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Identification of food security in the mountainous Guyuan Prefecture of China by exploring changes of food production

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Abstract

Mountainous regions are often affected by food shortages due to the adverse natural environmental conditions, inconvenient transportation and social marginalization, and the food security in these areas has become the focus of the academic community. Guyuan Prefecture is an environmentally fragile, mountainous region in western China. Although food production has increased steadily over the past four decades, 21.4% of the households in Guyuan Prefecture still suffered food shortages in 2008, the food insecurity has become more severe in this region in recent years. The goal of this study is to identify the key factors affecting food security between 1981 and 2005 and to provide some recommendations for improving food security. The panel model was used to analyze the significance and intensity of the primary factors influencing food production in this study. We identified the status of food security by examining the grain production per capita. Our results show that poor environmental conditions and population pressure are the major factors influencing food production in Guyuan. Food security might be improved if more fund and technology were invested in the fields of transportation and irrigation. Besides, climate change has a positive impact on food production, the increase in temperature tends to alleviate food insecurity. In addition, infrastructure construction in the agricultural sector should be strengthened and the population growth should be controlled in Guyuan Prefecture.

Key words: Food production, food security, mountainous region, poverty, Guyuan, China.

Introduction

According to the United Nations Food and Agriculture Organization (FAO), there were around 848 million undernourished people in the world during 2003-2005 [13], nearly 95% of which live in developing countries. Therefore, developing countries are most affected by hunger [15]. Besides, Africa and Asia account for more than three-quarters of the developing world's Low-Income Food-Deficit Countries [14]. In recent years, the higher food price has triggered the food crisis in the world, which brought the total number of undernourished people to 1.02 billion in 2009 [15]. Although the food prices have been stabilized somewhat, they are still higher than during the past decade. In addition, those who are most affected by the food crisis remain vulnerable to future food crises because of persistent hunger and poverty [1, 2, 23, 25, 38].

The food crisis caused by the high gain price has delivered a heavy blow the world, especially the mountainous regions [9, 14]. The FAO commissioned a literature review to assess the nutrition of people living in mountainous regions [14]. Hunger and the threat of hunger are nothing new to the millions of people living in mountainous regions [7, 22, 30, 33, 35]. The harsh climate, inaccessible terrain, and political and social marginality of mountainous regions increase the probability of food shortages [16, 21, 31]. According to the FAO, out of the 720 million people living in rural mountainous areas, as many as 245 million are at risk of hunger or are currently experiencing hunger [12].

Food security receives increasing concern in China [20, 39]. Since Brown [26] launched his wake-up call of "who will feed China", more experts have turned their attention to the food security in China[20]. It is invariably the poor who experience food insecurity, China's achievements in reducing poverty have greatly improved the food security. Nearly two-thirds of the Chinese population was classified as the poor in the late 1970s based on the World Bank's standard of one dollar per day. As a result of market reforms since 1978, the number of impoverished people without enough food and clothing decreased from 250 million to 26.1 million by 2004, with the share of the population living in poverty falling from 30% to 2.8%. The remarkable progress in the early 1980s resulted from far-reaching changes in socio-economic policy brought about by the well-conceived re-distribution of country's farmland. The Household Responsibility System (HRS) revised the thirty years of vested interests in just five years [4]. According to this policy, the farmland still belonged to the state, but peasants were free to plant crops and breed animals as they wished. As a result, China attained an average per capita food availability of 2,700 kcal/day[36]. The HRS unleashed the untapped potential of the peasantry and offered them incentives to increase production. China has already

achieved the first Millennium Development Goal of halving poverty by 2015. At the same time, the economic condition and living condition in poverty-stricken areas have been greatly improved.

Although food rationing was eventually abolished, malnutrition persists in remote areas with poor infrastructure and a harsh climate. There is 121.8 million hectare arable land in China at present, with the per capita arable land being about 0.10 hectare, about a third of that in the world. There was still 130.07 million hectare arable land in 1996, with the per capita area of 0.11 hectares; 6.4 percent of the arable land was lost in 11 years, largely due to urbanization especially after 2000 [27]. According to the three-step strategy for China's economic development arrangements for the next few decades, the industrialization, urbanization and modernization will continue to accelerate in China. China's development goal in this century is to reach the economic level of moderately developed countries. The area of arable land in China will diminish with the economic development, rural labour will be forced to move to cities and towns and the improved living standards will also increase demands for various food, especially the meat, poultry eggs and milk [10]. Chinese population is projected to reach 1.6 billion by 2030; as a result, 640 million tons of annual grain production will be needed [37]. In this sense, food security in China would be a challenge.

