Evaluation of the Land Production Potential in the Context of Returning Farmland to Forest in Karst Region: A Case Study of Guizhou Province

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Abstract In this paper, we take Guizhou Province (the heart of southwestern Karst region in China) as the research object. By establishing gray forecasting model and time series forecasting model, we conduct the accuracy test on the actual production capacity of land and the forecasted production capacity of land in 2007 and 2008, and then conduct comprehensive forecast of the land production potential in Guizhou Province in 2020. On this basis, considering the nutritional standards needed by three kinds of life type (dressing warmly and eating one's fill, well-off life, relatively affluent life), we evaluate the land production potential in Guizhou Province under the project of returning farmland to forest. Based on the evaluation results, we put forth the relevant recommendations for achieving sustainable land use in the context of returning farmland to forest in Guizhou Province.

Key words Karst region, Project of returning farmland to forest, Land production potential

China has a large population but the arable land resources are increasingly scarce. With economic development, accelerated process of industrialization and urbanization and population growth, the non-agricultural utilization of part of the arable land is serious, making the arable land resources subject to varying degrees of destruction[1] and the contradiction between human and land more prominent, which becomes the dominant factor restricting China's economic development. With the rapid socio-economic development, food demand will also grow rapidly, but due to dwindling land resources, especially the reduction of arable land, the situation will be more serious. Thus rationally and efficiently using land, and fully tapping the productive potential of land resources, is a major issue in front of us[2]. Especially in Karst region with serious soil erosion and stony desertification, land is the main production resource and rocky desertification of land is a symbol of poverty; poverty forces people to obtain more natural resources, eventually leading to the further deterioration of the ecological environment. How to rationally use land resources has become the primary problem to be solved. Returning farmland to forest provides an effective way to control ecological environment in Karst region. To return the arable land smoothly, the study on land production potential becomes critical.

Guizhou Province is located in the heart of southwest China Karst region, with a mild rocky desertification area more than 33 000 km^2, accounting for 18.8% of the province's land area, 26% of rocky desertification area of 8 southwestern provinces. At the same time, there is a potential rocky desertification area of 34 000 km^2, with a expansion rate of 2% to 3% annually. Among 100 rocky desertification comprehensive control pilot counties started by China in 2008, there are 55 in Guizhou Province[3]. Conspicuously, the rocky desertification in Guizhou Province is very serious, urgently to be controlled. Meanwhile, severe rocky desertification problems not only endanger the ecological safety of Guizhou Province, but also endanger the ecological safety of the Yangtze River Basin, and the Pearl River Basin. Guizhou Province is the only province without support of plain in China[4]. Returning farmland to forest and grass can restore and improve the environment's ability to repair itself in rocky desertification areas by vegetation, exerting a positive impact on the ecological status of Karst region in Guizhou Province, which is the best choice for the Karst region in Guizhou Province to implement the sustainable development of agriculture.

However, in the context of the implementation of the project of returning farmland to forest, the area of arable land is decreasing and the land production capacity in Guizhou Province is facing unprecedented challenges. So carrying out the evaluation of land production potential in Guizhou Province, is especially important to the smooth implementation of the project of returning farmland to forest in Guizhou Province, and even implementation of the policy of returning farmland to forest in the whole country.

1 Overview of the study area and research method

1.1 Overview of the study area Guizhou adjoins Sichuan Province and Chongqing Municipality to the north, Yunnan Province to the west, Guangxi Province to the south and Hunan Province to the east. Overall Guizhou is a mountainous province. However, it is hilly in the west while the eastern and southern portions are relatively flat. The western part of the province forms part of

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the Yunnan – Guizhou Plateau. Guizhou has a subtropical humid climate. There are few seasonal changes. Its annual average temperature is roughly 10 to 20 ℃, with January temperatures ranging from 1 to 10℃ and July temperatures ranging from 17 to 28 ℃. Like in China's other southwest provinces, rural areas of Guizhou suffered severe drought during spring 2010. One of China's poorest provinces, Guizhou is experiencing serious environmental problems, such as desertification and persistent water shortages.

The landforms of the province can be broadly divided into three basic types: plateaus, hills and basins. 92.5% of the area is mountain and hilly. There are myriad sinuous and intertwined mountains within, peaks rising one upon another. The Karst landform is very typical. The Karst (outcrop) area is 109 084 square kilometers, accounting for 61.9% of the total land area of the province. The Karst landform is widely distributed, with a wide range of morphological types and obvious regional differentiation, constituting a special Karst ecosystem[5].

