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Agricultural practices and sustainable livelihoods: Rural transformation within the Loess Plateau, China

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A B S T R A C T

Effective agricultural practices can enable and sustain rural livelihoods, particularly in rapidly developing and transforming areas such as the Chinese Loess Plateau. Drawing from the Sustainable Livelihoods Approach (SLA), a conceptual framework for agricultural practices and sustainable rural livelihoods for the Yangou watershed within the Chinese Loess Plateau is presented and discussed. It is found that agricultural practices that include building terraces, returning sloped farmlands to forestland and grassland, and expanding orchards all have had positive and significant impacts on farmers' livelihood assets, strategies, outcomes, and vulnerabilities. From 1997 to 2006, 48.4 ha (95%) sloped farmland in the Yangou watershed was converted to new land management, and the percentages of income from fruit sale and sale of labor to total income dramatically increased by 59% and 14%, respectively. The watershed community also experienced 159% raise in per capita net income from 1997 to 2003, while the watershed itself experienced a 99% decrease in sediment yield from 1998 to 2007. These positive and significant impacts of new agricultural practices on the sustainable rural livelihoods of the Yangou watershed are evident in the community's reduced dependence upon grain and subsidies income, the diversified strategies for livelihood, and the improved environmental indices. The successful implementation of new agricultural land management practices and policies in the Yangou watershed strongly suggest that similar transformations can be achieved in similar regions throughout China's vast rural areas of the Loess Plateau.

Introduction

The concept of sustainable rural livelihoods has a wide generic meaning, encompassing the protection and assurance of the means of livelihood for people and society, and the current concerns and policy requirements pertaining to sustainable development (Singh & Hiremath, 2010). Chambers and Conway (1992) proposed the concept of sustainable rural livelihoods includes capability, equity, and sustainability. The term livelihood refers to a means of earning a living by an individual or household that is a combination of the individual or household's assets, including activities and resources and access to these, mediated by institutions and social relations. Since sustainable rural livelihoods implies the means of livelihood can be transformed by activities and policies, it is important to assess the impact of agricultural practices on sustainable rural livelihoods, especially in developing countries.

Individuals in rural communities may be either self-employed (typically in farming) or involved in multiple livelihood activities (including casual labor or entrepreneurship) without having steady employment or income (Cherni & Hill, 2009). Thus, conventional methods of wealth assessment are too broadly generalized when applied to rural livelihoods, which tend to be very heterogeneous and dynamic (Ellis, 2002). Many studies have examined the effects of agricultural practices on ecosystems (Dale & Polasky, 2007; Truu, Truu, & Ivask, 2008) and environment (Galan, Peschard, & Boizard, 2007; Rao et al, 2009). The modeling of land use/cover changes and threat to rural sustainability have been broadly discussed (Kamusoko, Aniya, Adi, & Manjoro, 2009; Su, Jiang, Zhang, & Zhang, 2011), and the assessment of cultivated land quality (Liu, Zhang, &

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Guo, 2010), land management practices (Paudel & Thapa, 2004), and linkages between traditional land use systems and agricultural change (Lopez & Sierra, 2010) have been of great concern to scholars. Few studies, however, have highlighted the relevance of a sustainable livelihoods approach (SLA) for assessing the impact of agricultural practices on rural communities. SLA addresses the objectives, scope, and priorities for development to expedite progress in eliminating poverty (Ashley & Carney, 1999). Since SLA aims to provide the means for satisfying the basic needs of rural residents, the positive impact of agricultural practices (e.g., reduced pressure on the environment) implies that it will be possible for more people to fulfill their livelihood needs in the future (Chambers, 1986).

To reduce rates of soil erosion, the Chinese government in 1999 launched the "Grain for Green" (GfG) program. The objective of this program was to increase the vegetative coverage on steep slopes by planting trees or establishing grasslands on former cropland (Zhou, Rompaey, & Wang, 2009). The GfG program is one of the world's largest conservation projects, implemented to alleviate the deterioration of natural ecosystems, to safeguard water resources, and to promote sustainable development in rural China (Yang, 2001; Zhang et al., 2000). The project attempts to convert agricultural lands on steep slopes or heavily degraded land to forest or grasslands (Peng, Cheng, Xu, Yin, & Xu, 2007). Since 2000, agricultural practices including the conversion of sloped farmlands to terraces and building farm dams have been implemented to promote the ecological restoration on the Chinese Loess Plateau (Xu, Tang, Zhang, & Yang, 2009). Studies on farming systems in this region have indicated that restricted access to capital and lack of technical agronomic support were serious impediments to the development of agriculture and the restoration of the environment (Nolan, Unkovich, Shen, Li, & Bellotti, 2008). The impact of agricultural practices on sustainable rural livelihoods, however, has not yet been adequately addressed.

This study links the impact of agricultural practices to sustainable rural livelihoods. Using the Yangou watershed on the Chinese Loess Plateau as a case study, this paper demonstrates how agricultural practices have impacted the livelihood assets, means, and outcomes of the community, and the environmental indices of the region. The objectives of the paper are: (1) to present a conceptual framework of agricultural practices and sustainable rural livelihoods on communities and the environment of the Chinese Loess Plateau; (2) to apply this framework to assess the impact of agricultural practices; and (3) to contrast agricultural practices and present potential means for rural residents to fulfill their future livelihood needs. The components of vulnerability context, livelihood assets, transforming structures and processes, and livelihood outcomes of the Yangou watershed are analyzed by applying this framework to the impact of agricultural practices. This study seeks to provide the evidence required in making sound development plans so that sustainable rural development on the Chinese Loess Plateau can be achieved.

