ECOSYSTEM-BASED ADAPTATION THROUGH SOUTH-SOUTH COOPERATION

GOOD PRACTICE CASE STUDY

Mitigation of soil erosion and water shortage in the Yangou watershed, Loess Plateau of China

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Soil erosion is one of the most serious environmental problems in China. In 2000, the area prone to erosion by wind and water was 3.57 million km^2, accounting for 37.6% of the national territory, and the annual volume of soil erosion reached 5 billion tonnes (Li et al., 2009). This severe problem was partially due to the over-farming on steep slopes and continuous reclamation of forest and grassland for cultivation during the late 1900s. Devastating environmental and socio-economic impacts to communities were observed. The severe droughts in 1997 and the massive floods in 1998 have drawn the country's attention, and driven China to take strong initiatives.

In response, in 1999 the central government initiated the "Grain-for-Green programme" to combat soil erosion, ecological degradation and to alleviate poverty, through reconverting cropland back into forest and grassland as well as afforesting barren land. This programme started in the western China in three provinces – Sichuan, Shaanxi and Gansu – the most ecologically fragile areas after the serious flood in 1998 and with high levels of rural poverty. It became nationwide in 2002 (Liu and Wu, 2010) and is still ongoing until today. It is among the biggest programmes in the world (Liu et al., 2008), owing to its ambitious goals, massive geographical coverage, huge payments, and potentially enormous impacts.

Policy support and financial support provided from the national level are the two major significant interventions. The central government has issued laws to prohibit cultivation on steep slopes in ecologically fragile areas and to regulate the right of land management (Order No.367t of the State Council, China). In addition, China has adopted an innovative Payment for Environmental Services (PES) mechanism, providing farmers with, for example, cash and grain subsidies and tax incentives for converting cropland on steep slopes to forest and grassland (Liu et al., 2008; Gauvin et al., 2010).

Overall, this programme has generated both immense positive ecological and socio-economic effects. It has reduced surface runoff and soil erosion, enhanced carbon sequestration, reduced nutrient loss for maintaining soil fertility and ultimately increased food productivity (Lü et al., 2012; Liu et al., 2008). In the Loess Plateau region (covering parts of 7 Chinese provinces, including Shaanxi and Gansu), by 2008 surface water runoff has decreased with an average of 10.3 mm/year and around 3.44 billion tonnes per year of soil has been retained. Moreover, carbon sequestration in both soil and the rehabilitated vegetation has found to be 35.30 teragram (Lü et al., 2012). In addition, this programme has helped alleviate poverty through the PES mechanism, and supported numerous farmers to change their income structure by shifting farming to alternative industries, such as transportation and restaurant businesses.

Yangou watershed is located in a priority area for the programme, the Loess Plateau, where slope gradients are greater than 25 degrees and suffers soil erosion, ecological degradation, water scarcity and poverty, plus additional pressure from climate change. As an exemplary case, the project in Yangou watershed focused on a variety of interventions including: i) financial support set up; ii) land use adjustment on slopes; iii) water conservation for agriculture; iv) improvement of fertilizer efficiency; v) industrial structure adjustment; and vi) demonstrations.

Key lessons

- *Combining Payment for Ecosystem Services (PES) with laws* encouraged the participation of households and promoted the implementation of project activities. The financial support attracted local communities to participate in the project. Furthermore, funds were also vital for the sustainability of interventions as they were invested in the construction of infrastructure and ecosystem restoration.
- *Cooperation between research organizations and local government is fundamental* to seek solutions at the community level. This is vital for solving problems fundamentally. For the Yangou project, research-demonstration-transfer is a good-practice principle to mitigate watershed degradation. Research organizations provided both support for applying current technology and developing new technologies to solve challenges. To complement the work of research organizations, local government provided opportunities for local communities to participate in training and demonstrations as to encourage these communities to adopt new technologies.
- *A joint sponsorship from multiple sponsors is more realistic and necessary.* Multiple stakeholders including administrative departments at different levels played their own roles with relevance to their respective mandates. For example: The State Forest Agency of China sponsored the Grain-for-Green project, which promoted the sustainability of land use adjustment; The Ministry of Science and Technology of the People's Republic of China sponsored The National Key Technology Research and Development Programme; The Technology Department of Shanxi Province sponsored the key projects as to support scientists to conduct coordinated research experiments to demonstrate the necessary techniques in the Yangou watershed and transfer knowledge to local communities; Local government provided communities with basic infrastructure and funding to initiate activities. In addition, some private donors also sponsored certain mitigation actions.
- *Educating and training local communities* on multi-benefits of eco-restoration and relevant technologies – and thereby increasing their adaptive capacity to climate change.