1.2 The current situation of returning farmland to forest

Since the implementation of the project of returning farmland to forest in 2000 in Guizhou Province, it has experienced four stages: local pilot project, in full swing, steadily advancing, and improving policies. In 2010, a total of 1 879 mu of project construction task was completed including 6.57 million mu of arable land returned to forest, 10.52 million mu of afforestation and 1.7 million mu of hillsides closed for facilitating afforestation. The great ecological construction project benefits 1.97 million rural households and 8.24 million farmers, covering the province's 87 counties (cities, districts), 1 400 towns, and 14 000 villages (Fig. 1).

According to the monitoring of Provincial Academy of Forestry, the vegetation coverage in the project area has increased from 12.4% before returning the farmland to 78%; the area of soil erosion in the monitoring area has decreased from 3325 t/km^2 before returning the farmland to 1031 t/km^2.

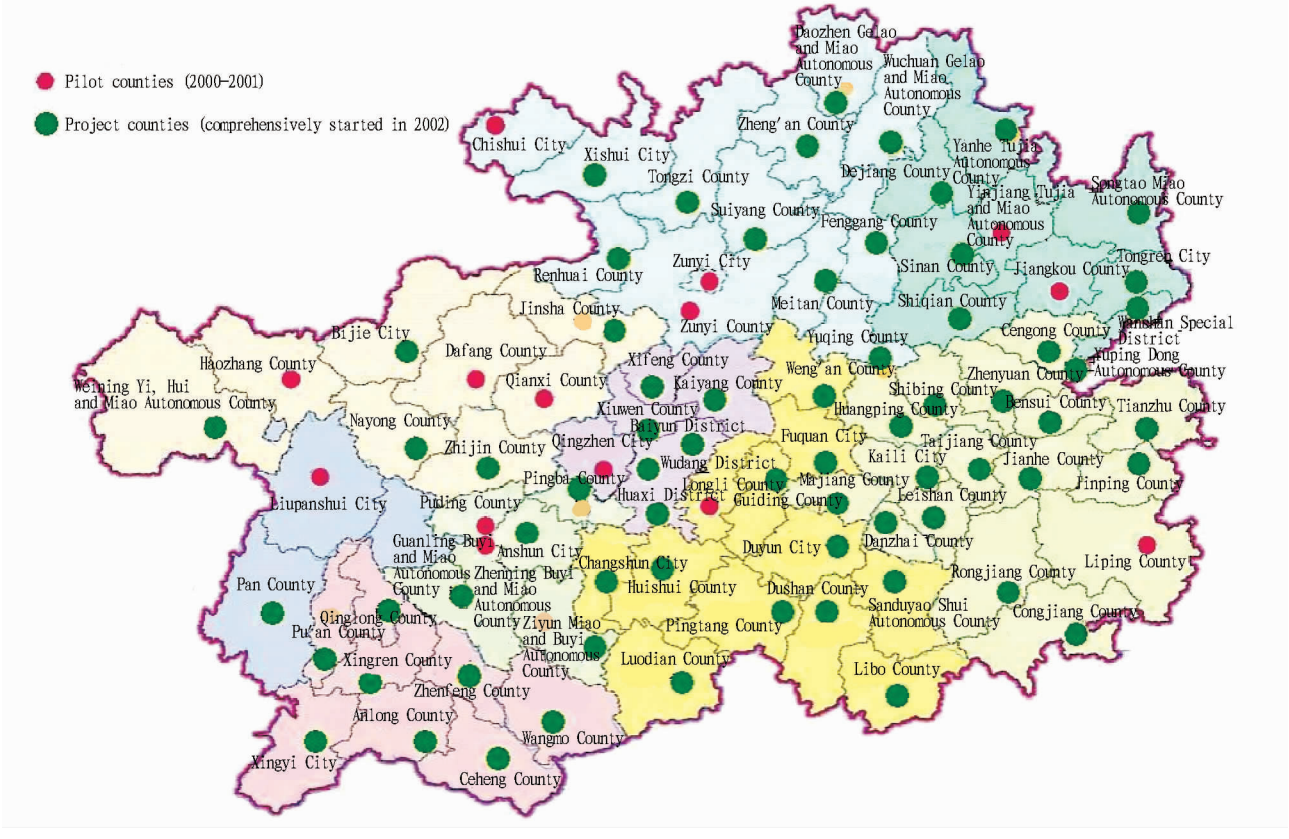

Fig. 1 Distribution of the project of returning farmland to forest in Guizhou Province

1.3 Research method

The trend extrapolation method is selected to forecast land production potential. According to the dynamic variation in the output of main crops and livestock in Guizhou Province during the period 1995 – 2008, we use gray prediction method and time series prediction method to establish model, and then according to the difference in the predictive accuracy of the two models, assign different weight on prediction results of the two models, for comprehensive prediction after adjustment.