Although China's food production has grown over the last several decades, inter-annual fluctuations in food supply and prices are still dramatic. The Chinese government has taken several measures to stabilize food prices so as to guarantee the nation's food security and stability [28]. China is currently confronted with the challenge of feeding its growing population as the food production resources become limited and domestic food production costs increase. Food availability and self-sufficiency in China are of great importance because it affects a large proportion of the world's population. In addition, the rapid industrialization has led to competition for resources between agricultural and non-agricultural sectors, rapid income growth, rapid urbanization and population growth [39], all of which increase the demand for agricultural products.

Hunger is more common in mountainous regions in China. These areas account for 69.4% of the total land area, with about half of the total population living in mountainous regions. There are more than 30 million people with an annual income under 637 Chinese yuan in the mountainous regions, which means more than 30 million people live on the edge of hunger [29]. Population growth, environmental deterioration and limited transportation infrastructure exacerbate the food shortage in these areas.

The goal of this paper was to explore the key factors affecting food security, with Guyuan Prefecture as the study area. We described the location and natural conditions of the study area, introduced the data and methodology used to estimate the impact of various factors on food security and presented the factors influencing food security and proposed possible solutions.

Case Study Area

Guyuan Prefecture is a sensitive area in the remote and environmentally fragile mountainous frontier region of western China (Fig. 1). The annual average precipitation is 472 mm and the annual potential evapotranspiration ranges from 1,250 to 2,000 mm. Rain-fed agriculture predominates in most parts of Guyuan Prefecture, but irrigated agriculture is still possible in some isolated areas. Farmers in Guyuan Prefecture have limited resources and practice subsistence agriculture. Their per capita holdings of cultivated land, forestry area, and grassland are 0.27 hectare, 0.28 hectare and 0.31 hectare, respectively [41]. Among the six land-use categories defined by the Chinese Academy of Sciences [9], the dominant land-use types in 2005 were grassland (46.8%) and cultivated land (43.2%), followed by forestry area (7.4%), built-up area (1.7%), and bodies of water and other unused land (<1%).

The major crops grown in Guyuan Prefecture are cereal crops including winter wheat (*Triticum aestivum*), summer corn (*Zea mays*) and potato (*Solanum tuberosum*). The remaining land is mainly used for the cultivation of millet (*Panicum miliaceum*), buckwheat (*Fagopyrum esculentum*), oilseed (*Brassica napus*), oats (*Avena sativa*), beans (including field bean, *Vicia faba*; common bean, *Phaseolus vulgaris* and pea, *Pisum sativum*), sweet potato (*Ipomoea batatas)*, leafy green vegetables (e.g. lettuce, celery), fruit trees and fodder crops.

As an ecologically fragile area, Guyuan Prefecture responds rapidly to changes in the natural environment, with sensitive ecosystems easily changing in undesirable directions in response to anthropogenic impacts. There is often severe soil erosion when the land is converted into agricultural or urban areas. The habitats for endangered species in Guyuan Prefecture are fragile ecosystems. All in all, Guyuan Prefecture has an unstable internal structure and is highly sensitive to external disturbances.

Guyuan Prefecture is surrounded by mountains with an altitude of 1,298-2,928 m. The landscape declines from north to south. The Liupan Mountains span three counties: Jingyuan, Guyuan, and Longde. The area of highest elevation (1,500-2,000 m) accounts for nearly 70% of the total land area. Areas at an elevation below 1,500 m or above 2,500 m each account for less than 5% of the total area of Guyuan Prefecture (Fig. 2).

