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Full Length Research Paper

Assessment of ecological, economic and social impacts of grain for green on the counties of north Shaanxi in the Loess Plateau, China: A case study of Mizhi County

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In order to noticeably and systematically assess ecological, economic and social effects of the grain for green project on county level, this study investigated the benefits of carbon sequestration to the soil of farmland-converted forestland (in 0 to 20 cm soil depth), the change in household income structure and social harmony. The results showed that, the soil organic matter content and organic carbon density of the forest land were 0.315% and 0.39 kgC/m^2 higher than those of the slope farmland and this change of land use brings about biological and economic benefits of soil carbon sequestration (in 0 to 20 cm soil depth) with a value of 16, 070,000 Yuan. The study surveyed the income structure and opinions of 50 farm households towards the grain for green project in 2010. Compared with their incomes 10 years ago, 69% of the farm households increased their net incomes 2 to 5 times, 56% of the farm households only increased their net incomes 0 to 1 time and 70% of the farm households had migrant workers whose income accounted for more than 50% of the net incomes of 63.6% of their farm households. According to the modified fundamental orientation theory, a society with a coordination coefficient of fuzzy membership of 0.87 belongs to the category of basic coordination state. The findings further revealed that, the grain for green project improved the counties concerned in regional ecological environment, farm household income, economic restructuring and optimization and social harmony.

Key words: Grain for green project, carbon sequestration, Loess Plateau.

INTRODUCTION

Since 1999, Chinese government has carried out a rather ambitious conservation program with a "win-win" purpose of environment rehabilitation and poverty reduction. The program is well-known as the grain for green project. Chinese government has invested more than 430 billion Yuan to convert 27 million mu of slope farmlands to forestlands in the past ten years and over 100 million farmers took part in the program from 1999 to 2008 (State Forestry Administration, 2008). However, the government and scholars have been more concerned with how to assess scientifically comprehensive benefits resulting from the grain for green project (Kong, 2004; Zhi, 2004).

It is clear from the Kyoto protocol to Hagen Conference that global climate change and its impacts have already become one of the world's priority issues in sustainable development and that, the international community is very concerned with its political, economic and environmental impacts (Lal, 2008). Although carbon sequestration is not a goal of the grain for green project, it is a measure capable of resulting in a wide range of environmental benefits of the grain for green project and the potential of afforestation as a short-term approach for reducing atmospheric carbon dioxide concentration is well recognized (Van Kooten et al., 1995; Sedjo et al., 1995). However, changes of land use annually produced a

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carbon footprint with between 0.7 and 1.6 Pg (IPCC, 2001), and the conversion of cropland to forestland has already become a basic action that reduces carbon emissions and increases carbon sink in the world (IPCC, 2000). At present, carbon sequestration in the grain for green project has reached a high level of national attention in China and other locations among environmentalists, politicians and agriculturists alike.

Common links between rural poverty and environmental degradation have been particularly shown in the case of China. Chinese government has worked out and promulgated various policies to kill two birds with one stone: addressing the common main causes of rural poverty and environmental degradation, to stick to the combination of resource development and environmental construction and to pursue the integration of the economic, social and ecological results (Pauline and Andreas, 2008), such as the grain for green project and so on. But some preliminary evidences show that, the impacts of the grain for green project on the incomes and shifts of involved farm households to non-farming income-generating activities are not sufficient to make substantial and long-lasting changes to the pre-program production status quo (Bennett et al., 2004; Uchida et al., 2005 and. Therefore, the critical factor for the grain for green project to further promote its sustainable development is how farmers can make a good living in a long run (Uchida et al., 2005).

The overall objective of this study was to fully assess ecological, economic and social perspective of the grain for green project. So we took ecological economic value of soil conservation service of carbon fixation as the ecological assessment, in order to indicate change in service function value assessment of ecological system of soil environment of Mizhi County after implementation of the grain for green project. The economic assessment aims to identify changes in the income structure of rural household after implementation of the project. Based on Bessel (1999) social sustainability indicators, the social impact of the grain for green project will be assessed using the coordination coefficient in systems. This paper presents the application of an integrated assessment approach to the grain for green project.

