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Grain-for-green policy and its impacts on grain supply in West China

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Abstract

China's grain-for-green policy of converting steep cultivated land to forest and grassland is one of the most important initiatives to develop its western inland regions. Using a multi-objective programming model, this study assessed the impacts of this policy in the upper reaches of the Yangtze River and the upper and middle reaches of the Yellow River. In addition to the strategic planning of converting cultivated land to forest and grassland and its associated impacts, three other scenarios were simulated. Results showed that impacts on grain supply at the national level were in the range of 2–3%. These results suggest that the proposed policy might not have a major impact on China's future grain supply and the world grain market. At the local level, however, impacts could be significant.

Keywords: Grain production; Marginal land; Agricultural policy; Multi-objective programming; P.R. China

Introduction

Known for its backward economy and vulnerable ecology and environment, western China (Fig. 1) consists of the provinces of Sichuan, Guizhou and Yunnan, Chongqing municipality, Tibet Autonomous Region in the southwest, and the provinces of Shaanxi, Gansu, Qinghai, Autonomous Regions of Ningxia, and Xinjiang in the northwest (Li, 2000). Altogether, it has 867 counties that account for more than one-half of China's total area (MCAC, 1997). Owing to a shortage of grain and a lack of other economic opportunities, farmers in western China for decades had to turn huge tracts of forest and grassland, much of it on steep slopes, into farmland. These land use changes resulted in severe soil erosion, flooding, and, ultimately, land degradation.

In addition, since 1999, the realization that the initiation of economic reforms was widening the gap between east and west China has made building up the western region the national development strategy—a strategy that is of great importance, as it will promote economic development and maintain long-term stability of the country. The strategy essentially has the following objectives: (1) to accelerate agricultural restructuring and rural development, (2) to increase farmers' income, (3) to upgrade the industrial sector and revitalize enterprises and traditional industries with high technologies, (4) to step up infrastructure construction, and (5) to enhance environmental protection. On November 12, 2002, furthermore, the 16th Party Congress declared ecological environmental protection and construction would be the top priority among these tasks. The strategy, known as the grain-for-green policy, is designed to shift about 15 million ha of low-yield farmland to forest and to afforest another 17 million ha of barren mountains and land. The severely eroded farmland will be restored to forest as soon as possible.

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Fig. 1. Coverage of the Western China and seven agricultural ecological zones.

In recent years, China's grain output has grown steadily. Several consecutive bumper harvests have left the country with huge stockpiles of grain. This has created good conditions for implementing a massive farmland-to-forests campaign. To compensate the loss, farmers will receive subsidies, in the form of grain and money, for turning cultivated land back into forest and pasture. To minimize income loss farmers might suffer from forest and pasture restoration, it is suggested that where natural conditions allow, fruit and other commercially valuable trees be planted. While the government will provide seedlings, farmers will be responsible for taking care of the restored forests and pastures and will retain all the profits from planting trees and grass on cultivated land.

Because sloping land is highly vulnerable to erosion, a number of laws and regulations clearly prohibit new land reclamation for agricultural purposes on steeply sloped land. The most recent and specific such law is "regulation on converting farmland to forests," which was approved by the State Council on the December 6, 2002. This regulation has been implemented effectively since 2002. Basically, it calls for already-cultivated land with slopes of more than 25° to be shifted gradually to forest and grassland and restored with vegetation, or changed into terraced land (e.g., see Water and Soil Conservation Law, article 14). Based on these regulations and laws, it is estimated the total land of 4 million ha (about 10% of the total cultivated land) should no longer be ploughed. Of this, about 38% is located in the northwest region, and 62% in the southwest region.

Under these regulations, slopes of more than 25° should not be farmed, but it is problematic and controversial to determine how much land with slope between 15° and 25° should be returned to forests and grassland. Since western China depends on the agricultural land to provide food for survival, it is not feasible to convert all the cultivated land with slope between 15° and 25°. This is not only an ecological problem, but also a socioeconomic one. For the land with less than a 15° slope, the general consensus is that it should remain in agricultural use in the near future, but it should be cultivated with more ecologically and environmentally friendly farming techniques.

According to a document issued March 29, 2002, by the State Forestry Administration Bureau, the State Development Planning Commission, and the Ministry of Finance, for every hectare of forest or pasture redeveloped, farmers in the upper reaches of the Yangtze River will receive 2250 kg of grain every year, while farmers will receive 1500 kg of grain every year in the upper and middle reaches of the Yellow River. The policy discourages farmers from cultivating redeveloped forests and pasture areas in the future. The government will also give farmers 300 Yuan (1 Yuan = 0.12 US$) per year for every hectare of forest and pasture they redevelop, to help cover medical and educational expenses (SFAB, 2000). This policy is welcomed by most of the farmers. So far, farmland conversion to forests and grasslands has been larger than expected (Xu and Cao, 2002).