GOOD PRACTICE DESCRIPTION

LOCATION: Yangou, a watershed located in the northern region of the Loess Plateau, China

IMPLEMENTATION PERIOD: 1997-2003

KEY STAKEHOLDERS:
Implemented by:
The Institute of Soil and Water Conservation (ISWC), Chinese Academy of Sciences (CAS)
Ministry of Water Resources (MWR) of the People’s Republic of China
Yan’an Municipal People’s Government
Donors:
State Forestry Administration of the People’s Republic of China
Ministry of Water Resources of the People’s Republic of China
Ministry of Science and Technology of the People’s Republic of China
Science and Technology Department of Shaanxi Province
Partners:
Yan’an Municipal Bureau of Land and Resources
Yan’an Municipal Bureau of Agriculture
Northwest Sci-Tech University of Agriculture and Forestry

Background information and climate change vulnerabilities

Water shortages, soil erosion, ecosystem degradation and poverty are the four main concerns in the Yangou watershed of the Loess Plateau, China. Agriculture, especially the cultivation of food crops, is the main livelihood option of communities in the watershed. Most of the arable land consists of highly erodible loessial soil on steep slopes. Intensive rainstorms, though occurring at low frequencies, trigger floods which result in severe soil erosion and water loss. In this region, the annual precipitation during the period from 1950 to 2006 showed a decreasing trend (Liu et al., 2008), while the temperature increased from 1960 to 2013 (Yan et al., 2014). In addition to anthropogenic deforestation, climate change is causing a progressive decrease in land productivity and a loss of ecosystem functions, which further impact local livelihoods. As a result of the low productivity of arable land and the mountainous environment, poverty is a severe social problem. Starting in the 1990s, the national government intended to improve the ecology of the Loess Plateau through the Grain-for-Green programme, the National Key Technology Research and Development Programme.

Fig. 1 The location (left) and typical landscape (right) of Yangou Watershed, Loess Plateau, China ©Yu Liu

Intervention technologies

- *Set financial and policy support*. In 1999, the central government launched the "Grain-for-Green programme", in order to combat deforestation, ecological degradation, over-cultivation of slopes and soil erosion. The Loess Plateau, with fragile loess ecosystem, was a priority area for the programme, where slope gradients are greater than 25 degrees. The government financed the investments needed for revegetation by adopting Payment for Environmental Services (PES) mechanism. The Grain-for-Green project provided compensation for the abandonment of crop planting in the form of both money and grain. In addition, the right of land management is guaranteed by the Act of Conversion of Degraded Farm Land into Forest (Order No.367t of the State Council, China) in 2002. In this Act, the right of management of contracted land extends from 30 years to 70 years. Local communities have the ownership of the timber on the revegetated land. They also have financial support for construction of small energy infrastructures and support of free tax for producing agricultural and forestry productions.
- *Eco-restoration and adjustment of land use on sloping lands*. The first step of the project was replacing sloped croplands with terraced cropland, together with the construction of dams in the incised valley to reduce the loss of water and soil. The ponds affiliated by dams also became sources of drinking water. The second step was revegetation of abandoned sloped cropland by increasing the coverage of grass, shrub and trees (see Fig 2).


Fig. 2 Ground picture (left) and satellite image (right) of revegetation in the Yangou Watershed ©Yu Liu

- *Multiple water trap techniques[1] employed to promote agricultural productivity*. Terraced farmland construction, deep furrows (Wang et al., 2001) and plastic mulch were applied to help to replenish and conserve water in the soil; ISWC selected drought-tolerant crop species as to promote agricultural productivity under climate change (i.e. reduced annual rainfall); ponds and cement tanks were built to collect rainfall runoff to increase water supply for irrigation and drinking. In addition, the "hole irrigation" technique was adopted for sustainable water consumption (Wang et al., 2001).
- *Improvement of fertilizer efficiency*. During the first 3 years, the fertilizer input increased 4-fold to provide nutrition, and corresponding fertilizer-use efficiency increased by 4.33% (Wang et al., 2001).

[1] Water trap techniques include infrastructures to buffer the through rainfall energy, improving of water infiltration, and runoff collection system. Mitigation of the rainfall energy technique refers to arrangement of vegetation vertically and horizontally. Terrace and shallow channel in the crop land and small ponds were constructed to improve the infiltration. Runoff collection system consists of channels and water tanks. It is used to collect runoff generated on the land element with high runoff coefficient, e.g., impermeable road and built-up area, compacted soil.