Study area

The Yangou watershed is located between 109°20′00″E-109°35′00″E and 36°28′00″N-36°32′00″N, in the middle of the Chinese Loess Plateau (Fig. 1). The mouth of the watershed is 3 km away from Yan'an and the main stream channel is 8.6 km long with a watershed area of 46.9 km^2. The Yangou river is a secondary branch of the Yan River and flows from southeast to northwest. The watershed slopes from southeast to northwest at elevations between 986 m and 1425 m. The gradient ratio of main channel is 2.41‰ and channel density is 4.8 km km^{-2}, which is typical for this region. The terrain gradient of the watershed is mostly composed of steep hill slopes (Xu, Tian, & Shen, 2002). The present land area lying within watershed gradients are as follows: 52% > 25°, 16% in 20°–25°, 13% in 15°–20°, 8% in 10°–15°, 6% in 5°–10°, 6% < 5°. The

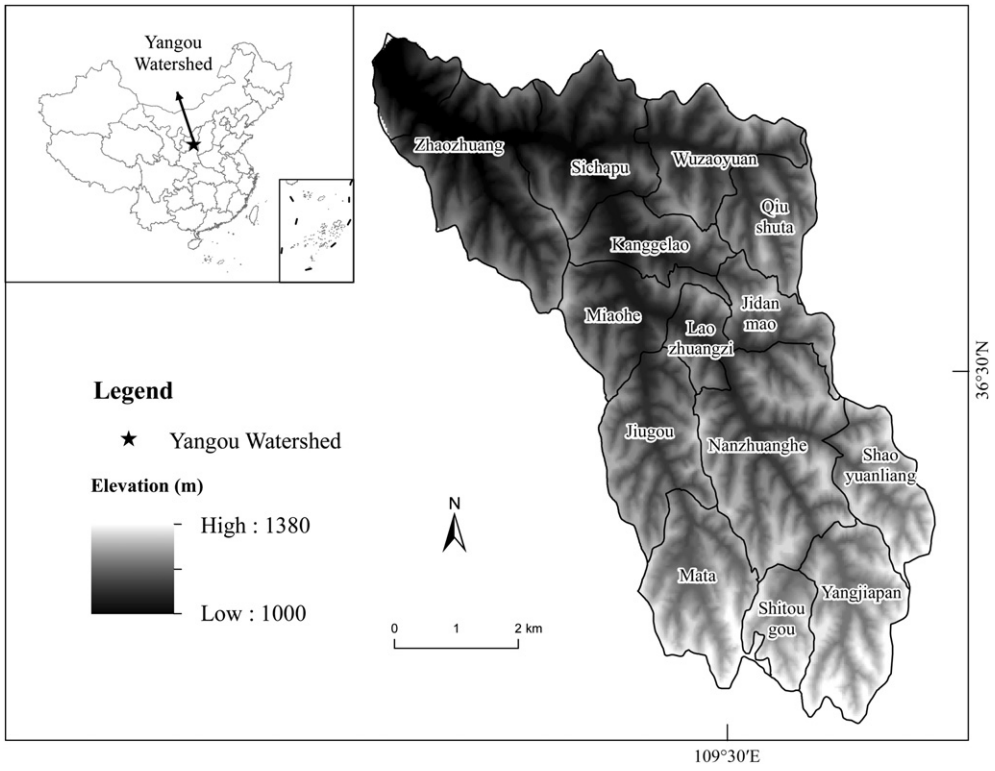

Fig. 1. Location of the Yangou watershed in China.

climate is near the transition from semi-humid to semi-arid, where the average annual temperature is 9.8 °C and the average annual precipitation is 558 mm. Precipitation from June to September occupies more than 70% of the total. The natural vegetation consists mainly of secondary natural forests, which have been seriously degraded due to excessive deforestation. Introduced vegetation is mainly composed of locusts, poplars, and other shrubs. Loessal soil occupies more than 90% of the land area, having 0.96–1.88 g kg^{-1} organic matter, 0.46 g kg^{-1} total nitrogen and 4.2 mg kg^{-1} rapidly available phosphorus. According to the field surveyed data (Ju, Liu, & Zheng, 2000), the mean annual discharge of the Yangou river in 1998 was 0.0025 m^3 s^{-1}, the total annual runoff was 378,300 m^3, and flood runoff accounted for 79% of this. The total loss of silt eroded in the gully mouth was 133,950 t, and soil erosion rate was 2856 t km^{-2} yr^{-1} of the watershed. The flow of perennial drainage, total loss of silt, and soil erosion rate in 2007 were 51,340 m^3, 1556.59 t and 33.12 t km^{-2} yr^{-1}, respectively.

Since 1996 with the implementation of the World Bank Financed Project and NKTRDP (National Key Technologies R & D Programme), land use in the Yangou watershed has undergone considerable change (Xu & Sidle, 2001). In 1997, there were 1831.1 ha of farmland in the watershed, making up 39% of the total area. Sloped farmlands accounted for 1617.6 ha or 88% of the farmland, and terraces accounted for 66.3 ha or 1% of the total area. In 2003, farmland decreased to 593.4 ha, down to 13% of the total area, terraces increased to 446.2 ha, up 10%, and the sloped farmlands was totally converted to terraces. There are 14 administrative villages and Goukou district in Yangou watershed. In 2006, the total population of the 14 villages was 3133, with a density of 67.8 person km^{-2}. The rural economy mainly relies on the agriculture, supported by farming, forestry, and livestock raising. The per capita net income of rural residents in 2006 was 325 USD (2168 RMB), derived mainly from apples and crops (corn, potato, sorghum, soybean, mung bean, black soy bean, and a small amount of artificial alfalfa).