Guyuan Prefecture is hit by poverty and food insecurity for its barren land and frequent disasters

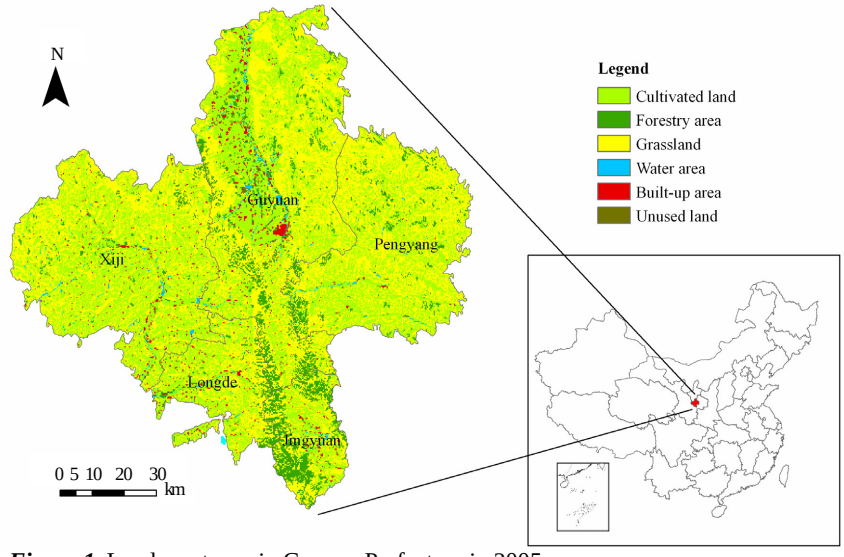


Figure 1. Land-use types in Guyuan Prefecture in 2005.

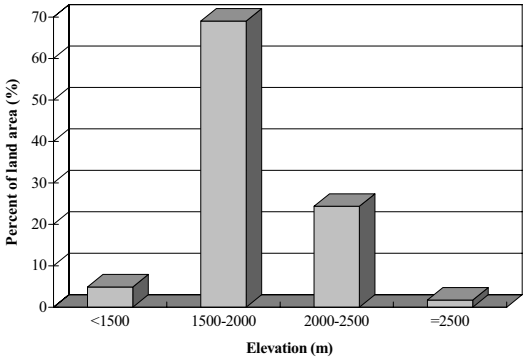


Figure 2. Distribution of land areas by elevation.

in the history when the subsistence was not resolved for a long period. Significant achievements have been made through policy, sciences and development of agricultural production since the new country is created, especially since the market reform. The goal of basic subsistence has been realized by 2000 and agricultural production reached the highest of history in 2004. However, the local peasants have not been self-sufficient yet. Food security of Guyuan Prefecture is still the problem we should pay more attention to.

Indicators of Food Security

Food availability: The availability of sufficient food of appropriate quality is one of the key indicators of food security. Increasing grain production leads to increased food availability. Therefore, it is essential to improve the productivity of crop grains in Guyuan Prefecture. Grain productivity in Guyuan Prefecture increased annually by 9% from 1971 to 2005 largely due to improvements in production technology and increased production inputs. At the same time, the population also increased. According to the statistical data, although there are fluctuations of grain production at the inter-annual time scale, grain production per capita showed an increasing trend on the whole between 1981 and 2005, which indicates that it is a sensitive indicator of food security (Fig. 3). It is also the key to the food supply in Guyuan Prefecture in recent years. Therefore, we selected grain production per capita as an indicator of food security.

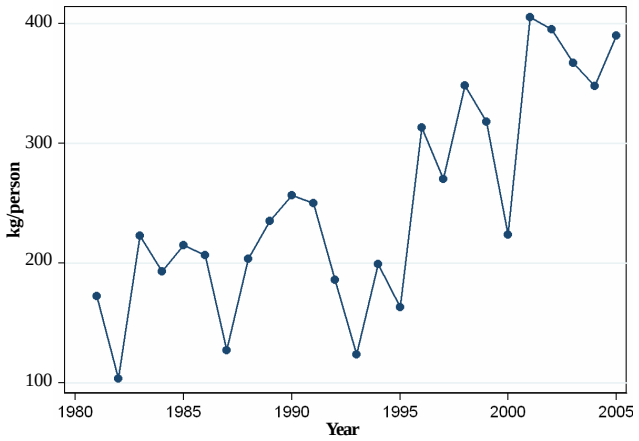
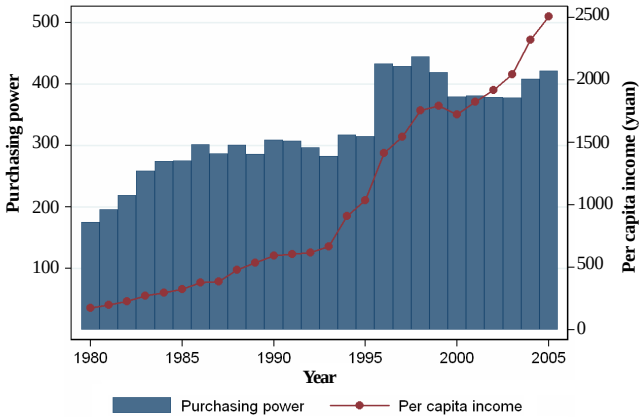


Figure 3. Changes in grain production per capita in Guyuan Prefecture.