MATERIALS AND METHODS

Profile of Mizhi

The area under study was Mizhi, a county (109°49′-110°29′E, 37°39′-38°05′N) located in North Shaanxi, Northwest China. The county covers 1,212 km^2 with an altitude ranging from 843 to 1252 m. The county is a semi-arid area with a middle temperate continental climate; an annual average temperature of about 8.6°C with its extremely high temperature at 39.6°C and extremely low at -31.8°C. Its annual precipitation averages 440.9 mm and mainly distributes between June and August; the annual sunshine time averages 2,679 h and the annual evaporation averages about 1,557 mm. The main soil is loessial. In addition, there is a river named Wuding River that flows through the county and joins the Yellow River.

Mizi, as one agro-pasture County uses more than 80% of its total area as cropland and its farmers raise a great number of goats. The county has 15 townships (towns) which involve 396 administrative villages and a population of more than two hundred thousand of which there are 180,000 rural residents. The county dominatingly has a traditional rural economy with a weak foundation.

Since 1999, Mizhi has carried out the grain for green project in all its 15 townships. According to the Forestry Bureau of Mizhi, the county has converted 13,968 Mu of croplands and degraded slope lands into forestlands and increased its farmers' per-capita net income drastically from 800 RMB to over 2300 RMB. Why the study chose Mizhi as its study area was that the county is facing challenges in its industry restructuring, while implementing the grain for green project.

Survey design

In order to assess impacts of the grain for green project on farm households and social sustainability, the study designed a questionnaire to investigate farm households in 2010. To avoid possible misunderstanding of the questions in the questionnaire, the study tested the questionnaire in January 2010 by asking 40 households of Mizhi to answer its questions. With the local officials' help, the study randomly chose villages from each rural or district depending on the relative areas of the district or area. It took two months to complete the survey. The study recovered a total of forty answered copies of the questionnaire of which 33 copies were valid and carried its analysis depending on the valid copies. The study employed other approaches to obtain relevant data, including face-to-face interview and informal discussion with local leaders/official, group debate with local people and comment on official records in environmental policy.

Soil sampling and soil carbon sequestration calculation

The carbon sequestration data were obtained by field work and a laboratory soil testing in 2009 while the soil data were obtained by sampling soils of 20 slope plots of farmland-covered forestlands and there were slope farmlands in less than 30 m away from the slope plots. In each slope plot and the slope farmlands, we randomly selected five sites under forests or crops by S-shaped mode and their soil samplings were done in 0 to 20 cm soil with 2.5 cm diameter punch tubes and thereafter, the five soil samples of the plot obtained were fully mixed and some around 1000 g soil samples were taken from their mixture by quartering and put into a zip-lock bag and tagged. In the meantime, the soil bulk density of the plot was obtained by stainless steel cylinders with a volume of 100 cm^3. As soon as they were in the laboratory, these soil samples were air-dried, pulverized, sieved with 0.25 mm sieve and stored for future use. The soil organic matter was determined by the Walkey-Black method (Schnitzler, 1982).

The soil organic carbon (SOC) was calculated by the following equation:

$$\text{Soil organic matter (\%)} = \text{soil organic carbon (\%)} \times 1.724 \quad (1)$$

The value 1.724 is a factor which indicates the extent of conversion of organic carbon to organic matter.

Soil organic carbon density was calculated in terms of soil organic carbon concentration, gravel (grain diameter> 2 mm) content and bulk density and its formula is as follows:

$$T = CPH(1-\delta)/10 \quad (2)$$

In which, T is the soil organic carbon density (g/cm^2), C is the soil

Table 1. Coordination degree analysis.

Degree of coordination U	0≤U<0.6	0.6≤U<0.8	0.8≤U<0.95	U≥0.95
State	NO-coordination	Basic un-coordination	Basic coordination	Good coordination

Table 2. soil organic matter contents and bulk densities in 0 to 20 cm soil.