Methods

The sustainable livelihoods framework

The Sustainable Livelihoods Approach (SLA) has evolved from three decades of changing perspectives on poverty, how poor people construct their lives, and the importance of structural and institutional issues (Ashley & Carney, 1999). The concept of livelihoods has become increasingly popular as a way of conceptualizing the economic activities poor people undertake in their communities (Adato & Meinzen-Dick, 2002). Livelihoods are a function of assets and structures, and a source of subsistence, income, identity, and meaning (Bebbington, 1999; Scoones, 1998). Resistance is understood as a defense of livelihood, in which movements emerge to protect assets by challenging the structures, discourses and institutions that drive and permit exploitation and dispossession (Bebbington et al, 2007). A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base (Scoones, 2009). Livelihood activities might be composed of, for example, year-round or seasonal formal-sector employment, informal trading or sale of labor, home gardens, and food processing, livestock production, cultivation or use of natural or common property resources, and labor exchange between family or neighbors. Hebinck and Bourdillon (2002) noted that livelihood provides a framework to focus on poverty within the context of the people who are poor, and on the processes that underlie such poverty. At the individual, household, and community levels, it is important to understand the poor's vulnerability sources, the variety of ways in which the poor might be affected by processes, and the multiple ways in which development interventions may have an impact on livelihood activities.

SLA also focuses on the importance of understanding the various components and factors of livelihood (Ashley & Carney, 1999). Here, "sustainable" implies that rural residents have the ability to enhance and ensure their future livelihoods. Resources or assets of an individual, household, or community can be thought of as capital to be utilized directly or indirectly to generate the means of survival or to sustain the material well-being at differing levels above survival (Ellis, 2002). In many cases rural residents have been regarded as passive recipients of government policies and exterior patronage. In this study, rural households could be regarded as passive recipients of the "Grain for Green" project of China, including both the specific policies and subsidies.

The sustainable livelihoods framework encompasses five sections (Fig. 2), which is intended to be dynamic due to both external interventions and the activities of the rural residents. The sections are: (1) vulnerability context; (2) livelihood assets; (3)

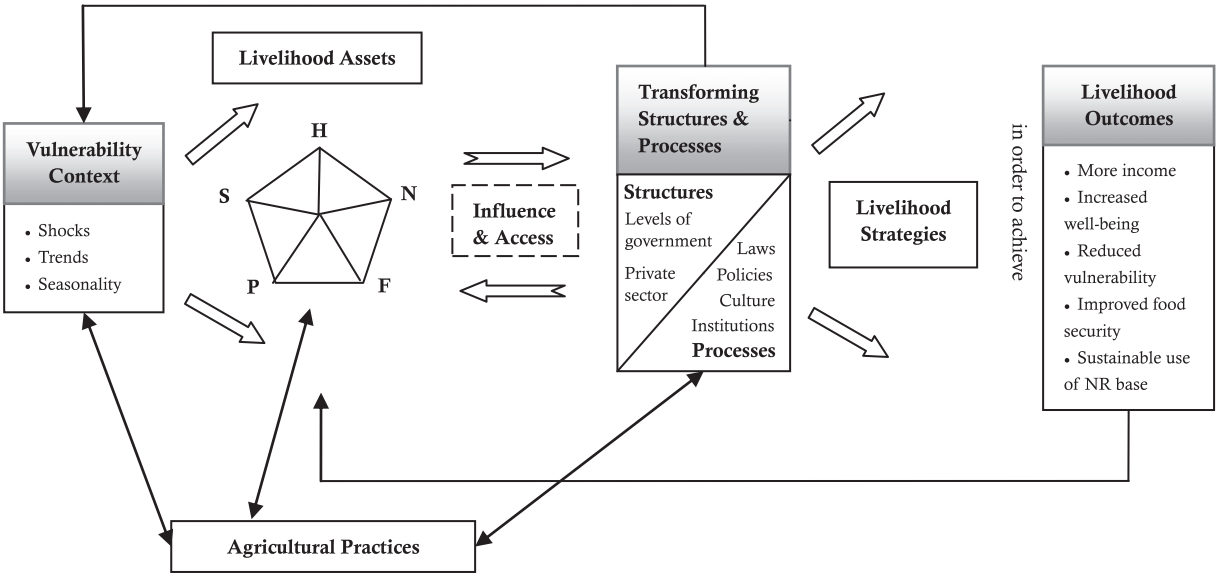

Fig. 2. The sustainable livelihoods conceptual framework with agricultural practices (adapted from DFID, 2002).

transforming structures and processes; (4) livelihood strategies; and (5) livelihood outcomes (DFID, 2000). The vulnerability context encompasses trends, shocks, and seasonality as people's decisions and livelihood strategies can be influenced by both perceived and actual vulnerability. An asset portfolio is to be considered natural, physical, financial, human, and social capital (letters in Fig. 2). Transforming structures and processes refer to institutions and organizations that affect how people use their asset portfolios to pursue livelihood strategies. These occur at multiple levels, from the individual to household to community levels. Livelihood strategies are the choices rural residents employ in pursuit of income, security, well-being, and other productive purposes. For income enhancement, well-being increase, vulnerability reduction, and resources sustainability, the results of these strategies vary among the individual, household, and regional levels. Livelihood outcomes encompass more income, increased well-being, improved food security, reduced vulnerability, and sustainable use of natural resources. Livelihood outcomes also can have a feedback effect on the vulnerability context and livelihood assets. Though the SLA does not prescribe the exact methods to be used for research, it does provide a useful description of components, and it is more a holistic and synthetic framework than an entirely new set of concepts. In order to assess the impact of agricultural practices on sustainable rural livelihoods, this study employs an SLA to provide a comprehensive perspective for a rural case study in China.