At the same time, in order to improve the prediction accuracy of the land production potential, this article conducts accuracy test on the actual land production capacity and predicted land production capacity in 2007 and 2008. Based on the standards of nutrients contained in the main consumer foods in Guizhou Province, we complete the forecast of land production potential in Guizhou Province in 2020. On this basis, considering the nutritional standards needed by three life types (dressing warmly and eating one's fill, well-off life and relatively affluent life) and the population carrying capacity, we assess the land production potential in

Guizhou Province under the project of returning farmland to forest. As to the data processing procedures applied to modeling, we adopt the related procedures in the Eviews5.0 statistical analysis software.

2 Results and analysis

2.1 Yield forecast Based on the dynamic variation in the output of main crops (including grain, oilseeds, fruits, vegetables) and animal products (including meat, eggs, milk) in Guizhou Province in the period 1995 – 2008, we establish the gray forecasting model and time series forecasting model. The grain mainly includes cereals, soybean and potato; oil crops mainly include peanut and rapeseed; fruits mainly include apples, pears, oranges, kiwi fruit, peaches and plums; meat includes pork, beef, mutton, rabbit meat and poultry meat; eggs include hens' egg, duck's egg, goose's egg and quail egg; milk includes cow's milk and ewe's milk.

The gray forecasting model of output of major crops and livestock is as follows:

Grain: $\hat{X}^{(1)}(t+1) = 123\ 741.763\ 472e^{0.008\ 473t} - 1\ 222\ 792.863\ 472$
($C = 0.436\ 7$, $p = 0.827\ 3$)

Oil crop: $\hat{X}^{(1)}(t+1) = 1\ 293.524\ 227e^{0.043\ 045t} - 1\ 234.724\ 227$
($C = 0.3821$, $p = 0.909\ 1$)

Fruit: $\hat{X}^{(1)}(t+1) = 487.210\ 655e^{0.084\ 927t} - 466.240\ 655$
($C = 0.131\ 1$, $p = 1.000\ 0$)

Vegetables: $\hat{X}^{(1)}(t+1) = 4745.222\ 283e^{0.058\ 039t} - 4\ 470.922\ 283$
($C = 0.112\ 1$, $p = 1.000\ 0$)

Meat: $\hat{X}^{(1)}(t+1) = 2\ 729.777\ 172e^{0.038\ 619t} - 2\ 624.277\ 172$
($C = 0.3438$, $p = 0.9231$)

Eggs: $\hat{X}^{(1)}(t+1) = 85.340\ 172e^{0.062\ 158t} - 79.540\ 172$
($C = 0.3495$, $p = 0.9231$)

Milk: $\hat{X}^{(1)}(t+1) = 10.805\ 861e^{0.112\ 034t} - 9.405\ 861$
($C = 0.345\ 5$, $p = 0.923\ 1$)

where t represents the year; x represents yield; C represents posteriori differential ratio; p represents small error probability. When $C < 0.5$, $p > 0.8$, the gray model is qualified, passing the test.

The time series forecasting model of output of major crops and livestock is as follows:

Grain: $\hat{X}_t = 1\ 824.691 + 0.981\ 549X_{t-1} - 0.448\ 56E_{t-1}$ ($R^2 = 0.900\ 5$)

Oil crop: $\hat{X}_t = 21.850\ 11 + 1.983\ 003t$ ($R^2 = 0.9276$)

Fruit: $\hat{X}_t = 184.885\ 2 + 0.944\ 29X_{t-1} - 0.46439E_{t-2}$ ($R^2 = 0.944\ 5$)

Vegetables: $\hat{X}_t = -439.621 + 1.026\ 353X_{t-1}$ ($R^2 = 0.961\ 9$)

Meat: $\hat{X}_t = 18.894\ 75 + 3.996\ 534t + 0.075\ 994t_2 - 0.001\ 5t_3$ ($R^2 = 0.987\ 2$)

Eggs: $\hat{X}_t = 56.969\ 64 + 0.994\ 016_{t-1}$ ($R^2 = 0.926\ 9$)

Milk: $\hat{X}_t = 630.665\ 8 + 0.999\ 771\hat{X}_{t-1} - 0.225\ 26E_{t-1}$ ($R^2 = 0.915\ 9$)

where t represents the fitted value of X; E_t is the residual of X_t; t represents time; R^2 represents the determination coefficient of goodness of fit.