Economic justification of land-use change from farmland to forests is when land use for forest management generates a higher value (Park et al., 1998; Zhang et al., 2000, Zhang, 2001). Historically, most developed countries have experienced conversion from forestland to pastoral and agricultural land, and then a return of land back to forests (Mauldin et al., 1999; Mather, 1992; Pfaff, 2000). This study is not intended to assess which land use is most efficient, nor is it designed to evaluate how much or what kind of land should be changed. The grain-for-green policy has been tested since 1999 in Gansu, Shaanxi and Sichuan provinces and implemented throughout the western regions since 2002. There is little doubt on this policy will have a significant impact on western China, the rest of the country, and even the world as a whole. What is unknown, however, is the direct impact the grain-for-green policy will have on grain supply. As this information is going to be important for policy makers, we attempt to estimate this impact. Therefore, the objective of this study is to assess the impact on grain of current policy as well as other three scenarios.

Data

The primary source of data regarding cultivated sloping land in this paper is from the 1996 national land survey, which provided the most systematic, comprehensive and coherent quantification measurement of China's land, given the technology available (about this survey, see Lin and Ho, 2003). The survey—conducted from 1984 to 1996 using the most recent aerial photos, Landsat images, and maps available—gathered systematic county-level data on the types, area, and locations of land use. Most provinces and counties began to use the 1996 national land survey results as their published statistical data (National Bureau of Statistics of China, 1999). The survey's accuracy and reliability are widely accepted.

The slope classification of cultivated land is based on the threshold of soil erosion, irrigation, agricultural machinery, and land use, etc., which have relation with slope (Ma, 2000). All the cultivated land is classified into 5 types: $<2°$, $2°–6°$, $6°–15°$, $15°–25°$, and $>25°$. It is mainly obtained by GIS overlay and is interpreted by fields on the spot. The survey covered 2843 counties, 43,000 towns, 740,000 villages, 25,000 farms, and 400,000 administrative units. Most of the land survey was conducted from 1990 to 1995, but it was subsequently adjusted to the standard date of October 31, 1996.

According to the 1996 national land survey, a total of 38 million ha in western China is cultivated, accounting for 28% of all cultivated land in China; however, the cultivated sloping land in the west accounts for a high percentage of the land area in China (For more details of the sloping land and their distribution, see Figs. 2 and 3). Except for Xinjiang and Tibet in west China, the cultivated sloping land accounts for more than half of the total agricultural land in the rest of western provinces. The upper reaches of the two largest rivers in China, the Yangtze and the Yellow, are located in west China, so this region is critical not only to itself (for example in relation to biodiversity and land degradation), but also to the middle and lower reaches of the two rivers, which cover almost half of China's territory. It has been criticized that the desertification, resulting from deforestation and grassland degradation, has caused frequent damaging floods and sandstorms in northern China.

Methodology

The loss in grain production is exactly the sum of production in each piece of land not used in farming. To estimate the loss of grain production, the most straightforward method is based on the loss in land

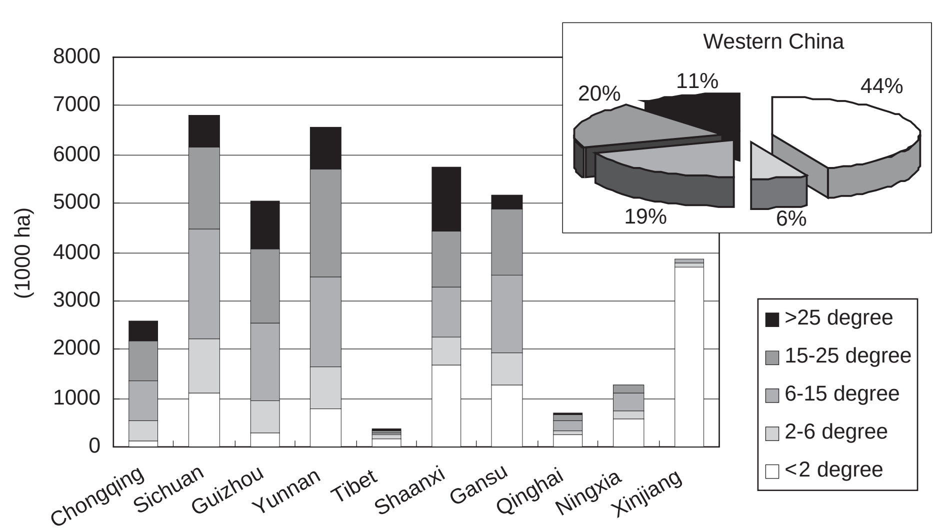

Fig. 2. Structure of cultivated land in Western China.