Food access: Food access is another important indicator of food security based on self-production and the market trade. The grain pricing mechanism in the remote Guyuan Prefecture has not changed remarkably. Economic development has been somewhat slower over the past two decades, and the lack of purchasing power has already deprived the local people of access to food on the market although food is available. The poor people totalled 83 thousand in Guyuan Prefecture by the end of 2008 as indicated by a high poverty incidence of 6.3%. Of all the poverty-stricken families, the poor households relying just on crop farming and/or livestock breeding accounted for 46.7%. Although the per capita income is increasing all the time from 1981 to 2000, it is still pretty low since these poor households were quite often confronted with the difficulty to afford for their food when there are climatic hazards [6]. Low purchasing power is one of key reason for food insecurity. The author measures the purchasing power with the per capita income which is divided by the price index of agricultural production. The results show that the purchasing power did not change too much during 1981-2005 (Fig. 4). The amount of food available from the market is very small, so it is not taken as the food security assessment indicator in this study.



Note: the purchasing power is calculated from the per capita income.

Figure 4. Purchasing power of Guyuan Prefecture.

The lack of economic opportunities in rural areas is responsible for household nutrition insecurity in Guyuan Prefecture. We do not consider the impacts of the market on food security. In addition, grain production and grain storage did not change remarkably, and food requirements are typically met through crop farming. Thus, we focus on agricultural production in Guyuan Prefecture in this study.

Food stability: Food stability here refers to both the availability and access dimensions of food security. To be food secure, a population, household, or individual must have access to adequate food at all times. They should not risk loosing access to food as a consequence of sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g., seasonal food insecurity). Self-supply is now the main mode of food access in Guyuan Prefecture. There was almost no grain imported into Guyuan from other regions since Ningxia region realized the balance between production and demand in 2005 [32]. The climate has significant impacts on agricultural production, especially the rain-fed farming [8]. Although climate conditions fluctuate over years, the changing trend has been stable in recent years and they do not lead to many disasters for the agricultural production. Agricultural production does not suddenly be reduced due to the climate changes. Therefore, we do not consider food stability when assessing food security in Guyuan Prefecture.

Food utilization: The dietary structure in Guyuan Prefecture didn't change dramatically since Guyuan Prefecture developed slowly. Spring wheat and summer corn are the primary crops, with the proportions of other crops being considerably smaller than that of wheat and corn (Fig. 5). The utilization of food is non-differential among the five county-level administrative regions in Guyuan Prefecture. Maybe someone says that eggs and meat, which were luxury goods in the past, have gradually become parts of food with the development of socio-economy. However, although the consumption of meat and poultry eggs increased all the time from 1981 to 2005, the per capita consumption is less than 0.15 kg/day (Fig. 6). Therefore, meat, milk and poultry eggs cannot be substituted for some crops. Food after preliminary processing grain accounts for the main part in the daily life [40]. In this sense, food supply is quite incentive to the food utilization. So food utilization is not a sensitive indicator of food security in Guyuan Prefecture.

Based on the research presented above, we conclude that grain production per capita is the most suitable indicator of food security in Guyuan Prefecture.

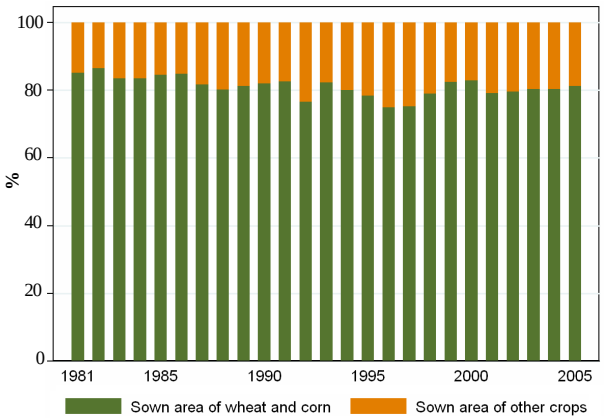


Figure 5. Crop proportions in Guyuan Prefecture.