The two models of the each type of food above are the results derived according to the known yield change trend in Guizhou Province, due to shortcomings in the gray forecasting and time series forecasting, coupled with the impact of objective factors and government behavior.

Based on the relevant literature, in order to make the predicted results more consistent with actual local conditions, according to difference in the two models' prediction accuracy, we give different weight on the prediction results of both. After adjustment, they are used for the forecast of output of major crops and animal products in Guizhou Province in 2020. At the same time, in order to further improve the prediction accuracy, this article also conducts forecast accuracy test.

We convert the actual output of main crops and animal products in Guizhou Province in 2007 and 2008 into the nutrients, to get the actual land production capacity in recent two years; we convert the fitted value of output of main crops and animal products in the prediction model into nutrients, to get the predicted land production capacity in recent two years. We conduct a comparative analysis of the actual land production capacity and predicted land production capacity in 2007 and 2008.

Table 1 Test of difference degree of predicted land production capacity

Nutrients	Error//10^7 kg/10^{12} kJ		Relative error//%	
	2007	2008	2007	2008
Protein	-5.30	-0.15	-3.85	-0.10
Fat	-10.55	-18.41	-5.20	-8.47
Calorie	-9.16	-6.17	-4.04	-2.63

From Table 1, the relative error of the predicted land production capacity and the actual production capacity in 2007 and 2008 was both less than 10%. In 2007, the average error was 8.34, and the average relative error was 4.36%; in 2008, the average error was 8.24, and the average relative error was 3.73%.

It can be seen that the differences between the predicted land production capacity and the actual land production capacity in Guizhou Province in 2007 and 2008 are small, and the forecast is basically in line with the actual situation. Based on this, it can be predicted that the output of major crops including grain, oil crop, fruit and vegetables in Guizhou Province in 2020 will be 12.452 6 million tons, 1.225 7 million tons, 1.494 8 million tons, and 21.648 2 million tons, respectively; the output of major animal products including meat, eggs, and milk, will be 2.374 million tons, 0.191 3 million tons, and 0.124 5 million tons, respectively.

2.2 Measuring of land production potential According to the nutrients contained in per 100 g of major consumer food from *Main Food Composition Table* 2009, coupled with nutritional characteristics of local products, we work out the standard of nutrients contained in main consumer food in Guizhou Province, as is shown

in Table 2.

Table 2 The nutrients contained per 100 g of major consumer food in Guizhou Province

Food type	Protein//g	Fat//g	Calorie//kJ
Grain	9.17	3.92	1351.93
Oil crop	0.00	100.00	3765.60
Fruit	0.44	0.36	207.28
Vegetables	1.50	0.30	92.05
Meat	10.96	49.91	2077.02
Eggs	12.50	9.86	604.59
Milk	1.50	3.70	280.33

According to the standards of nutrients, in combination with the predictive value of output of main consumer food in Guizhou Province, we calculate the nutrients contained in various types of food, and then subtotal these nutrients, to get the nutrients contained in major consumer food in Guizhou Province in 2020, namely the land production potential in Guizhou Province in 2020 (Table 3).

Table 3 The land production potential in Guizhou Province in 2020

Food type	Protein//10^7 kg	Fat//10^7 kg	Calorie//10^{12} kJ
Grain	114.19	48.81	168.35
Oil crop	0.00	122.57	46.15
Vegetables	32.47	6.49	19.93
Fruit	0.66	0.54	3.10
Meat	26.02	118.49	49.31
Eggs	2.39	1.89	1.16
Milk	0.19	0.46	0.35
Total	175.92	299.25	288.35

2.3 Evaluation of land production potential In accordance with the nutritional and well-off standards recommended by China, the world's nutritional standards, the overall objective of food and nutrition development in 2010, and trends of gradual improvement in people's living standards in the next decade, coupled with the actual situation in Guizhou Province, we work out the per capita consumption nutritional standards regarding three life types in Guizhou Province in 2020 (Table 4).

We conduct calculation under three life types (dressing warmly and eating one's fill, well-off life, relatively affluent life). Under the life type of dressing warmly and eating one's fill, the largest beating population in Guizhou Province in 2020 is 50.734 million; under the well-off life type, the largest beating population in Guizhou Province is 45.902 2 million; under the relatively affluent life type, the largest beating population in Guizhou Province is 41.9107 million.