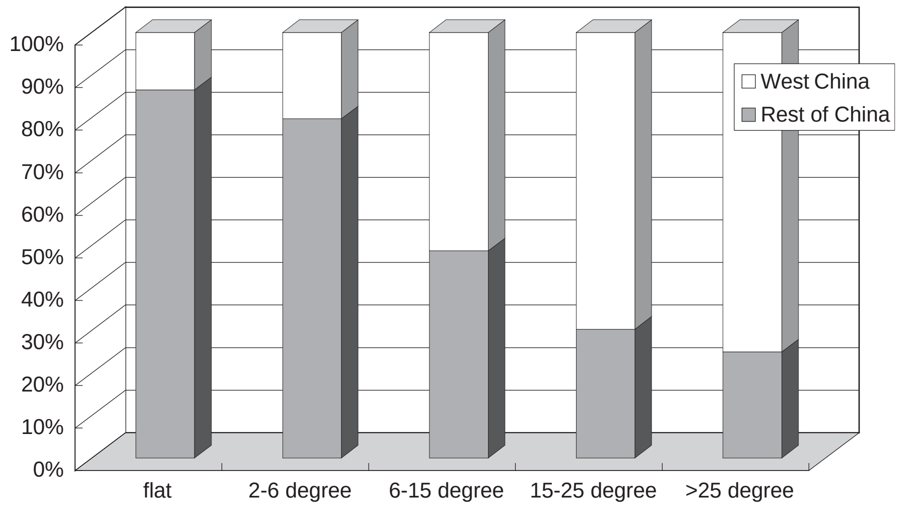

Fig. 3. Share of cultivated sloping land in the West to total China.

and the grain productivity. So there are two components of the methodology used: the estimation of the loss in agricultural land and change in average farm land productivity.

Cultivated land loss

In order to determine how much cultivated land with slope ranging from 15° to 25° can be restored, we first need determine the threshold of cultivated land per capita for west China to ensure sufficient cultivated land. This threshold is the minimum area of cultivated land per capita that can meet food demand (Cai et al., 2002). It is determined according to grain production, food consumption, and grain self-sufficiency rate (Yao et al., 1999; Li et al., 2003). Many researchers have studied the threshold of cultivated land per capita in China. It is widely accepted by many scholars and decision makers that when per capita cultivated land is less than 0.053 ha, food supply will be threatened (Feng and Li, 2000; Wang, 2001; Yan, 2002). For different purposes, different assumptions have been made—e.g., 0.08 ha in Du (2003), 0.17 ha used for acceptable value for arable land safety (Chen and Zhou, 2002), and 0.11 ha recommended for western China (Cai et al., 2002). At present, the average cultivated land per capita in western China is mostly greater than 2 ha, higher than the average level of the country (Li, 2000). But the per capita grain production is lower than the country average level. In the year 1996, for instance, it was only 359 kg per capita (national average was 412 kg per capita).

As land productivity in western China is less than the national average and as food self-sufficiency is high according to the previous research findings, three scenarios, or assumptions, in this paper were made at the county level: (A) retaining 0.133 ha (2 mm) per capita; (B) retaining 0.1 ha (1.5 mm) per capita; and (C) retaining 0.067 ha (1 mm) per capita. The rest of cultivated sloping land was forced to shift into forests and grasslands.

Population statistics and projection are essential for each scenario. We adopted population data for each of the areas under study from 'China's Population Across the Millennia' (Sun, 1994). The base year is 1996; the same as for the land survey, and the forecasted year is 2010, as the policy is implemented from 2002 to 2010. For all the counties, population projection assumes an increasing rate, with the provincial population as the sum of the respective counties.

The procedure illustrated by Fig. 4 is used for the calculation of cultivated land being converted.

Change in average land productivity

Partly to estimate the change in land productivity, a field survey was conducted in those provinces in 2000 and 2001. The survey attempted to investigate three aspects: the farmers' attitudes toward the policy; the existing situation of converting land, including the grain production farm land with different slope degrees; and farmers' suggestions and comments about the policy. Altogether, 118 rural households were interviewed (Feng and Zhang, 2002). The relationship between the slope and the grain production from the survey is presented in Table 1.

Table 1 shows a strong negative relation between slope degree and grain production. This is not surprising, since, as slope increases, so also does soil and water erosion. For instance, soil becomes thin, and content of organic matter tends to be poorer. For instance, the content of organic matter in sloping land between

15–25° and land with larger than 25° land is generally only 30–60%, and only 10–40% of flat land. The field investigation provided some preliminary inputs for analysis in the next step; the results are consistent with other studies (Ding, 2002; Guo et al., 2000; Pei et al., 2003).

Since socioeconomic and natural conditions vary significantly from one region to another, it was necessary to divide the whole region into agro-ecological zones that were different from the provincial administrative boundaries (Fig. 1). Among the various methodologies for agricultural land classification (Chen, 2001; Feng, 2001), we chose Chen's (2001) method, which has been widely applied throughout the China. Within an agricultural zone, there are many similar characteristics, such as cli'te, rural calendar, geographic condition, grain production situation, etc. According to this classification, western China is divided into seven agricultural ecological zones (Fig. 1).