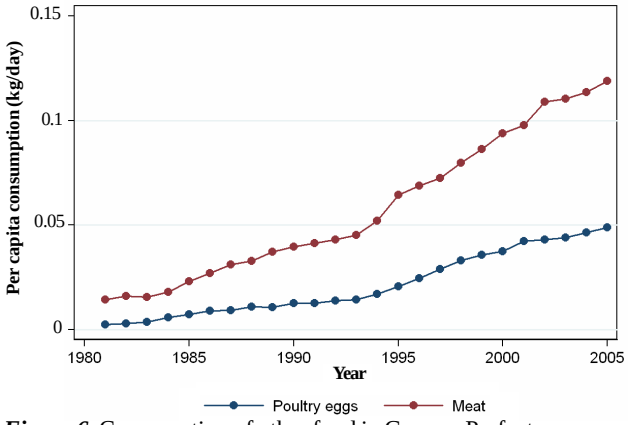


Figure 6. Consumption of other food in Guyuan Prefecture.

Data and Analysis

Geophysical data: Geophysical data include measurements of climatic change, information on terrain slope and information on soil property variability (Fig. 7). The original meteorological data consisting of average temperature (*temp*), average precipitation (*rain*), relative humidity (*humidity*), and sunshine hours (*sun*) between 1981 and 2005 come from the China Meteorological Bureau. We transformed the text-based data into a 1 km × 1 km grid using the kriging method. The mean or sum value in Guyuan Prefecture was also calculated and interpolated into the 1 km×1 km grid [11]. Information on altitude (*altitude*) was derived from DEM data for Guyuan Prefecture at a scale of 1:250,000. Information on the volume of loam (*loam*) and the content of soil organic matter (*organ*) comes from the national soil survey of China, and was also exported into the 1 km × 1 km grid using the kriging method. Finally all of these data are calculated at the country level.

As a measure of accessibility, road density is important to grain price as it affects the ease to move grain across regions. Areas with higher road density are more accessible. The road network used to calculate the road density (*road_density*) was derived from a 1:250,000 topographic map of Guyuan Prefecture.

Socio-economic data: The socio-economic dataset consists of variables including population density (*population*), agricultural population proportion (*agri_pop*), agricultural investment (*invest*), agricultural output value from farming, forestry, animal husbandry, and fishery in the agricultural sector (*agri_output*) in the Guyuan Prefecture from 1981 to 2005 (Fig. 8). All of the selected socio-economic data show the increasing trend on the whole though there are some fluctuations during 1981 to 2005. All of the data were derived from provincial statistical data and investigation. They are all collected at the country level.