Land type	Average SOM content (g/kg)	Average soil bulk density (g/cm^3)
Grassland/forest ecotone	0.855	1.099
Cropland	0.54	1.12

organic carbon concentration (g/kg), P is the average soil bulk density (g/cm^3), δ is the gravel volume in percentage and H is the soil thickness (cm).

The total soil carbon sequestration was calculated as follows:

$$Q = T \times 10^{-2} \times S \quad (3)$$

Where *Q*, is the total solid carbon amount (ten thousand tons); *T* is the soil organic carbon density (g/cm^2); 10^{-2} is the unit conversion factor (converting g into ten thousand tons and c m^2 into h m^2); *S* is the afrorestation area (h m^2).

Ecological economic value of soil conservation service of carbon fixation was calculated as follows:

$$V = \left[Q \times (C_1 + C_2) \times 10^{-4}\right] / 2 \quad (4)$$

Where *V* is estimated ecological economic value of soil conservation service of carbon fixation (ten thousand Yuan); C_1 is the afforestation cost for carbon fixation (Yuan per ten thousand ton); C_2 is Sweden's carbon tax rate (U.S. dollar per ten thousand ton of carbon); *Q* is the total solid carbon (ten thousand ton); 10^{-4} is the unit conversion factor (Yuan is converted to million Yuan).

Model of assessing social impacts of the grain for green project

The study adopted the orientation theory (Bossel, 1999) to assess social impacts of the grain for green project on social sustainability of Mizhi. Bessel's orientation theory mainly involves the six fundamental environmental properties as follows: environmental state, resource scarcity, diversity, variability and other actor systems (Bossel, 1999). These properties can be assessed in terms of a full set of basic environmental orientors (existence, project efficiency, living choice, security, adaptability and coexistence) and systemic ones (psychological satisfaction) (Bossel, 1999). These orientors were used to assess social sustainability of the system under investigation.

In this study, we designed seven specific measures of these orientors (Table 3). The data for these measures was collected by asking farmers whether their sense of achievement was enhanced by having taken part in the grain for green project, the answers to those questions are "Yes". For example, to capture the meaning of orientor of "security" related to the project, farmers were asked whether the grain for green project increases their net income. The answers related to these questions are "Yes" or "No". For each measure, we sorted out how many answers "Yes" or "No" and the orient impact value chosen by the answers relation to these questions were only selected answers of "Yes". The integrated social assessment of the grain for green project was obtained by coordination coefficient of fuzzy membership of the value of the answers "Yes" of seven orientors related to the project. Formula for coordination coefficient of fuzzy membership is as follows (Wang and Chou, 2007):

$$U = \exp\left\{-k\left(x - x'\right)^2\right\} \quad (5)$$

Where U is the coordination coefficient in systems; x is the actual value; x′ is the system coordination value, in this paper, x′ is equal to 1; k=2/S, where S is the standard deviation of the actual value. A scale from 0 to 0.95 is used to grade the coordination coefficient in systems (Table 1) (Wang and Chou, 2007).

RESULTS

Ecological impacts

The comparison of the soil organic matter contents of the farmland-converted forestland or grassland with those of the farmland (Table 2) showed that, the implementation of the grain for green project increased the soil organic matter by more than 0.315% on average, that is to say, the semi-arid agricultural croplands were converted into grassland/forest ecotones and the soil degradation was alleviated; as a result, the soil environment of Mizhi was significantly improved. The soil organic carbon density of the forest /grass ecotone and the cropland (in 0 to 20 cm soil) were 1.09 kgC/m^2 and 0.7 kgC/ m^2, respectively. And the cropland was not likely to lose soil organic carbon after being converted into forestland. Therefore, the SOC storage in 0 to 20 cm soil was estimated at about 5×10^4 ton from 1998 to 2008 in Mizhi. The calculation by ecological and economic method (Anason, 1990; Xue, 1997) showed that, RMB16.07 million of the ecological and economic benefit of soil carbon sequestration (in 0 to 20 cm soil depth) was produced.

Table 3. Social coordination coefficients of the indicators of Mizhi based on the questionnaires.