Our strategy exploited two relationships: (1) α, the ratio of flat land productivity (P_0) to the average productivity C, and (2) β, the ratio of sloping land productivity P_i (i is from 1 to 5) to P_0 (P_1 to P_5 is the land productivity with slopes from 2° to 6°, 6° to 15°, 15° to 25° and >25°, and terrace, respectively). The justification for such an approach lies in the fact that it is easier to find the relationship of the productivity between each land category than the accurate productivity:

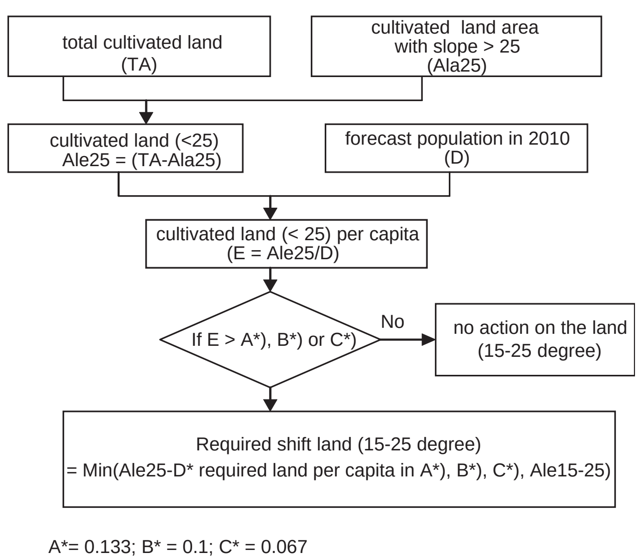

Fig. 4. Computing procedures for land conversion.

- α is greatly dependent on the land structure; α will be relatively high for counties with high shares of steep sloping land, α close to 1.0 for counties with high shares of flat land;
- β is the ratio of unit production of different slopes land to flat land; it is rather stable regardless of the specific counties, even though the land productivity may greatly vary from region to region (county to county).

Given α and β, the loss of grain production based on the change of land is estimated using following equation:

$$\hat{Y}_i = C_i\alpha_i\left(S_{io} + \sum_{j=1}^{5} S_{ij}\beta_{ij}\right), \tag{1}$$

where $\hat{Y}_i$ and C_i are the estimated total grain production and average production per unit of land in county i; α_i is the ratio of production from the flat land to average production for total cultivated land in county i; S_{i0} is the area with slope <2° (flat land), S_{i1} to S_{i5} is the area with slopes from 2° to 6°, 6° to 15°, 15° to 25° and >25°, and terrace, respectively. Correspondingly, β_{ij} is the ratio of average unit production of S_{ij} to that of S_{i0}. The essence of Eq. (1) is to convert all sloping land to equivalent flat land ($S_{ij}\beta_{ij}$) and the average productivity to flat land productivity ($C_i\alpha_i$).

Now the remaining task is to estimate α_i and β_{ij}. Multi-objective programming models are widely used in many fields (Xu and Wu, 1993; Xue et al., 2002). When some restrictions are established, a multi-objective programming model can find the optimized value of variable while at the same time minimizing deviations from the goal. The model has been used to construct

Table 1
The grain production distinguished by different land slopes

Region	Number of household surveyed	<2° kg/ha	2–6° kg/ha	6–15° kg/ha	15–25° kg/ha	>25° kg/ha	Terrace kg/ha
Loess Plateau	50	4500	4125	2850	1313	1125	3375
Inner Mongolia Plateau	5	5250	4350	3375	1200	900	3150
Qinghai-Tibet Plateau	5	5625	4500	3375	2400	1125	4125
Sichuan Basin	20	9000	7500	6000	2775	1875	6000
Yungui Plateau	10	6000	4500	3750	2250	1500	3750
Hengduan Mountains	8	4875	4125	3000	2250	1500	3000
Northwest dry region	20	7500	5625	4500	1500	750	3750

models of regional development, environmental management, food demand and supply, etc. In our study through the field investigation and existing study results, we were able to construct the production relationship between different slopes, namely restrictions on the model, and county-specific production data was available. Therefore, we constructed a multi-objective programming model, imposing the following restrictions:[1]

$$1 \leqslant \alpha \leqslant 2,$$

$$0.75 \leqslant \beta_1 \leqslant 1,$$

$$0.5 \leqslant \beta_2 \leqslant 0.8,$$

$$0.3 \leqslant \beta_3 \leqslant 0.6,$$

$$0.1 \leqslant \beta_4 \leqslant 0.4,$$

$$0.5 \leqslant \beta_5 \leqslant 1,$$

$$\left|\frac{y_i - \hat{y}_i}{y_i}\right| \leqslant 5\%.$$

The value α_i was significantly affected by the structure of sloping land in different counties. Since there are many types of land slope structure in every agricultural ecological zone, to get a reasonable α_i, we classified every zone according to structure of land slope by the hierarchical cluster analysis method. Percentages of agricultural land with different slopes were used as variables, and Euclidean distance was used as the measure of similarity, and squares sum of dispersion variables were employed as the method of cluster. The hierarchical cluster analysis method is used widely in similar studies (Li et al., 1992; Lin, 2001; Tian, 2003), and with this method, we grouped similar land structure into distinct clusters. The α_i and β_{ij} were then estimated as

$$\min \sum_{i=1}^{n} \sqrt{(Y_i - \hat{Y}_i)^2}$$

subjective to the restrictions mentioned above.