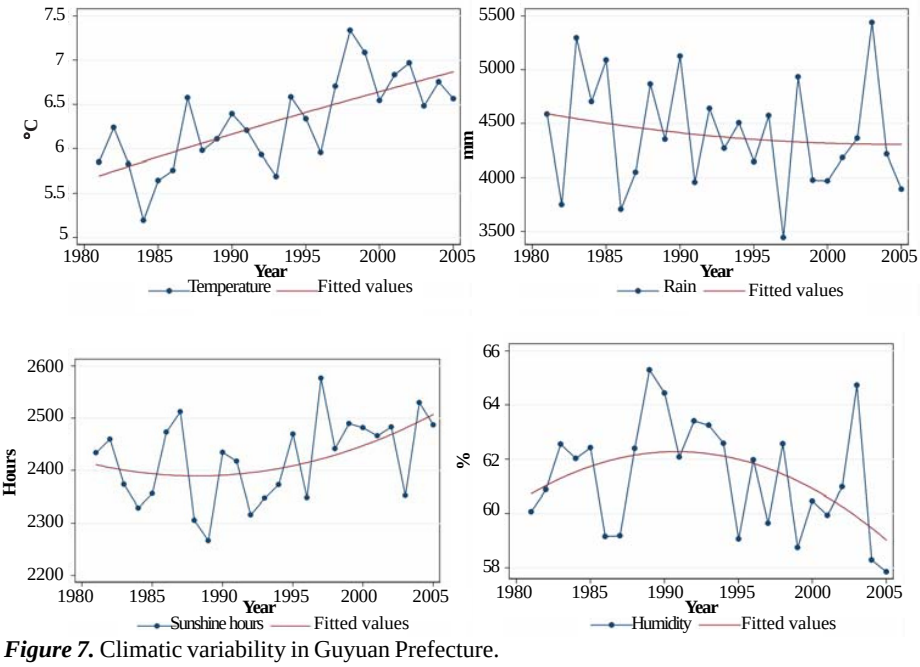


Figure 7. Climatic variability in Guyuan Prefecture.

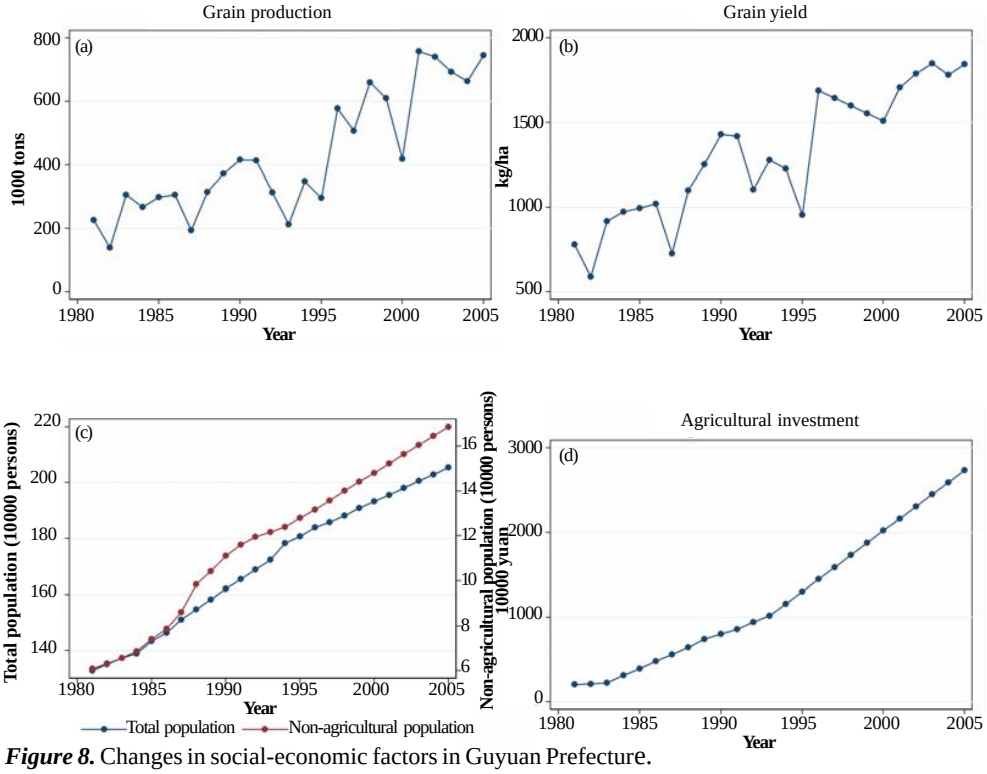


Figure 8. Changes in social-economic factors in Guyuan Prefecture.

Methodology

We built a panel data model to explore the factors influencing food security in Guyuan Prefecture [5, 17, 18]. The panel data model includes cross-sectional and time-series information related to the factors influencing food security and the indicators used to measure food security. It describes not only the laws of sample data from various regions at a particular time, but also changes of the major factors and/or indicators of food security over time. In comparison to the cross-sectional data and time series models, panel data models increase the sample space, promote the degree of freedom of samples and reduce the impacts of multi-collinearity between the explanatory variables on the estimation results [19]. We performed logarithmic transformation on the original data values of all variables. The panel data model is as follows:

$$Y_{it} = \beta_1 + \sum_{j=2}^{k} \beta_j X_{jit} + \sum_{p=1}^{s} \gamma_p Z_{pi} + \delta t + \qquad (1)$$

where Y is the explained variable (indicator of food security), X_j refers to observed explanatory variables (factors influencing food security) and Z_p identifies the unobserved explanatory variables. Among the indices, i is the unit of observation, t refers to the time period, and j and p are included to differentiate between different observed and unobserved explanatory variables. ξ_{it} is a disturbance term assumed to satisfy the usual regression model conditions. A trend term, t, has been introduced to allow for a shift in the intercept over time. X_j indicates the variables of interest, while Z_p is included to illustrate the unobserved heterogeneity and as such constitutes a nuisance component of the model.