Indicator	Questionnaire specific to indicators	Yes
Existence	Whether does the grain for green project affect the grain supply of your family?	0.75
Project efficiency	Whether do you converse all25-degree-and-over sloped farmland to forestland?	0.99
Living choice	Whether do you support to the grain for green project when food subsidy is finished the end?	0.85
Security	Whether does the grain for green project increase your net income?	0.70
Adaptability	Whether does grain subsidy make up for your loss in the grain for green project?	0.85
Coexistence	Whether does the grain for green project promote your education on environmental consciousness?	0.99
Psychological satisfaction	Whether are you satisfied with the vegetation coverage after the implementation of the grain for green project?	0.96
Coordination degree		0.87

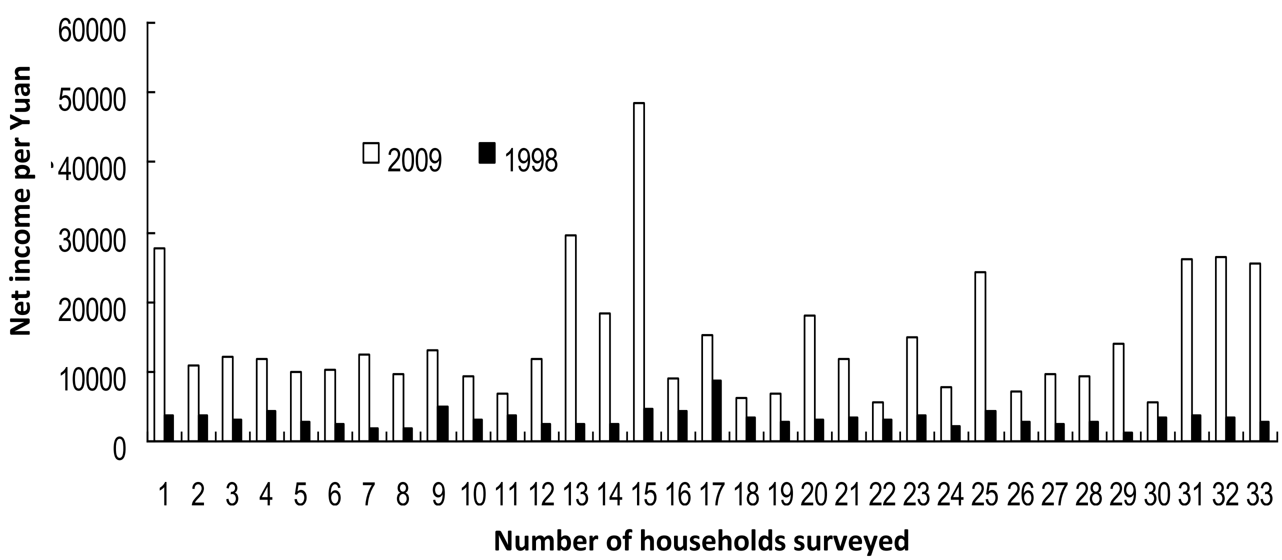

Figure 1. Net income of the farm households before and after the implementation of the grain for green project.

Economic benefit

After the implementation of the grain for green project, the farm households of Mizhi have experienced some changes in net income (Figure 1). Statistical analysis showed that, the farm household increased their net incomes one to nine times, the farm households, 69% increased their net incomes 2 to 5 times and 19% increased their net incomes 6 to 9 times, but only 9% increased their net income less than two times. Before the afforestation, 75.6, 15.4 and 9% of the farm households had net incomes that ranged between 2000 and 4000, 4000 and 7000, 1000 and 2000 Yuan, respectively. Ten years after the afforestation, 22, 40.6 and 37.4% of the farm household had net incomes that ranged between 2000 and 5000, 10000 and 20000, 5000 and 10000 Yuan. That is to say, the farm households increased their net income after the implementation of the grain for green project.