In the expression, Y_i is the actual grain production in county i, while $\hat{Y}_i$ is the estimated production.

Estimated results and analysis

Loss in cultivated land

Based on these assumptions and the procedure shown in Fig. 4, the results of restoration rate are as listed in Fig. 5. Note that the unit of analysis is county level rather than provincial level.

When the scenarios are compared with the provincial strategic plans (see Fig. 5), the following general patterns can be observed.

First let us consider the Northwest.

In Shaanxi province, almost 20% of cultivated land has slopes greater than 25°, which is approximately equal to the planned converting land area. For those slopes that are less than 25°, it is not essential that the land use be changed, but more ecological and environmental friendly farming methods must be practiced. In Gansu, the Scenario C could not meet the requirement of the planned strategy, which implies that some slopes land less than 15° are required to be shifted to forests and grassland. In Qinghai, the proposed areas for land use changes account for half of the cultivated land, the figure is higher than the Scenario C. This is because the planned land use changes cover not only the sloping land but also some severely dry land, high-altitude land, and newly reclaimed land. The situation of Ningxia is quite similar to Qinghai. Xinjiang has a very small area of deep-slope farmland and low-slope farmland. But the plans are mainly targeted to the land that is prone and vulnerable to desertification. Those lands are usually planted in cotton, thus there will be no serious negative impact on grain production.

Now let us consider the Southwest.

In Chongqing municipality, the land planned for change is much less than the amount of existing land with slope of 25°. It should be noted, however, that this amount is only the planned area for the first period. In the second period (2010–2030), another 180,000 ha of farm land are to be restored to forests and grassland. In Sichuan, due to different data sources, there is a gap between the sloping land greater than 25° and the planned shifting land; otherwise, they should be quite close. It is proposed to target only land with a greater than 25° slope. In Guizhou, the proposed land use change is also divided into two phases: 0.2 million ha for the first phases before 2010, 0.3 million ha for the second phase during 2011–2030. In Yunnan, the main target of land use change is on the sloping land greater than 25°, and 80% of it should be converted before 2010.

Change in average land productivity

The results are shown in Table 2. In Table 2, each type represents one structure for different zones. Sichuan Basin has many types for its complexity of sloping land structure. For type 1, the land area with slope less than 2° is more than 70%, while land area with slope greater than 25° occupies only 2.84%. The productivity is much closer to the flat land, so we take the value 1.00 for α. In contrast, for type 5, the proportion of $<2°$ and $>25°$ is 2.03% and 68.27%,

[1] Note that for different zones, changing the threshold values implied little change in expected outcomes.

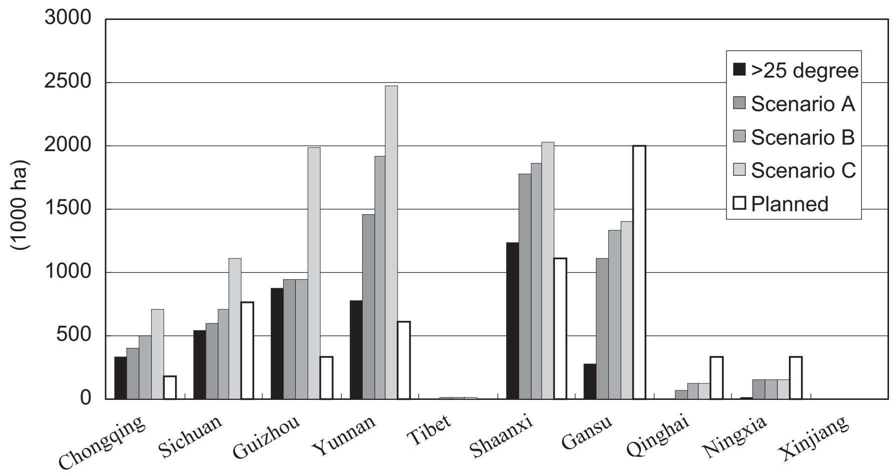

Fig. 5. Scenarios of converting land use versus the planned target.

