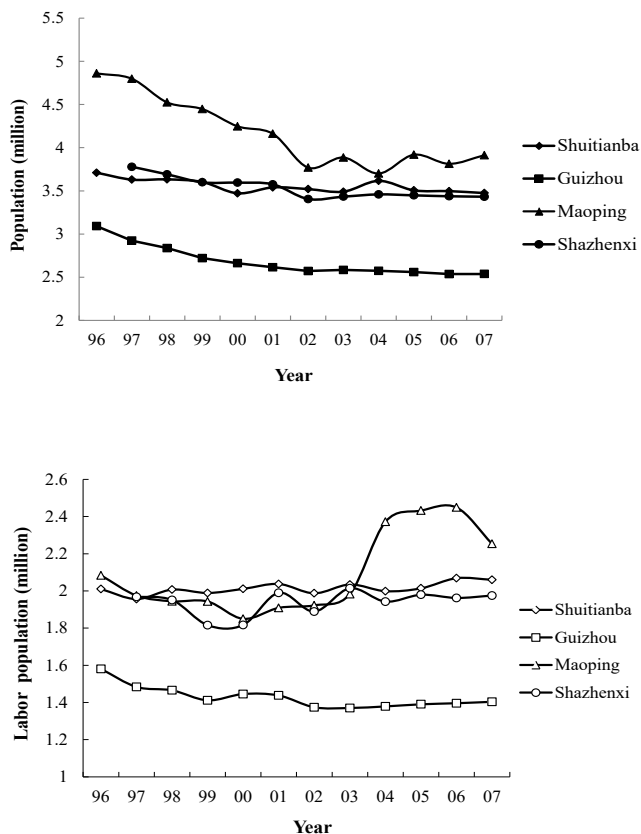


Figure 6. Changes of population and labor resources in Zigui County during immigrants resettlement.

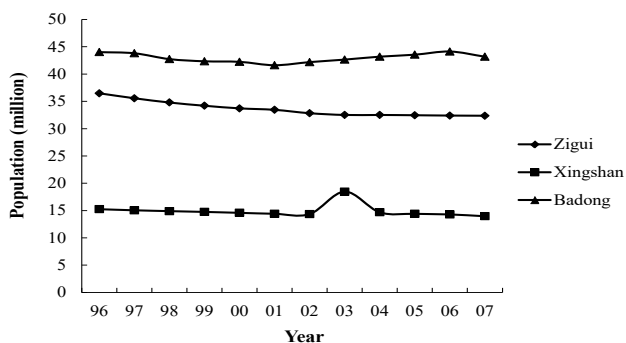


Figure 7. Changes of population and labor resources of 3 counties in the head part of the TGR during immigrant resettlement.

For impoundment and resettlement in the head part of the TGR involved a wide range areas and a large population, it was difficult to collect the data and statistics. Part of data in some towns and some years was missed, and also some unusual values were collected. But based on the available precise data, the overall trend of populations in different regions of this area were clear reflected. The maximum resettled population numbers were observed in immigrant households (Type B) and immigrant households (Type C) secondly with average 3-4 peoples per family; average 2-3 peoples per family were resettled in immigrant households (Type D). The survey results generally conformed to local actual situation. Generally, the populations influenced by impoundment in the head part of the TGR were properly resettled by moving outward and upward from the submerged areas.

**Effects of impoundment on the productivity of agricultural land in the head part of the TGR Grain cultivated area and yield**

Based on the agricultural statistics in Zigui, Xingshan and Badong County in the head part of the TGR during the period of ten years (Fig. 8 and Fig. 9), grain cultivated area decreased to a certain degree in five towns of Zigui County and in three counties, but a part of the investigated counties or towns exist fluctuations. Affected by the immigrant and impoundment of the TGP, total grain yield in each county reduced after 2002, and then maintained a stable level. Total grain yield related to the land fertility and rural labor force resources. The main reason of grain yield reduce was water submerging of farmland and immigrant resettlement. But grain yield in each county and town in the head part of TGR still remained stable during impoundment of the TGP.