After the implementation of the grain for green project, Mizi had converted totally 13967.67 hm^2 of farmlands into grass/forested land by 2009 and its farm households had experienced some changes in their net income from crop planting (Figure 2). The farm households increased their net incomes from crop planting up to 3 times. The farm households, 37.5% increased their net incomes from crop planting 1 to 2 times, 56% increased their net incomes from crop planting less than one times and merely 6.5% increased their net income from crop planting more than two times. Statistical analysis showed that before the project afforestation 76, 15 and 9% of the farm households had net incomes from crop planting that ranged between 2000 and 4000, 4000 and 7000 and 1000 and 2000 Yuan, respectively and ten years after the

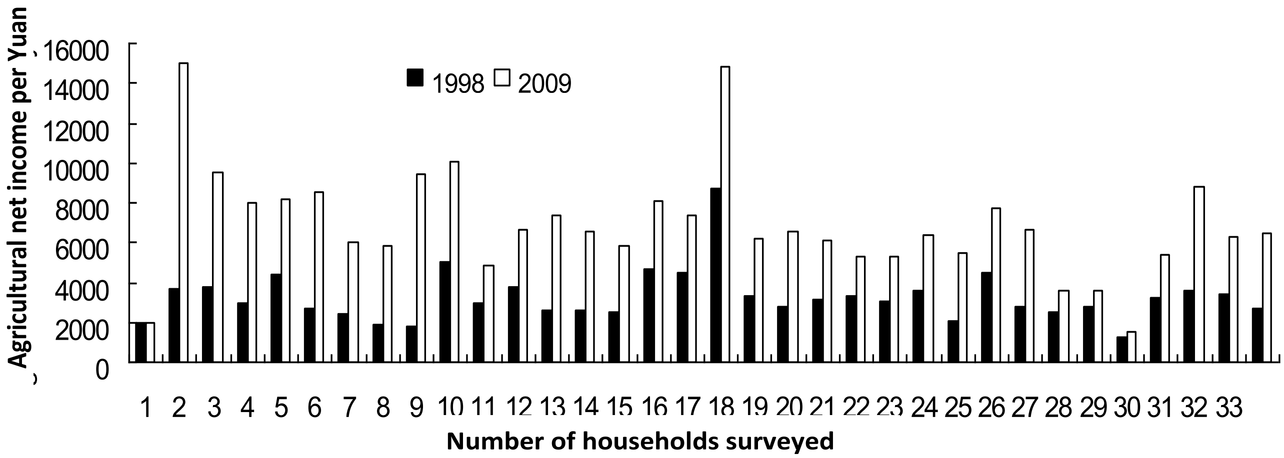

Figure 2. Net incomes of the farm households from crop planting before and after the implementation of the grain for green project.