Table 2
Multi-objective programming model coefficient estimates

		A	β_1	β_2	β_3	β_4	β_5
Sichuan Basin	Type 1	1.00	1.00	0.80	0.50	0.40	1.00
	Type 2	1.17	0.90	0.86	0.60	0.40	0.95
	Type 3	1.27	0.80	0.80	0.60	0.40	0.78
	Type 4	1.61	0.87	0.60	0.56	0.40	0.70
	Type 5	1.92	0.70	0.60	0.60	0.40	0.70
Yungui Plateau	Type 1	1.16	0.75	0.75	0.60	0.30	1.00
	Type 2	1.91	0.75	0.60	0.60	0.30	0.74
Hengduan Mountains	Type 1	1.16	0.75	0.75	0.60	0.40	0.86
	Type 2	1.34	0.76	0.75	0.60	0.40	0.61
	Type 3	1.69	0.75	0.75	0.60	0.40	0.69
Qinghai-Tibet Plateau	Type 1	1.05	1.00	0.75	0.60	0.30	0.95
	Type 2	1.41	1.00	0.75	0.60	0.30	0.82
Loess Plateau	Type 1	1.43	1.00	0.62	0.60	0.30	0.75
	Type 2	2.00	1.00	0.75	0.45	0.30	0.75

Note: Two other regions, Inner Mongolia and Northwest dry region, use directly inquisition data since the county is fewer.

respectively, so α value is 1.92, which is much higher than that of the type 1. It means that if one type has a high α value, the proportion of steep sloping land is larger, and vice versa.

To test the estimate, we compared the results derived from our model with actual yields with different slopes. Based on the data we obtained from Gansu Forest Survey Institute, the production of 6–15°, 15–25° and greater than 25° land for 56 counties, the mean relative error for above 25° and 15° to 25° sloping land was less than 10%, suggesting the efficacy of our model.

Loss in grain production

Based on these parameters and the land use changes in the scenarios, we calculated the loss in grain production for each county, each region, and all of western China. For comparison, the 1996 production was used as the base level. Impacts on total grain production are the sum of all regional production estimates (see Table 3). Reorganizing the outputs, we also calculated grain production loss for each province (see Table 4).

As may be seen from Table 3 and 4, total loss of grain production, under scenarios (A), (B), and (C), was 7.68, 9.29, and 14.63 million tons, respectively, accounting for 7.52%, 9.09%, and 14.31%, respectively, of the total grain production as against the grain production from western China, which was about 20% of the country as a whole.

The results are shown in Table 4. If those plans were carried out, the total grain loss in west China would be 7.14 million tons, accounting for 6.98% of grain production of China in 1996. For different provinces, the absolute loss value ranged from 0 ton to 2.09 million tons. The relative loss also showed some differences. In

Table 3
Estimated grain production loss associated with shifting land use (by regions)

Region	Scenarios	Converted land (1000 ha)	Of total (%)	Estimated loss (1000 tons)	Of total (%)
Loess Plateau	A	2095	22.31	1564	9.99
	B	2370	25.24	1896	12.11
	C	2514	26.77	2118	13.53
Sichuan Basin	A	1776	16.83	3354	6.89
	B	1995	18.90	3848	7.90
	C	2612	24.75	5800	11.91
Yungui Plateau	A	2411	20.52	2511	10.52
	B	2870	24.43	3189	13.36
	C	4504	38.34	6237	26.12
Qinghai-Tibet Plateau	A	59	9.54	40	4.12
	B	74	11.96	52	5.35
	C	80	12.93	57	5.86
Hengduan Mountain	A	152	20.76	187	12.96
	B	201	27.45	276	19.13
	C	253	34.55	383	26.54
Inner Mongolia Plateau	A	0	0.02	0	0.00
	B	0	0.03	0	0.00
	C	1	0.35	1	0.06
Northwest dry region	A	43	0.91	23	0.18
	B	47	0.99	29	0.23
	C	47	0.99	29	0.23
Total	**A**	**6537**	**17.17**	**7680**	**7.52**
	B	**7557**	**19.85**	**9289**	**9.09**
	C	**10010**	**26.29**	**14625**	**14.31**

Qinghai province, the loss reached 42.80% of its production in 1996. Thus, decision makers would need to take this into consideration. Compared with our three scenarios, for provinces of Gansu, Qinghai, and Autonomous Regions of Ningxia the planned grain loss was higher than the scenarios C, while for Sichuan province, the planned loss was slightly higher than scenario B. The rest of the provinces' grain losses were lower than scenario A.

While west China still relies on local production due to the self-sufficiency goals of traditional policy, low market economy share, and poor transportation system (which is why this study is primarily based on county-level unit), it would be interesting to examine the impacts if we were to assume policy implementation at the provincial level. Particularly, given that China now has stepped into an era of a market-based economy, grain flow from county to county is becoming more common. At the provincial level, government makes some policies to ensure grain supply. Since 1994, for instance, China has set up a system in which the provincial governor is responsible for demand-and-supply balance at the province level (Lu, 1996; Yang, 2001). In 1997, the government called for "maintaining a dynamic balance of cultivated land" to protect the quantity and quality of cultivated land (Zou, 1997; Zheng and Feng, 2003). The same three scenarios were also applied at the provincial levels. The converted land area and corresponding grain loss are listed in Table 5.