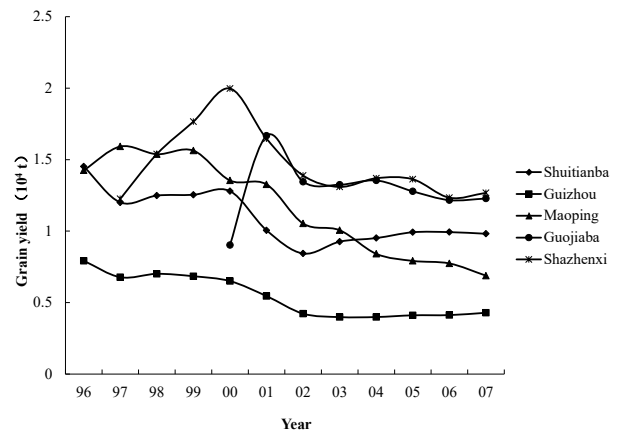
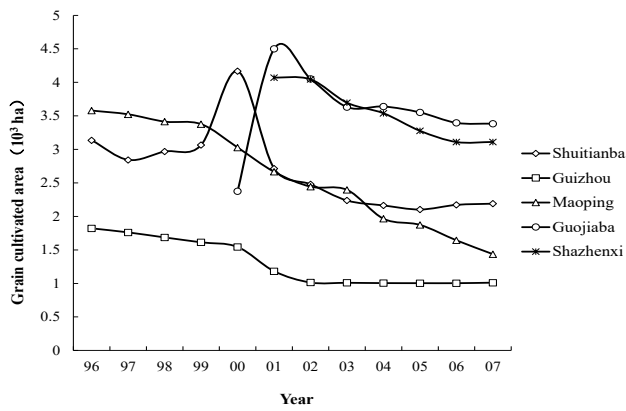


Figure 9. Changes of grain yield in the head part of the TGR during impoundment.

Citrus cultivated area and yield

Citrus is one of the pillar industries of Zigui County. According to local agricultural statistics (Fig. 10), citrus cultivated area and yield increased year after year since 1996 in each towns of Zigui County. Compared with the data in 1996, the total cultivated area and yield of citrus in 2007 increased by 1.34 and 0.7 times, respectively. The expansion of the citrus orchard, improvement of citrus varieties and increasing inputs of fertilizer and pesticide, made local citrus production development rapidly in recent years. After impoundment of the TGP, many high quality citrus orchards in low altitude areas were submerged and the citrus production in this area was impacted greatly. But thanks to the adjustment of agriculture industry structures and implementation of regional citrus industry strategies, the scale of citrus production in this area was fast enlarged instead. So the advantage industry in Zigui County was not notable affected during impoundment of the TGP.

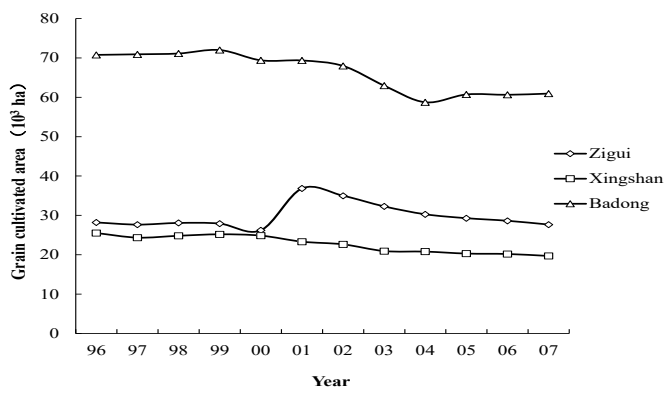
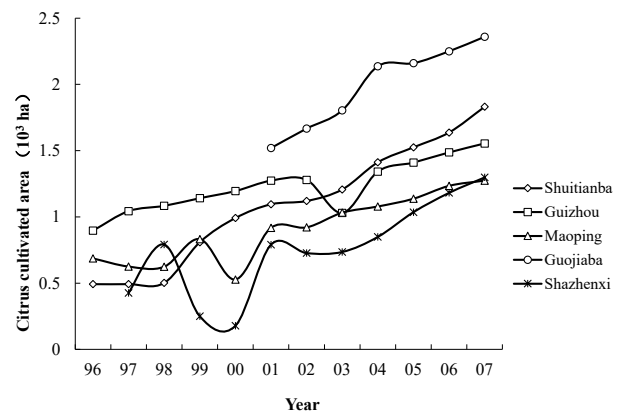
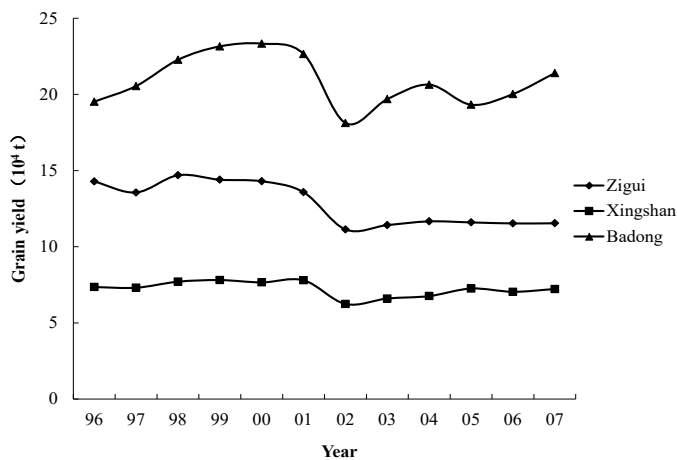
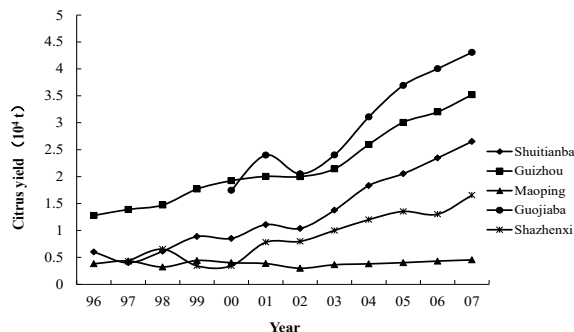