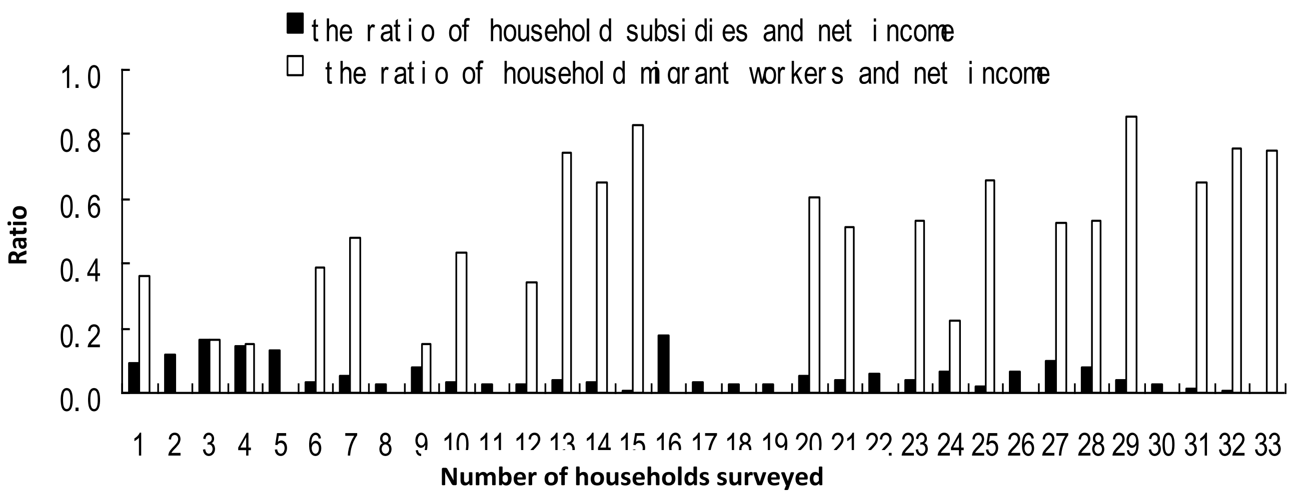

Figure 3. Proportions of the governmental subsidies and the incomes of the farm household members as migrant workers to the net incomes of the farm households.

project afforestation 50, 28, 13 and 9% of the farm households had net incomes from crop planting that were between 5000 and 7000, 7000 and 10000, 1000 and 5000 and more 10000 Yuan, respectively. That is to say, the farm households slowly increased their net incomes from crop planting during the implementation of the grain for green project.

After the conversion of much cropland into forestland, a high proportion of the farm households had members who were likely to migrate to work in urbane area or involve in some other economic sectors. The conversion from farmland into forestland can only be economically justified when it generates a higher value. It can be seen from Figure 3 that, the incomes of migrant workers were the main parts of the net incomes of their farm households. 70% of the farm households got more than 50% of their net incomes from their members as migrant workers and 36.6% of the farm households got 10 to 20% of their net incomes from their members as migrant workers.

According to an administration document jointly issued by the State Forestry Administration Bureau, the State Development Planning Commission and the Ministry of Finance on March 29, 2002, for every hectare of forest or pasture that they convert from farmland, the farmers in the upper reaches of the Yellow River will receive 1500 kg of grain per year as well as 300 Yuan per year for helping them cover medical and educational expenses (SFAB, 2000). It can be seen from Figure 3 that, 87.5% of the farm households had a subsidy for farmland to forestland or grassland conversion that accounted for less than 10% of their total net incomes and 12.5% of the farm households had a subsidy for farmland to forestland or grassland conversion that accounted for 10 to 20% of their total net incomes.

Social impacts

Table 3 presents the values of the seven indicators for probability sampling of farmers' answer implementation of the grain for green project. The probability sampling ranged from 0.7 to 0.99. An integrated social assessment value of 0.87 indicated that, the grain for green project had an effect of "basic coordination" on Mizhi as a whole. The system security orientor that is measured by farmers' net income scores the lowest, indicating that, the relationship of regional poverty and ecological degradation is one of heat problems that the society cares all the time in the Loess Plateau. These probability sampling for orientors such as the system's project efficiency, coexistence, psychological satisfaction, adaptability and living choice range from 0.85 to 0.99, indicating a good condition, but for the orientor of existence that is measured by grain supply scores, the value is 0.75, indicating a bad condition, that is, the grain for green project has negatively affected the grain supply system in Mizhi. In a word, the results showed that the grain for green project has positive impacts on the farm households of Mizhi.

DISCUSSION

The implementation of the grain for green project has altered the environmental reconstruction of Mizhi and consequently initial targets, such as bringing about an apparently good effect on the project for local society, improving farmers' living and environment conservation, have come true. The study opened up an approach for assessing ecological, economic and social impacts of the grain for green project with the purpose of carrying out an accurate project assessment and then putting forward highly pertinent proposals for decision makers to work out suitable project regulations for local sustainable development.

The project is one of the most important large-scale initiatives to combat land degradation in its ecological vulnerable regions. The results of ecological assessment indicated that, the grain for green project has strikingly improved the level of soil organic matter. Lots of researches indicate that, the conversion of cropland to forestland made soil organic carbon effectively promoted (Zhu et al., 2005). Soil organic matter is a useful indicator of rehabilitation of degraded soil. The improvement in soil organic matter after implementation of the grain for green project showed that, the evolution of ecosystems has been positive to development in Mizhi County. The changes in soil organic matter indicates that, the project actually improve the local natural environment to some extent.