Compared to Table 4, we find that when we look at the figures at the provincial level, the conversion areas and the corresponding grain loss both are decreasing as a whole.[2] This is not surprising since implementation of the policy at the provincial level means the land allocation is province-wide, resulting in increased land-use efficiency to some extent. The policy implication is straightforward: The policy should consider only the land quality in terms of slope, regardless of the county if there no other constraints.

Conclusions and discussions

Based on the assessment above, the loss in grain production at county and provincial levels, according to the three scenarios, will be around 2–3%. (Total production in China was 460 million tons in 2000.) Since the process of converting land use will last 10–30 years, the impacts on the total grain market should be small, in general. Although the impact at the national level might be relatively small, impact at the local level might be significant. For example, in Gansu, Yunnan, and Shaanxi, relative converting land under the three

[2]But for some provinces, such as Gansu, the conversion areas and the corresponding grain loss are both increasing at the provincial level as more cultivated land will be returned to forest and pasture land if implemented at provincial level.

Table 4
Estimated grain production loss with shifting land use at county level (by provinces)

Province	Scenarios	Converted land (1000 ha)	Of total (%)	Estimated loss (1000 tones)	Of total (%)
Chongqing	A	399	15.51	1090	9.30
	B	493	19.15	1357	11.58
	C	711	27.59	2118	18.07
	Planned	*183*	*7.11*	*503*	*4.29*
Sichuan	A	603	8.88	1359	3.90
	B	714	10.51	1614	4.63
	C	1106	16.28	2868	8.23
	Planned	*769*	*11.32*	*2087*	*5.99*
Guizhou	A	951	18.78	989	9.77
	B	951	18.78	989	9.77
	C	1989	39.28	2854	28.18
	Planned	*333*	*6.58*	354	*3.50*
Yunnan	A	1456	22.17	1453	11.66
	B	1913	29.13	2123	17.04
	C	2474	37.67	3177	25.49
	Planned	*613*	*9.33*	*599*	*4.81*
Tibet	A	13	3.58	12	1.54
	B	16	4.59	16	2.06
	C	20	5.76	22	2.83
	Planned	*0*	*0.00*	*0*	*0.00*
Shaanxi	A	1778	30.88	1709	14.04
	B	1863	32.35	1797	14.76
	C	2024	35.14	2107	17.31
	Planned	*1116*	*19.38*	*1108*	*9.10*
Gansu	A	1118	21.64	875	10.66
	B	1328	25.71	1096	13.36
	C	1396	27.02	1164	14.18
	Planned	*2000*	*38.71*	*1716*	*20.91*
Qinghai	A	64	9.39	86	6.95
	B	120	17.56	184	14.86
	C	130	19.01	202	16.32
	Planned	*333*	*48.87*	*530*	*42.80*
Ningxia	A	154	12.20	105	4.07
	B	159	12.60	112	4.34
	C	159	12.63	112	4.34
	Planned	*333*	*26.40*	*239*	*9.25*
Xinjiang	A	1	0.03	1	0.01
	B	1	0.03	1	0.01
	C	1	0.03	1	0.01
	Planned	*0*	*0.00*	*0*	*0.00*
Total	**A**	**6537**	**17.17**	**7680**	**7.52**
	B	**7557**	**19.85**	**9289**	**9.09**
	C	**10010**	**26.29**	**14625**	**14.31**
	Planned	***5680***	***14.92***	***7136***	***6.98***

Note: The impacts from scenario of "Planned" are estimated at the Provincial level since no planned land use shift at county level available.

scenarios are all above 20%, and the associated grain losses are also very high. If the government's policy is implemented, per capita grain production of all the provinces will decrease, and most provinces cannot reach the present average level of China. At the county level, the policy will also result in great impacts on some counties. Overall, in western China, there are 22 counties with grain loss expected to reach 50% in all the three scenarios. Thus, the effects of the policy on converting marginal farmland into forests and grassland cannot be overlooked.