Research methodology

The study seeks to identify the current and relevant agricultural practices responsible for promoting sustainable rural livelihoods, and to explore how these practices have impacted a specific community's livelihoods assets, means, and outcomes. The small rural community of Yangou watershed was chosen for study. Scoones (1998) recognized five key elements of the definition of sustainable livelihood for measuring if a livelihood is sustainable or not. Creation of working days, poverty reduction, and well-being and capabilities are three elements focusing on livelihoods, linking concerns over work and employment with poverty reduction with broader issues of adequacy, security, well-being and capability. Livelihood adaption, vulnerability and resilience and natural resource base sustainability are two elements adding the sustainable dimension, looking, in turn, at the resilience of livelihoods and the natural resource base on which, in part, they depend. However, the SLA does not provide a formal research methodology. In this study, a specific conceptual framework for agricultural practices and sustainable rural livelihoods was designed for the Chinese Loess Plateau (Fig. 3). Here, the focus is on vulnerability analysis and livelihood assets, strategies, and outcomes of the Yangou watershed. Vulnerability, livelihood assets, and outcomes belong to state variables that might be affected by agricultural practices. Livelihood strategies belong to process variables meaning that the choices rural residents employ in pursuit of outcomes might be affected as agricultural practices have an impact on their concepts, information structures, and capital. Taking vulnerability into consideration, the framework emphasizes agricultural practices as transforming processes that run through the holistic circle from livelihood assets to livelihood outcomes. The composition of farmers' income, a pivotal factor of livelihood outcomes, is considered to be an important indicator to measure sustainable rural livelihoods.

In this study, the decline of farmers' vulnerability, enhancement of livelihood assets, diversification of livelihood strategies, and improvement of livelihood outcomes are main indicators to measure if the objective of sustainable livelihood is achieved. The framework emphasizes: (1) the analysis of vulnerability encompasses not only rural residents but also the human-land system of farmers and environment in which natural and social shocks, sensitivity, and resilience are key elements; (2) indicators for measuring livelihood assets including farmland, labor force, livestock and retail business, among others; (3) livelihood strategies are specialized as adjustments of structures of agricultural land use, employment, and production and changes of policies, techniques, and cultures; and (4) livelihood outcomes include more income, sustainable use of natural resource, and reduced vulnerability, as well as improved environmental indices. To be specific, the natural resource employed in this study mainly refers to the scarce land resources in the Loess Plateau of China. We measure if the natural resource is sustainable used by analyzing the structure of cultivated land, the decline of slope farmlands, and the increase of dam lands and terraces.

This paper introduces how the "Grain for Green" project has been implemented in Yangou watershed. The change of land use

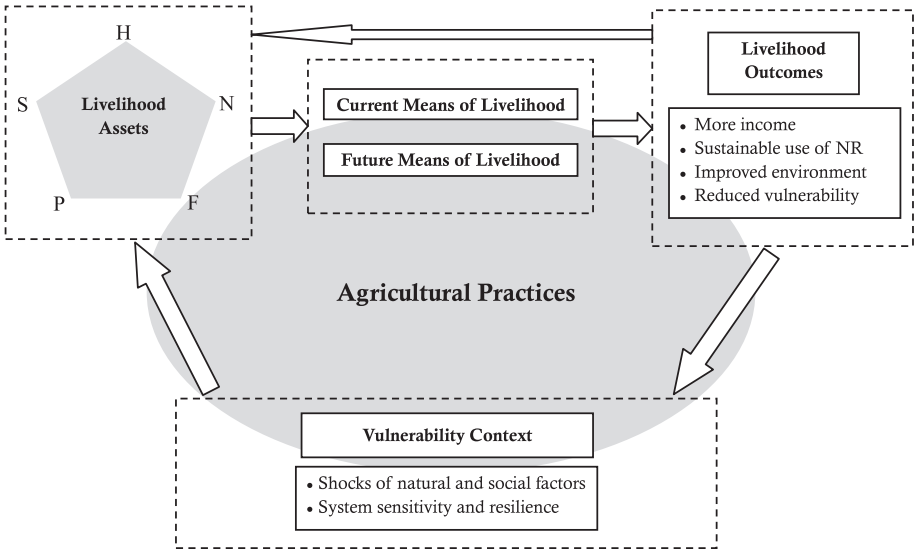

Fig. 3. The specific conceptual framework for agricultural practices and sustainable rural livelihoods on the Chinese Loess Plateau.

structure in Yangou watershed is analyzed by the land use data collected during 1988–2003. The population data are derived from statistical data before 1997 and census data of statistical yearbook during 1997–2006. Data for runoff and sediment transport in the mouth of the watershed during 1998–2007 were collected at the Yangou observation station. For livelihood assets portfolios and net income of farmers, a sample survey was conducted face-to-face among 84 rural households in 14 villages in Yangou watershed from May to July 2006. Population, labor force, structure of cultivated land, converted slope farmlands, orchards, livestock, poultry, and subsidy from government data were gathered through this household survey. Additional materials were collected from documents of Yan'an city government.