The economic assessment of the project in this study region proved that, the grain for green project had little by little increased the total net incomes of the farm households. But as a whole, the net income from crop planting accounted for a significantly lower proportion of the total net income. The farmers mainly got the majorities of their net incomes mainly from working as migrant workers. The implementation of the grain for green project has effectively promoted the farm households' net incomes and surplus labor mobility (Hu, 2005). But a lot of researchers have raised doubts about prospect of increasing farmers' agricultural income and being employed farmers (Uchida, et al, 2004; Zhu et al., 2005). So the farmland to forest conversion project is still facing great challenges in sustainable development in a long term (Pauline and Andreas, 2009; Cao et al., 2009). As for the whole, we may suggest that the local government organize training for agricultural workers by demonstrating techniques for panting fruit trees and breeding livestock and encourage farmers' laborer to hold the certain knowledge and the technical skill.

Results of social assessment showed that, the farmland to forest conversion project favored social harmony of Mizhi. Although the indicators scored relatively low, such as the existence indicator, measured by grain security, the living choice indicator, measured by farmers continuous support in the farmland to forest conversion project, the living security indicator, measured by increasing the farmers' income, all other indicators, such as efficiency, coexistence and psychological satisfaction indicator, have indicated satisfactory of the project to social harmony of region. As a whole, the main contents of the probability sampling of satisfactory can be summarized as follows: the project has been beneficial to social sustainability.

The low farmers' net income in surveyed farmers' households do not mean an overall reduction of farmers' net income in Mizhi County. Accounting to the published statistics, the per capita net income for farmers in Mizhi County comes to 3368 Yuan in 2008, 317% increase over 1998 (Mizhi Prefecture Statistical Yearbook, 1998 to 2008). Discussions with local leader and farmers revealed how the net income increases despite the conversion of agricultural lands to forestland or grassland: (1) expanding in animal husbandry and orchards; (2) increased income of farmers from labor service outside their hometowns; (3) increases in the prices of agro-products such as potatoes and other major farm produce. Therefore, to increase the farmers' income we must continuously strengthen agriculture restructuring and labor mobility.

The low food security in surveyed farm households does not mean an overall reduction of grain yields in Mizhi. Accounting to the published statistics, the total grain yields in Mizhi County reached 80194 ton in 2008, 72% increase over 1998 (Mizhi Prefecture Statistical

Yearbook 1998 to 2008). Discussions with local officials and farmers revealed why the grain yields increases despite the conversion of agricultural lands to forestland or grassland: (1) slope farmlands with a degree above 25 converted to forestlands are largely marginal and amongst the lowest productivity; (2) basically the Loess Plateau because of its poor ecological environment as a whole have not been able to accelerate its food production growth rates enough to keep up with its rapidly increasing populations; (3) the environmental improve-ments reduce the risk of natural disasters and consequently, increase the grain yields to some extent. Therefore, there is no illustration that the grain yield capacity of Mizhi County will reduce significantly in the long run. Actually, the conversion of agricultural lands to forestland or grassland may have significant impacts on food security in Mizhi County.

The farmland to forest conversion project provides farmers who convert degraded and steeply slope cropland into forests or grassland with the state support in several forms. Such as grain subsidy, cash subsidy and free saplings, given to the farmer at the beginning of the planting period. An annual grain subsidy is 1500 kg/ha in the Yellow River and the cash subsidy is RMB300 per year. Actually, the local government only provided two thirds of these subside in Mizhi County; farmers were still satisfied to receive the subsidy, because the subsidy also can compensate local farmers' cropland loss. Certainly, if the subsidy will be called off or expired a long time, some farmers may plan to return to converse sloped forestlands with a degree above 25, to croplands.

According to the assessment of the ecological, economic and social effects, it was clear that the implementtation of the farmland to forest conversion project would achieve favorable ecological results, expanding the channels for the farmers to increase their net incomes and promoting social harmony and stability. However, currently, there are some problems to be resolved, for instance, re-employment of surplus rural labor force, agricultural restructuring and optimization, food security and subsidy and so on. But if Chinese government can well solve these problems through scientific planning and sound public policy, the"win-win"goal of environmental conservation and poverty alleviation will be achieved in the future.

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