All the variables related to food security are first transformed into panel data which is capable of uncovering group effects, time effects, or both of the factors influencing food security. These effects are either fixed or random. A fixed effects model assumes differences in intercepts across groups or time periods, whereas a random effect model explores differences in error variances. We use a Hausman test to determine whether a fixed or random effects model is appropriate. The Hausman test is used to assess the null hypothesis that the coefficients estimated by the random effect estimator are the same as the ones estimated by the consistent fixed effects estimator. If the results are: insignificant P-value, Prob > χ^2 = 0.9999, larger than 0.05; it is appropriate to use the random effect estimator. However, if the P-value is significant, we must use the fixed effect estimator. With the Hausman test results shown in Table 1, we need to use the random effect estimator to estimate the effects of factors on food security.

Results

To meet current and future food demands, it is necessary to understand the causes of food security in Guyuan Prefecture between 1981 and 2005 first. We used a random effects model based on panel data to explore the relationship between the endogenous and exogenous variables related to food security in Guyuan Prefecture between 1981 and 2005. Food security is measured with the grain production per capita. In order to explain the causal mechanism of food security clearly, we examine the influencing factors by dividing them into geophysical conditions and socio-economic variables.

Impacts of geophysical conditions: Geophysical conditions, most of which are not easy to change, are the controlling factors of grain production and food security in Guyuan Prefecture. Among these factors, average altitude exerts an obvious negative influence on grain production and food security. The higher the altitude is, the lower the grain production per capita is and the greater the food insecurity is. In addition, these areas of high altitude are also not suitable for cultivation, the levels of urbanization and industrialization are low and transportation is limited, all of which encourage people to emigrate and make it difficult to deliver grain to meet demands in these areas. Although soil organic matter has positive impacts on food security and grain production, its influence is not significant in Guyuan Prefecture (Table 2). The content of soil organic matter is low due to the barren soil and low investment in Guyuan Prefecture.

We examined average temperature, average precipitation, sunshine hours, and humidity in order to assess the influence of climate change on grain production. Estimation results show that average temperature is the only factor significant to grain production and food security. Increased temperature promotes grain production growth to some extent. The coefficient of average temperature on grain production is 10.279 and is significant at the 5 % level. However, there are no significant impacts of precipitation, sunshine hours, and humidity, three of the climate variables with asynchronous changing trends on the grain production.

Table 1. Hausman test of parametric estimation models on grain production in Guyuan Prefecture.

	Coefficients of estimation			sqrt(diag(V_b-V_B))
	(b)	(B)	(b-B)	
	Fixed effects model	Random effects model	D-value	SE
Production	0.003	0.003	0.000	0.000
Yield	0.029	0.030	-0.001	0.002
Temp	8.990	10.281	-1.291	2.561
Rain	-0.112	-0.102	-0.010	0.020
Humidity	3.867	3.704	0.163	0.365
Sun	0.014	0.015	-0.001	0.005
Organ	-3.942	7.300	-11.242	21.815
Population	-0.001	-0.001	0.000	0.000
Agri_pop	0.087	0.050	0.038	0.080
Agri_output	-0.335	-0.357	0.022	0.044
Invest	0.120	0.119	0.000	0.002
χ^2=(b-B)'[(V_b-V_B)^(-1)](b-B)=0.27				
Prob>χ^2=0.9999				

Note: (b) is the result of the fixed effects model, (B) is the result of the random effects model..

Table 2. Regression results of the random effects model based on panel data from the Guyuan Prefecture.