Research results and analysis

Implementation of the "Grain for Green" (GfG) project in the Yangou watershed

The Yangou watershed is one of the areas which firstly implemented the GfG project and the comprehensive control of soil and water loss. Since the 1980s, a series of measures had been taken in the watershed. These measures included: (1) building terraces as supplement for basic farmland, and converting all sloped farmlands to forest or grassland on the basis of ensuring food security; (2) planting forest and grass to enhance vegetation coverage to control soil and water loss; and (3) promoting animal husbandry and fruit industry relying on the resources of forest and grass. In Yangou watershed, special attention has been paid to building terraces, regulating riverway and flatland, and converting sloped farmlands and barren slopes. At the beginning of the implementation of the GfG project, ecological restoration and large-scale conversion from sloped farmlands to forest and grassland were emphasized to alleviate the deterioration of the natural ecosystem induced by human activities such as overgrazing. Enclosure of barren ravines and slopes were employed to facilitate the self-restoration of natural vegetation, because these measures can speed vegetation growth and address soil and water conservation benefits.

A dramatic increase of sloped farmlands and a sharp decline of forest and grassland persisted before 1988. From 1988 to 2003, land use change can be divided into two stages. In 1988, the proportions of key land use types of the watershed were: 37.2% cultivated land, 34.2% forest land, 24.9% grassland, 1.9% orchard, and 1.7% residential land. Sloped farmland accounted for 92.1% of total cultivated land. A slight land use change occurred between 1988 and 1997, with a small increase in cultivated land, grassland, and orchard areas by 1.8%, 1.1% and 3%, respectively, and forest area decreased by 3%. The increased cultivated land mainly consisted of terrace and dam lands with no change to the sloped farmlands (Table 1).

With the implementation of the GfG project, land use patterns of the Yangou watershed underwent dramatic changes during 1997–2003. By clarifying the responsibility, authority, and benefits of governments, research institutions, and farmers (Tian, Liang, & Liu, 2003), a series of agricultural practices were successively completed in these 5 years, and included converting sloped farmlands to terrace, rebuilding and expanding apple orchard, and increasing vegetation cover. The most remarkable characteristic of land use change in the period was the large-scale conversion from sloped farmlands to terrace. As shown in Table 1, sloped farmlands decreased by 100%. The proportions of land use types in 2003 were 17% cultivated land, 46% forest, 16.8% grassland, 13.9% orchard, 2.5% residential land, 0.4% water area, and 3.3% unused land. Compared to 1997, the area of cultivated land decreased by 1032.9 ha (56.4%), and all sloped farmlands had been converted. Orchard area increased to 653 ha, which is nearly four times that of 1997. Planted forest areas increased by 702.5 ha (65.1%), and the area of wild slope grassland decreased by 450.7 ha (36.8%).

Vulnerability analysis

The analysis of vulnerability includes rural residents and the human-land system, where natural and social shocks, sensitivity, and resilience are the key elements. In 1997, sloped farmland amounted to 1617.6 ha, accounting for 88.3% of cultivated land and per capita net income of farmers was 114 USD (763 RMB). Grain yield remained unstable because of varied agricultural climatic conditions. Due to restricted access to capital and lack of technical agronomic support, farmers were vulnerable to natural and social shocks, such as drought and diseases. They cannot afford the medical costs caused by serious diseases, and they need to struggle to keep up with the cost of living in drought years. Soil erosion rate in 1997 was 6000 t km^{-2} yr^{-1}, which indicated severe landscape degradation due to large-scale sloped farmland. The human-land system of farmers and the environment was vulnerable to natural and social shocks, and resilience deficiency was the major impediment to the environmental restoration. Farmers had no access to capitals, subsidies, and occupational chances, which caused the lack of resilience of them to improve livelihoods, in turn, pay attention to the environmental restoration.

Since the agricultural practices including building terraces, returning sloped farmlands to forestland and grassland, and expanding orchards were implemented in the Yangou watershed in 1997, the degree of watershed control reached 70%. The built terrace amounted to 516 ha, and per capita terrace in 2003 reached 0.165 ha. Due to the subsidies of the GfG project and profitable

Table 1
Land use change of Yangou watershed during from 1988 to 2003.

Land use categories		1988		1997		2003	
		Area (ha)	Proportion (%)	Area (ha)	Proportion (%)	Area (ha)	Proportion (%)
Cultivated land	Dam land	138.39	2.94	147.18	3.14	215.89	4.52
	Terrace	0.00	0.00	66.32	1.41	582.30	12.20
	Sloped farmlands	1616.70	34.29	1617.60	34.51	0.00	0.00
Orchard		92.33	1.96	174.10	3.71	651.48	13.64
Forest	Secondary forest	379.54	8.05	379.54	8.10	379.54	7.95
	Shrub and arbor plantation	1230.50	26.10	1078.66	23.01	1770.10	37.07
Grassland	Planted	0.00	0.00	0.00	0.00	16.79	0.35
	Wild slope	1176.32	24.95	1224.00	26.11	773.30	16.46
Residential, industrial, and mining land		81.13	1.72	–	–	117.57	2.50
Water area		–	–	–	–	18.78	0.40
Unused land		–	–	–	–	255.51	3.31
Total area		4714.91	100	4687.40	100	4698.96	100

Data source: land use data of the Yangou watershed from 1988 to 2003 by local land management department.

income from terrace and orchard agriculture, per capita net income of farmers dramatically increased from 114 USD (763 RMB) to 295 USD (1968 RMB). Sediment transport rates decreased by 5919.4 t km^{-2} yr^{-1} (98.7%), as almost all sloped farmlands were converted to terraces, forest, and grassland. The environment also had been dramatically improved and per capita net income of farmers was greatly enhanced by agricultural practices. As a result, the vulnerability of farmers to shocks dramatically decreased while the sustainability of the human-land system of farmers and environment increased.