Figure 8. Changes of grain cultivated area in the head part of the TGR during impoundment.

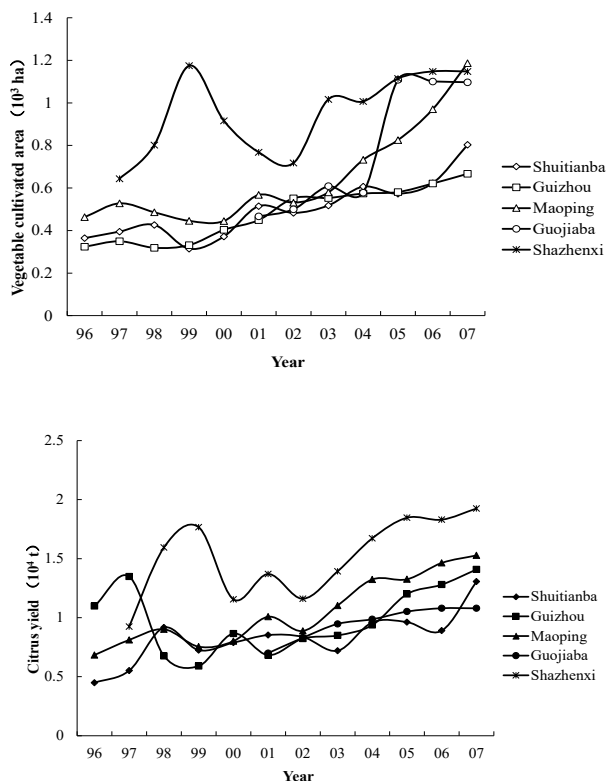




**Figure 10.** Changes of citrus cultivated area and yield in Zigui County during impoundment.

### Vegetables planting area and yield

During the resettlement and impoundment, vegetable cultivated area and yield in each towns of Zigui County had a clear ascendant trend (Fig. 11). Vegetable planting area and yield was positively related. Total vegetables area in Zigui County was less than citrus area, but was not notable affected by resettlement and impoundment. The expansion of the vegetable field, increasing inputs of fertilizer and pesticide and improvement of vegetable varieties, still made vegetable production improved in study areas.



**Figure 11.** Changes of vegetable cultivated area and yield in Zigui County during impoundment.

## Survey of immigrant satisfaction level in the head part of the TGR

### Satisfaction level of human settlement conditions

The construction process of the TGP lasted for a long time, a special social group ‘the involuntary resettlements’ in the TGR areas were influenced. After the original life environment and economic conditions changed, the psychological pressure and distress of involuntary resettlements may become serious [17]. To truly reflect the actual satisfaction level of resettlement in the head part of the TGR, sampling questionnaire survey was used in this research, and percentages of the immigrants with different attitudes accounting for the total survey sample size were calculated and listed.