As of the end of 2009, the total permanent population in Guizhou Province was 39.754 8 million, that is, according to the estimated land production potential in Guizhou Province in 2020, in the next decade, if the population in Guizhou Province is less than or equal to 10.979 2 million, we can guarantee the life of dressing warmly and eating one's fill; if the population in Guizhou Province is less than or equal to 6.147 4 million, we can guarantee well-off life; if the population in Guizhou Province is less than or equal to 2.155 9 million, we can guarantee the relatively affluent life.

It can be seen that in the context of implementation of the project of returning farmland to forest on a large scale, the land production potential situation in Guizhou Province has become more and more urgent, and the government and related departments need to pay attention to it.

Table 4 The per capita consumption nutritional standards in Guizhou Province

Life type	Protein g/d	Fat g/d	Calorie 10^4 kJ/d
Dressing warmly and eating one's fill	95	95	1.25
Well-off life	105	105	1.42
Relatively affluent life	115	115	1.59

3 Conclusions and recommendations

In Karst region, the ecological environment is fragile, and the contradiction between human and land is increasingly acute, doing serious damage to forest vegetation, causing a lot of soil erosion, making the area of rocky desertification constantly expand. The studies on the rocky desertification control are also becoming increasingly prominent. Rocky desertification control in essence includes three aspects: ecological restoration and reconstruction, soil and water conservation, and economic development. And the restoration of the vegetation is the key. The project of returning farmland to forest provides an effective way for the ecological environment control in Karst region, helping improve the environmental capacity and stability in the Karst mountainous areas, and achieve sustainable use of agro-ecological environment and resources in the Karst mountainous areas.

Taking the case of Guizhou Province, we carry out the evaluation of land production potential in the context of the project of returning farmland to forest in Karst region, and the evaluation results show that the land use structure changes arising from the project of returning farmland to forest started from 2000, in combination with other human activities, have exerted gradually emerging impact on the land production potential in Guizhou Province, and the situation becomes more and more urgent. Therefore, in order to ensure the stability of society, the basic livelihood of the masses and the happiness of future generations, it is necessary to guarantee the continuity of the project of returning farmland to forest, and address the food problem for people.

3.1 Controlling the population growth, improving the quality of the population and easing the contradiction between human and land The population in the next 10 years will continue to grow constantly. Once the population is not controlled effectively, it may be beyond the limits of land production potential, further imposing greater pressure on resources and environment. In the case of current shortage of land resources, it is necessary to earnestly implement the family planning policy, strictly control population growth, develop corresponding population development

and mobility policy, and improve the quality of the population.

The rapid increase of the population will have a direct impact on the development of the regional economy. If the population growth rate is reduced, the dependency ratio will be lower, the pressure of education will be smaller, and it will be more conducive to the improvement in the quality of the population, economic development and people's living standards. As for the problem of low educational level of the agricultural population at present, we should vigorously develop education, improve the quality of the population, develop human resources, and transform the population burden into great wealth. We should reduce the population growth rate and use human capital to replace natural capital. In the future, we should resolutely implement the national and provincial population policies, do a good job in family planning, strengthen cultural education, and improve the quality of the population.

3.2 Increasing input to middle-and-low-yielding field and improving soil quality The transformation of middle-and-low-yielding field is one important way to improve the benefit of arable land use. The main measures for middle-and-low-yielding field are as follows:

(1) Fertilizing the soil, and improving soil structure. We should pay more attention to reducing chemical fertilizer, increasing farmyard manure, implementing straw returning and intercropping system.

(2) Vigorously promoting supporting practical techniques. We should actively carry out plant growing in suitable period, fertilization, scientific management, pest control and other high-yield cultivation techniques to increase the yield per unit area.

(3) Really doing a good job in the construction of farmland water conservancy, to ensure the production water for arable land. In view of the actual situation of Guizhou Province, the reason for the middle-and-low-yielding field in the province is infertility, thinness, stickiness, and coldness of soil. Based on the ecological view of building large-scale farming, we should combine improvement and use, biological measures and engineering measures, organic manure and inorganic fertilizer, and adhere to the comprehensive management of mountains, water, field, forest, road, grass according to local conditions; build water conservancy projects, improve irrigation conditions; level the land, and prevent soil erosion; promote green manure, vigorously return straw to the field; increase organic fertilizer, promote fertilizer formulation, improve the soil quality; constantly eliminate the negative factors, continue to raise cropland productivity.