Diversified livelihood assets

Indicators for measuring the livelihood assets of farmers include farmland, labor force, livestock, and retail business. Before the agricultural practices were implemented in Yangou watershed, the livelihood assets of farmers mainly consisted of sloped farmlands and livestock. In order to collect data on livelihood asset portfolios and net income of farmers, a sample survey was conducted among 84 rural households in 14 villages (6 rural households each village) in the Yangou watershed from May to July 2006. As shown in Table 2 and Fig. 4, the total labor force for the 84 rural households surveyed amounted to 204, accounting for 53.7% of the total population. Cultivated land area amounted to 41.8 ha, which includes terraces (93.8%) and sloped farmlands (6.2%). During the process of implementing the GfG project and agricultural practices from 1997 to 2006, 48.4 ha (94.9%) sloped farmlands was converted, orchard area increased sharply to 47.8 ha, raised livestock amounted to 223, and raised poultry amounted to 502.

Due to the building of terraces, returning sloped farmlands to forest and grassland, and expanding orchards implemented in Yangou watershed, a dramatic change took place in the livelihood assets portfolio of farmers. Cultivated land area decreased sharply, which reduced the vulnerability of farmers to natural shocks. A large-scale conversion of sloped farmlands had a positive impact on decreasing sediment losses of the watershed. A dramatic increase in terraces and orchards provided diversified livelihood assets for the rural households. From the perspective of sustainability, the diversified livelihood assets provided alternative choices for farming slopes, which could sharply reduce the threat of the activities of farmers to the human-land system of the Yangou watershed.

Varied livelihood strategies

Livelihood strategies are the choices that rural residents employ in pursuit of income, security, well-being, and other productive purposes. For Yangou watershed, agricultural practices including building terraces, returning sloped farmlands to forestland and grassland, and expanding orchards were emphasized as transforming processes to diversify the means of livelihood (earning a living) and to broaden livelihood strategies. Selling grain and receiving subsidies from the government were the two primary means of livelihood of rural residents in Yangou watershed before 1999. Obtaining grain from sloped farmlands was the primary means of livelihood that was vulnerable to natural shocks.

Since the agricultural practices were implemented, a dramatic change of livelihood strategies of rural households took place. As shown in Fig. 5, the percentage of income of grain sale to total income decreased to 9.3%, and the percentage of income of subsidies from government decreased to 8.1%. The percentage of income of fruit sale and sale of labor dramatically increased by 59.5% and 14.2%, respectively. The effect of agricultural practices reduced the dependence upon grain and subsidies income, whereas the diversified livelihood strategies included selling fruit from the expanded orchards, year-round or seasonal formal-sector employment, and informal trading or sale of labor.

Due to the agricultural practices from 1997 to 2003, cultivated land decreased by 1032.9 ha (56.4%), or at a rate of 172.2 ha yr^{-1} in the Yangou watershed. As a result, grain cultivation made up only a small proportion (9.3%) of the total income, which indicated that farmers did not rely on grain cultivation as their main source of income (Fig. 5). Much of the agricultural labor force was released from grain cultivation and was shifted to the secondary and service sectors. For instance, the surplus labor of rural households began to engage in full-time or part-time employment from the township enterprises. The labor force also began to derive income from fruit sale and retail business. Such changes of livelihood strategies can improve the environment, diversify economic activities, and increase the income of farmers.

Substantial livelihood outcomes

In addition to more income, sustainable use of natural resources, and reduced vulnerability, livelihood outcomes also include sustainable rural livelihoods and improved environmental indices. Per capita net income of farmers and sediment transport rates are recognized as two indicators to quantitatively measure the impact of agricultural practices on livelihood outcomes of rural households, and both proved to be satisfactory as the per capita net income of farmers noticeably increased and sediment transport rate sharply decreased.

Per capita net income experienced a steady and rapid increase from 114 USD (763 RMB) to 295 USD (1968 RMB) from 1997 to 2003 (Fig. 7). This was largely because farmers began to assume

Table 2
Livelihood asset portfolios of 14 surveyed villages in the Yangou watershed in 2006.

Village	Population	Labor force	Terraces (ha)	Sloped farmlands (ha)	Converted sloped farmlands (ha)	Orchards (ha)	Livestock	Poultry
Zhaozhuang	25	14	0.1	0.8	3.9	2.2	38	28
Sichapu	26	16	2.1	0.2	4.5	1.1	9	33
Wuzaoyuan	23	14	2.7	0.1	4.3	2.9	11	48
Qiushuta	23	10	2.1	0.0	2.0	1.9	9	41
Kanggelao	26	14	3.5	0.0	4.3	3.5	3	10
Miaohe	29	15	2.8	0.0	3.1	5.3	3	25
Laozhuangzi	25	13	2.0	0.0	2.5	3.9	16	37
Jidanmao	29	14	2.1	0.0	2.3	2.9	8	41
Jiugou	30	17	5.3	0.1	3.8	5.1	9	68
Nanzhuanghe	27	14	3.5	0.0	4.0	2.9	16	27
Shaoyuanliang	30	15	4.0	0.0	6.9	2.6	14	44
Mata	31	20	3.2	1.0	5.3	5.0	56	40
Shitougou	28	15	2.8	0.5	0.1	5.9	11	38
Yangjiapan	28	13	3.4	0.0	1.6	2.6	20	22
Total	380	204	39.2	2.6	48.4	47.8	223	502