According to the survey results, overall evaluation of the investigated immigrants to the human settlements conditions in rural area was good. 65.17% of the investigated immigrants thought that residential conditions became better; 61.19% of the investigated immigrants considered that dwelling surroundings became better; 45.27% of the investigated immigrants thought that living conditions became better, but there were still 20.4% people believed that living conditions became worse; 52.24% of the investigated immigrants thought that traffic conditions became better. The results indicated that most of the immigrants were satisfied with conditions of the human settlements conditions in rural area of TGR. Under the background of stable and rapid development of the national economy, the rural living environment was still improved after resettlement and impoundment of the TGP.

### Satisfaction level of humane relationship

The human relationship in the head part of the TGR was harmonious. 77.11% of the investigated immigrants believed that neighborhood relationship in rural area was very harmonious; 71.64 % of the investigated immigrants though that the relationship between cadres and masses was harmonious. The results demonstrated that the social environment in the TGR was harmonious and stable after resettlement and the rural immigrants were generally satisfied with local resettlement achievements.

### Satisfaction level of plant conditions

The plant conditions in rural area were influenced to a certain degree after impoundment of the TGP. 51.24% of the investigated immigrants thought that the economic condition became worse after impoundment and resettlement, only 17.1% people believed that economic income increased; 79.6% of the investigated immigrants considered that the ways of production and labor had no changes; only 6.96% people thought that production and labor conditions improved. Relocation and

resettlement work objectively led to rural farmers economic income reducing in the area of the head part of TGR, and the labor production conditions in this area were also need to be improved.

### Satisfaction level of public products

The investigation data indicated that implementation of the immigration policies in the TGR area is good, but it still needs to be strengthened in some respects. About 39.6% of the investigated immigrants were satisfied with the immigration policies, but there still 23.27% people were dissatisfied with these; Most of the investigated immigrants believed that the conditions of cultural education, medical treatment and public health in rural area were improved, and more than 50% people felt confident about the future development, but there still 19.8% people felt worried about the future. The results suggested that with the stable implementation of the immigration policies, the local government need to open multiple channels through efforts to develop the local rural economy, increase economic income of farmers, expand public opinion and propaganda, and then to strengthen the confidence of immigrants about the future development. Focusing on how to look at the construction of the TGP, about 79.7% of the investigated immigrants believed that it was necessary, which indicated that most of the immigrants in the head part of the TGR supported the construction of the TGP. The huge comprehensive benefits of the TGP will improve economic and social development in the future.

### Satisfaction level about ecological environment conditions

The ecological environment conditions in rural area in the areas of head part of the TGR were also influenced after impoundment. The investigation results showed that about 50% of the investigated immigrants thought that natural disaster in rural area increased, and 20.3% people thought that natural disaster had no changes; about 50% of the investigated immigrants thought that farmland plant diseases and insect pests increased in the field, but 24.75% people thought that diseases and insect pests had no changes; 65% people considered that the waste disposal facilities in rural area had no changes, and only 15% people believed that the waste disposal facilities increased. The investigation results suggested that ecological environment conditions in rural area became worse after impoundment of the TGP and resettlement. With the cultivated land area in reservoir area reducing, land carrying capacity in the head part of the TGR also decreased. Unreasonable cultivation measures of newly reclaimed land, increasing inputs of fertilizers and pesticides, were the important factors of ecological environment destruction in this area [18,19]. The local government needs to implement the policy and strengthen management efforts on ecological and environmental problems.

### Conclusion

The construction and impoundment of TGP led to some problems such as population relocation, cultivated land submerging, movement of cities and towns and settlement of immigrants and so on. The objectives of this research are to investigate the long-term effects of impoundment and resettlement of the TGP on the land carrying capacity, agro-ecological system and ecological environment in areas of the TGR. The total population of selected countries and towns in the head part of the TGR was reduced during immigration resettlement. We confirmed in this study that the immigrants influenced by impoundment of the TGP were generally resettled properly, and labor resources in rural area were not notable decreased. During construction of the TGP, a large part of the cultivated land in low altitude area was submerged in the TGR areas. The total land resources in reservoir area were inevitably decreased, and thus further intensify the human-land conflict. Under the decrease of total cultivated land and the per capita cultivated land, production of grain, citrus and vegetable in study areas remained stable during impoundment. The residential environment, housing, living and traffic conditions in the TGR were improved after resettlement, and the social environment was also harmonious and stable. Most of the immigrants in study areas were filled with confidence for the future and supported the construction of the TGP for its huge comprehensive benefits in the future. Finally, the results of our investigation confirm that the ecological environment in rural areas were influenced to a certain extent. The natural disasters, plant diseases and insect pests increased after resettlement and the waste disposal facilities were deficiency in the head part of the TGR.

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