Our results suggest that if restrictions are imposed only at the provincial level, impacts on grain production decrease. The policy implication is to lift the self-sufficiency policy at county level, and even the provincial level. Either the grain production or environmental protection should follow the principles of efficiency, and comparative advantage between the regions. However, due to the poor market economy and transportation in general, food redistribution between counties is going to be difficult and costly. Furthermore, in western China, the land area varies

Table 5
Estimated grain production loss associated with shifting land use on province level

Province	Scenarios	Converted land (1000 ha)	Of total (%)	Estimated loss (1000 tones)	Of total (%)
Chongqing	A	340	13.21	934	7.97
	B	340	13.21	934	7.97
	C	382	14.84	1089	9.29
Sichuan	A	539	7.93	1259	3.61
	B	539	7.93	1259	3.61
	C	833	12.27	2317	6.65
Guizhou	A	875	17.28	930	9.19
	B	953	18.81	1066	10.53
	C	2132	42.10	3134	30.95
Yunnan	A	778	11.85	760	6.10
	B	1879	28.61	2395	19.22
	C	2700	41.11	3614	29.00
Tibet	A	6	1.74	5	0.59
	B	26	7.43	28	3.56
	C	26	7.43	28	3.56
Shaanxi	A	1238	21.49	1229	10.10
	B	1733	30.09	1840	15.12
	C	2202	38.24	2420	19.88
Gansu	A	1435	27.77	1205	14.68
	B	1435	27.77	1205	14.68
	C	1435	27.77	1205	14.68
Qinghai	A	6	0.83	5	0.40
	B	124	18.24	195	15.75
	C	130	19.19	205	16.59
Ningxia	A	159	12.63	112	4.36
	B	159	12.63	112	4.36
	C	159	12.63	112	4.36
Xinjiang	A	1	0.03	1	0.01
	B	1	0.03	1	0.01
	C	1	0.03	1	0.01
Total	**A**	**5377**	**14.13**	**6440**	**6.30**
	B	**7189**	**18.89**	**9304**	**8.84**
	C	**10001**	**26.28**	**14125**	**13.83**

significantly among the counties. The largest one, for instance, has an area of 198,790 km^2 (Ruoqiang, Xinjiang), while the smallest is only 91.87 km^2 (Linxia, Gansu). Food distribution within the large county is already difficult, so it is realistic for government policy to target the county level.

To estimate the impacts of land conversion on grain production, we calculated the impact on actual yields. Note that per-unit grain production in west China has continued to increase since its surge in 1949 (National Bureau of Statistics of China, 1999), and the potential for yield increase is still extremely high (Gu et al., 1999; Wang and Dai, 1997; Yang, 1997). Our estimation did not take this information into consideration. Percentage of grain production of west China has increased from 17.47 in 1952 to 20.66 in 1998 (National Bureau of Statistics of China, 1999). With the development of the economy, we would expect cultivated land to decrease in the future in eastern China (Hong and Li, 2000). Grain production of the west, then, might become more important. Further research needs to include all these factors to evaluate land use policy. While the model does not include mechanical input and fertilizers, their use on average per unit of land will likely increase when total land decreases. In addition, the ecological and environmental improvements may play some positive role in the remaining cultivated land. All these factors are not included in this study, so the estimates here are very preliminary. We must be cautious to use these estimated figures. In addition, for policymaking it is far from enough to investigate the impact of grain loss alone. Cost–benefit analysis of such policy is another important area of research.

As the population migrates and labor flows from one place to another and even grain transportation from the east to the west, especially at the county and village levels, many difficult challenges will arise, making local self-sufficiency more important. This concern has already been pointed out in many other empirical studies (see, e.g., Hou and Xiao 2000; Lu et al., 2001). How to redistribute the demands and supplies of the grain across the counties needs to be carefully studied. We need to examine the integration of converting policy to the construction of commodity grain production base and regional economic development to ensure sustainable development at regional level.

As our scenarios suggest, the marginal impacts of this policy vary across regions. For instance, the marginal impact in Sichuan Basin is much larger than in the Loess Plateau. At the provincial level, in Guizhou, Yunnan, and Qinghai, converted land and grain loss increase sharply with the retained area changed from 0.13 to 0.06 ha. While increasing cultivated land and grain loss in Ningxia and Xinjiang is much smoother, sensitivity analysis shows that the assumptions greatly affect research results. In this study, we applied the same three scenarios for both provincial and county levels. Further improvement can be made by implementing different criteria in each province and even at the county level. From this assessment, however, several policies still can be formulated. First, the grain-for-green policy should allow for differences between different counties. It should include adjustable measurements to local conditions, and priority should be given to farmers' livelihoods. Second, grain-for-green policy should be integrated with other policy and economic reforms. The best long-term strategy is to encourage population emigration from environmentally sensitive area to higher-population-capacity areas. Allocating population might be a more efficient way to increase land-use efficiency than the traditional land use policy. Third, converting cultivated land to forest should be coordinated with improvement of the remaining cultivated land and infrastructure development and other resources management. Also, the constraints in transportation and limited economic opportunities in west China make local security of the food supply more important.

So far, this policy has been implemented well. The key reason for the success is cash and food compensation, which generally exceed farmers' net production, and in some cases, gross yields, on the targeted land (CCICED, 2001). But can we continue to keep such compensation when the converted land area increases? How long can compensation last? What will happen when compensation stops after 5 or 8 years? So far, the policy implementation is strict and swift. The abrupt introduction of the policy, without necessary planning in advance, may lead to problems. Therefore, follow up monitoring and evaluation become important issues.

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