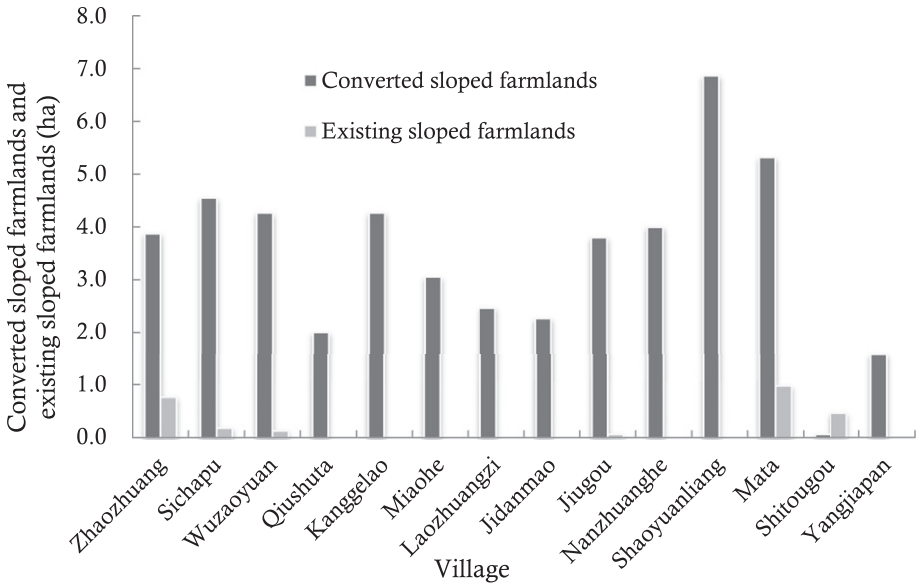

Fig. 4. Data of converted sloped farmlands and existing sloped farmlands from 1999 to 2006 by village.

diversified livelihood asset portfolios and various livelihood strategies in response to the implementation of agricultural practices. More income was derived from fruit sales and retail businesses. Based on data from the Yangou observation station during 1998–2007 (Table 3, Fig. 6), sediment transport rate decreased sharply despite a distinct fluctuation of rainfall among years. Sediment transport rate was lower than 620 t km^{-2} yr^{-1} since 2000, which was 80% less than that observed in 1998. In particular, there was a dramatic decrease of more than 95% in 2003, 2005, 2006, and 2007. As sediment yield is clearly a function of both rainfall and runoff rates, as conditioned by land use and land cover, yield should be normalized by these hydrologic indices. Using this approach, Fig. 6 shows that the dramatic decrease in normalized sediment yield in direct response to the implemented agricultural practices. In 2003, forest land consisting of secondary forest, shrub, and arbor plantation made up 45% of the total land area, while forest land and grassland made up 61%. The conversion of this landscape to terraces, orchards, forests, shrubs, and grasslands dramatically decreased the rate of soil erosion, as expressed in the sediment yield of the watershed.

As noted above, substantial livelihood outcomes including more income, sustainable use of natural resource, reduced vulnerability, and improved environmental indices can be recognized as livelihood assets of the conceptual framework. Correspondingly, these changes of livelihood assets will affect future livelihood strategies of rural households, as they begin to derive income from non-agricultural sector such as sale of labor in township enterprises. This reduced dependence on subsidies from government and the diversified livelihood strategies are significant to the sustainable development of the Yangou watershed.

Discussion

An appraisal of the impact of agricultural practices on sustainable rural livelihoods should not concentrate solely on the increase of per capita net income of farmers because such an approach could

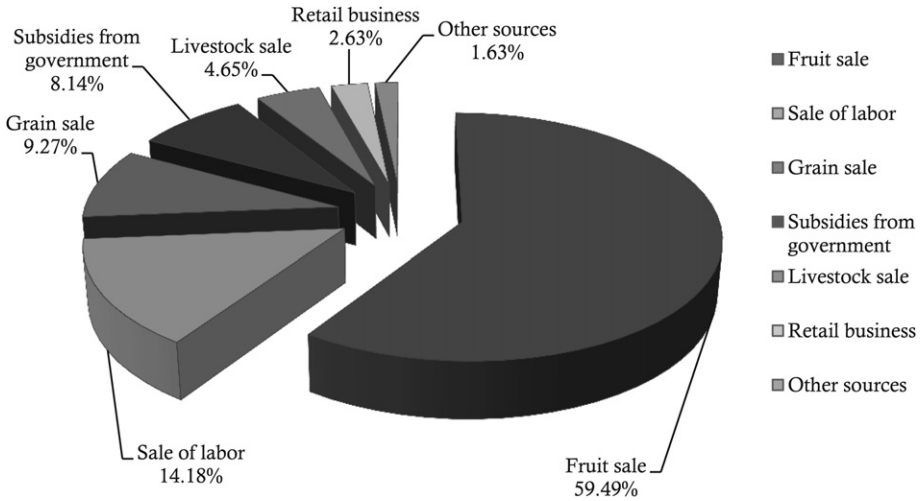

Fig. 5. The composition of the income of farmers of 84 surveyed rural households in the Yangou watershed in 2006.

Table 3
Monitoring materials of rainfall, runoff, soil erosion, and sediment yield in the Yangou watershed from 1998 to 2007.