According to projection, through the improvement in the soil of middle-and-low-yielding field, if 50% of middle-and-low-yielding field can be turned into high-yielding field, for every one hectare, the grain output will increase by 1500 kg, we can increase the grain output by 2.391 million tons under the conditions of never increasing arable land. Of course, from a technical point of view, the improvement in the soil of middle-and-low-yielding field has been fully completed at present, but the key is sufficient capital and input, which requires national and local financial support, and farmers' input.

3.3 Taking actions that suit local circumstances and making full use of non-arable land resources In order to ensure the social and economic development, promote the optimal allocation of land resources and achieve the sustainable use of land resources, it is necessary to fully take advantage of the non-cultivated land resources. The area of mountainous areas in Guizhou Province is large, and the natural conditions are favorable for the development of forestry, animal husbandry production. There is an urgent need to make full use of the woodland reserve resources, expand the area of forest land; strengthen the protection of existing woodland, actively develop and improve the structure of forest varieties.

At the same time, it is necessary to protect and operate well the existing woodland, strengthen the management and protection of existing woodland, turn the shrubbery, open woodland and immature forest land into forest land, greatly improve the province's forest coverage and prevent excessive exploitation and deforestation. In addition, it is necessary to appropriately increase the area of garden plot, adjust the structure of garden plot varieties, improve product quality, vigorously improve varieties, and enhance the benefit of garden plot. If increasing input to improve varieties, strengthen the management and transformation of low-yielding garden plot, the yield potential of subtropical orchard and tea garden in Guizhou Province is great. Moreover, there is a need to reasonably develop and take full advantage of the rich grassy slopes to develop animal husbandry, transform existing pasture, so that animal husbandry becomes an important industry for comprehensive development of agriculture in the province.

In the specific implementation process, since the land is affected by the natural and social conditions, there are significant regional differences in the land. The local economic development and the construction of ecological agriculture often have local characteristics, and in different regions, the soli property and suitability are different, so o achieve the sustainable use of land, we must adhere to the principle of taking actions that suit local circumstances, take full account of local natural and socio-economic conditions, give play to the advantages of land resources, and reflect the local economic characteristics.

Based on the general situation of mountainous areas in Guizhou Province, namely the natural characteristics of high mountains, barren soil and three-dimensional climate, it is necessary to implement the adjustment of agricultural structure, rationally grow the Chinese herbal prickly pear, kiwi fruit and cubeb litsea spices whose supply falls shout of demand at present. These are all the advantages of Guizhou. Through industrialized development and increase in economic benefits, we can not only protect and restore the natural ecology, but also give full play to the potential of land resources, which is an effective way for the construction of ecological agriculture and reasonable use of land resources in Guizhou Province.

3.4 Actively developing ecological agriculture and strengthening the rocky desertification control Ecological agriculture,

on the one hand, uses optimized structure of agriculture system and advanced agricultural technology, to promote the utilization rate of agricultural resources, reduce waste and increase the value-added of the agricultural resources; on the other hand, uses good ecological environment to protect the existing agricultural resources, thereby effectively promoting the sustainable use of agricultural resources. It is necessary to train a group of eco-agriculture construction personnel, to guide the development of ecological agriculture in various regions; improve the environmental awareness of the village cadres and farmers. Only when the resources and environment awareness of village cadres and farmers is improved, can they pay attention to the protection of the ecological environment in the development of agricultural production, so as to promote the sustainable use of agricultural resources.

In order to improve the production potential of the land in Guizhou Province, we need to pay attention to the following aspects:

(1) Increasing vegetation. According to the law of vertical and hierarchical structure of plant communities, taking actions that suit local circumstances to plant shrub, herb and ground layer vegetation; carrying out environmental transformation and natural repair in the ecologically deteriorated regions.

(2) Strengthening the construction of basic grain ration farmland. With the growth of the population, the per capita amount of food is constantly declining, and the farmers and herdsmen blindly reclaim the land under the production conditions of low grain yield, further making the ecological environment of agriculture in the province deteriorate. Accelerating the construction of basic grain ration farmland in rural areas is a premise of fundamental solution to the problem of food security.

(3) Exploring the development of animal husbandry. The development of the ecological animal husbandry is one of the effective measures to increase food security.

(4) Strengthening the construction of rural energy such as biogas. In order to ensure the results of returning farmland to forest and forest conservation, it is necessary to accelerate the development of ecological agriculture, and vigorously adopt various measures, to greatly enhance the production capacity of the land in Guizhou Province.

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(From page 20)

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