	Dependent variable: Grain production per capita					
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Production	0.002	0.003	0.003	0.003	0.003	0.003
	(15.06)**	(20.35)**	(15.66)**	(14.43)**	(14.82)**	(16.75)**
Yield	0.046	0.040	0.043	0.041	0.046	0.030
	(5.15)**	(5.54)**	(5.92)**	(5.57)**	(6.52)**	(4.32)**
Population		-0.001	-0.001	-0.001	-0.001	-0.001
		(4.89)**	(4.67)**	(4.18)**	(5.32)**	(6.63)**
Agri_pop		0.229	0.027	-0.104	0.322	0.054
		(0.55)	(0.06)	(0.22)	(0.76)	(0.14)
Agri_output			0.121	0.125	0.060	0.357
			(0.65)	(0.61)	(0.31)	(1.99)*
Road_density			-4.320	-2.333	-16.063	-31.082
			(2.08)*	(0.78)	(2.50)*	(4.95)**
Rain				-0.076	-0.059	-0.103
				(1.01)	(0.80)	(1.54)
Sun				0.007	0.005	0.014
				(0.11)	(0.08)	(0.27)
Temp				6.343	15.553	10.279
				(0.86)	(2.01)*	(2.47)**
Humidity				1.515	1.874	3.700
				(0.59)	(0.75)	(1.64)
Altitude					-2.194	-4.228
					(2.49)*	(4.93)**
Organ					3.803	7.889
					(2.11)*	(4.51)**
Invest						0.119
						(5.95)**
Constant	67.876	219.476	298.184	159.338	-	-
	(2.06)*	(13.28)**	(7.30)**	(0.60)	1,407.041	2,812.013
					(2.20)*	(4.55)**

Note: ***, **, and * are significance levels of 1%, 5% and 10%, respectively.

Impacts of socio-economic variables: Socio-economic variables are the important influencing factors of grain production since they have the decisive impacts on food security; it is easy to improve the food security through these factors in most areas, including Guyuan Prefecture. Population, agricultural population, agricultural output and agricultural investment are used to identify and characterize the relationship between economic or population growth and food security. The larger the population is, the large the demand for food is, so food insecurity is more likely in these area where the population is larger. In this sense, population size has a negative impact on food security. The growth of agricultural population promotes grain production as they can input more labour. However, our results show that the impact is marginal. Maybe the contribution of increasing agricultural population is weakened with more and more agricultural population going to work in cities in recent decade. The expansion of agricultural output, including farming, forestry, animal husbandry, sideline production and fishing, stimulates the development of agricultural sectors and promotes the expansion of cultivated land. The coefficient for grain production is just around 0.357 and is significant at 10% level (Table 2).

Estimation results show that road density has a significant positive effect on grain production and food security. The coefficient of road density is 31.082, indicating that transportation system reduces the chance of food insecurity. Convenient traffic makes more information and chances flow in, more people go out to look for work and more technologies imported from other regions. Grain production and grain yield are also used to examine food security. Grain production and grain yield both have positive impacts on grain production per capita. An increase in grain production or yield promotes the grain production per capita to some extent. The coefficients of grain production and grain yield are 0.003 and 0.030, respectively, being significant at the 5% level. Agricultural investment also has obvious positive impacts on agricultural production, with the coefficient of 0.019 being significant at the 10% level. However, the agricultural investment in Guyuan Prefecture is relatively lower than the eastern area of China, especially before 2000. This is also the main reason for the food insecurity.

Conclusions

Food security in mountainous areas is an important research focus throughout the world. It is essential to explore the current situation of food security in mountainous regions and identify the key factors leading to food insecurity so as to guarantee sustainable agricultural production. Guyuan Prefecture is the representative of mountainous regions that have been affected by food insecurity in the past in China. In this study, we have identified the key factors affecting food security. We built a panel data random effect model to identify the key factors influencing food security in Guyuan Prefecture between 1981 and 2005. Our results show that poor natural conditions, low agricultural input and population pressure are the major factors influencing food security. Among these factors, terrain elevation controls grain production to some extent. Climate change also has an impact on grain production, mainly by the increase of air temperature. Road density promotes grain production and reduces food insecurity. Population growth constrains grain production to some extent and increases the pressure on food security.

Based on the results above, we propose some recommendations. There is an urgent need to improve the infrastructure for transportation, irrigation, and mechanization. On the one hand, it is necessary to promote the circulation of grain between regions so that grain can be supplied by other provinces or countries. On the other hand, agricultural production and grain production should be increased; population growth should be controlled and it is necessary to increase the opportunities for the agricultural population to engage in non-agriculture production. Migrant workers can relieve the pressure of food security in some areas and earn extra money for food.

Acknowledgements

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