Year	Rainfall (mm)	Runoff (10^4 m^3)	Soil erosion (t)	Sediment yield (t km^{-2} yr^{-1})
1998	567.8	37.83	133,950.00	2900.61
1999	494.6	27.00	70,782.00	1532.74
2000	367.0	22.70	27,242.00	589.91
2001	551.2	18.23	28,324.36	613.35
2002	496.7	8.90	14,489.20	313.75
2003	657.8	4.63	3722.59	80.61
2004	411.5	18.13	26,085.00	564.85
2005	475.4	17.00	6160.00	133.39
2006	441.6	3.31	13.46	0.29
2007	662.6	10.13	1556.59	33.71

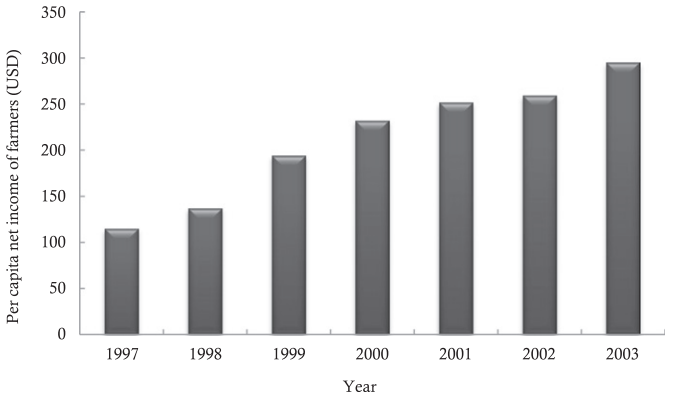

Fig. 6. Relationship between sediment yield normalized by rainfall (A) and runoff (B) in the Yangou watershed from 1998 to 2007.

obscure the holistic framework upon which the livelihood of the farmers is dependent. This study established a conceptual framework for agricultural practices and sustainable rural livelihoods on the Chinese Loess Plateau, and has shown that this framework can effectively assess the impact of agricultural practices on sustainable rural livelihoods. Within this framework, the relationship between agricultural practices and vulnerability, livelihood assets, strategies, and outcomes can be explicitly presented. The case study of the Yangou watershed community has shown that this framework can determine how agricultural practices lead to rural transformation development within the Chinese Loess Plateau.

At present, transformation in rural development of China can be characterized by accelerated rural industrialization and urbanization processes. For example, cultivated land has been lost to factory workshops and rural laborers have been transformed into industrial workers (Long, Zhou, Pykett, & Li, 2011). The interregional inequality of rural transformation development, however, has been rising, most notably between the more highly developed eastern region and the lagging central and western regions. The Loess Plateau is located in the central and western part of China and is infamous for its severe soil erosion problems and vast rural areas. Controlling soil erosion, promoting rural transformation, and achieving sustainable rural livelihoods have been central concerns of the local government. New agricultural practices implemented in the Yangou watershed include building terraces, returning sloped farmlands to forestland and grassland, and expanding orchards. These agricultural practices have had positive and significant impacts on the sustainable rural livelihoods of the Yangou watershed. Because the watershed is a typical area for its development status and regional characteristics within the Chinese Loess Plateau, the success in implementing these agricultural practices in the watershed provides compelling evidence that local governments can recommend sound and progressive rural development policies.

Despite the success of these agricultural practices in the Yangou watershed, future attention should be focused on narrowing the disparity between urban and rural areas and achieving urban-rural coordination development. Much of the agricultural labor force has been released from grain cultivation due to these agricultural practices. More measures to facilitate sustainable rural livelihoods are needed to help this released labor force to derive steady income from their future means of livelihood. Rural residents who have professional skills would better shift their livelihoods into high value-added manufacturing and the service sector to improve their livelihoods.

Conclusions

The Yangou watershed experienced a dramatic improvement of the human-land system including farmers' vulnerabilities, livelihood assets, strategies, outcomes, and the environmental indices since agricultural practices were implemented. These practices included building terraces, returning sloped farmlands to forest and grassland, and expanding orchards. The vulnerabilities of farmers to shocks have been dramatically reduced by the improved environmental indices and the enhanced per capita net income. According to a sample survey conducted among 84 rural households in 14 villages in the Yangou watershed, nearly all sloped farmlands was converted, and the amount of orchard area increased sharply. The percentages of income for fruit sales and sale of labor in total income have increased dramatically. Due to the implemented agricultural practices, the Yangou watershed experienced a 159% raise in per capita net income from 1997 to 2003, and a 99% decrease in sediment yield from 1998 to 2007.

The positive and significant impacts of new agricultural practices on the sustainable rural livelihoods of the Yangou watershed are evident and essential to the sustainable rural development of the watershed. The enhanced income, improved environmental indices, and reduced vulnerabilities of farmers are recognized as new livelihood assets that will influence the future livelihood strategies in the holistic framework. It is concluded that the

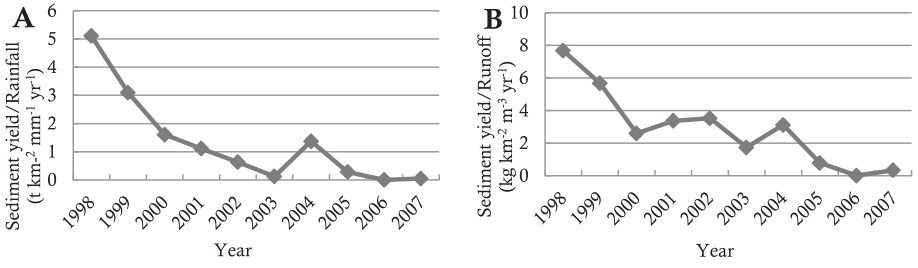

Fig. 7. Per capita net income of farmers in the Yangou watershed from 1997 to 2003.

reduced dependence upon the grain and subsidies income and the diversified livelihood strategies are essential to the sustainable rural development of the Yangou watershed. The success in implementing the agricultural practices in the Yangou watershed strongly supports the future promotion of similar policies elsewhere in the region, as China continues to experience large-scale transformation within its vast rural areas.

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