Fig. 3 Orchard (hill top in left picture) and terrace farmlands (right picture) in Yangou watershed ©Yu Liu

- *Adjustment of industrial structure*. ISWC introduced supplemental and diverse livelihoods to ensure that the wellbeing of local communities was not adversely affected by the reduction of total area of arable land. The livelihood diversification includes, for example, new orchard crops such as Fuji apple and Pink Lady apple, fish-farming for both local sale and recreational fishing, and other commercial activities like labour services for the manufacturing sector, and shop running (Dang and Liu, 2009).
- *Demonstration of agricultural activities*. It comprises four aspects: i) crop and orchard planting; ii) management techniques; iii) techniques to promote efficient water use (Liu et al., 2005); and iv) technologies of livestock captivity (Xie, 2001).

Description of the results

- *Economy*

The annual income per person increased from 763 RMB in 1997 to 1,855 RMB in 2005 (130% increment). In addition, the sources of income of local communities significantly changed as a result of the project. From 2000 to 2005, the proportion of the planted cropland in the total arable area decreased from 78% to 57% (Dang and Liu, 2009). Also, the proportion of income from crop planting decreased from over 50% in 1997 to 36% in 2005 (Dang and Liu, 2009). Orchard increased rapidly. Apple planting became one of the key pillars of the local economy. In addition, non-agricultural incomes such as income from handcraft industry and wages also increased. Between 1998 and 2000, investment in local labour for infrastructure construction and revegetation for soil erosion control increased to one-third of the total investment (Ju et al., 2007). These changes in income sources imply an alleviation of the pressure on ecosystem through agricultural activities which are the most influential land use activities on the ecosystem.

- *Ecosystem function and services*

Land structure has changed in mainly two aspects. (1) Of the total Yangou basin of 47 km^2, the sloped cropland dropped from ~34% of the total basin area in 1997 to ~3% in 2003, and ~0.5% in 2009. (Xu et al., 2012). Now, dam farmlands and terrace cropland occupy 97.3% of the arable land. As compensation for the decline in cropland, the grain productivity increased by 63% (Wang et al., 2001). The crop yield in the terrace farmland increased to 8.25 t/ha, with an increment of approximately 3 t/ha (Wang et al., 2001). (2) From 1997 to 2003, vegetation restoration proceeded successfully. The coverage of vegetation in the watershed increased from ~27% to ~70%.

Soil erosion was successfully controlled. After the project, the average rate of soil loss decreased by 100-fold and now it is below the tolerant erosion rate of this region. The average concentration of sediment in the runoff dropped by 6-fold (Xu et al., 2012). The base flow steadily increased after the project, while the proportion of flood runoff showed a decreasing trend. It indicated a replenishment of the soil water (Xu et al., 2012).

The threats from water shortage were reduced. The volume of water lost through floods was minimized due to the dams, terraces and gathering infrastructures for rainfall runoff (Xu et al., 2012). Additionally, the efficiency[2] of water use in agriculture has increased by 59.1% (Wang et al., 2001).

- *Building local capacity*

Through the demonstration of technology in situ, local communities acquired knowledge of mitigating water loss, promoting the productivity of natural ecosystems and conserving ecosystems. After initial trainings, local community members had acquired sufficient capacity to develop alternative livelihoods such as fish farming. From 1997 to 2010, though the warm-dry climate affected land and crop, the local's income, crop yields and vegetation coverage increased.

[2] The water use efficiency (*WE*) is defined as the grain yield per unit water for one hectare cropland. To evaluate the water use efficient, the soil water storage in the beginning of planting (SW_0) and after the crop harvest (SW_h), rainfall depth in the growth season (*P*), and the grain yield (*G*) were measured. Then the water use efficiency is calculated based on a soil water budget approach: $WE = G / [(SW_0 + P) - SW_h]$.

GOOD PRACTICE ANALYSIS[‡]

Knowledge building

How has the project built upon or applied the findings of specific research projects? How has the project actively contributed to international understanding on Ecosystem-based Adaptation?

Before the project was launched, scientists had already started developing techniques in this region, which was pivotal in catalysing the mitigation actions. In the restoration of Yangou watershed, scientists conducted comprehensive research on the environmental and socioeconomic challenges faced by local communities. Furthermore, scientific research has identified and promoted a range of techniques as to promote community development. Following this research, local governments organized the demonstration of new techniques and training for local communities. Through this link, the results of scientific research were applied directly to environmental protection and development of livelihoods. For example, the rainfall-gathering infrastructure is a design that developed from one research project that was conducted by ISWC, CAS and MWR. In addition, fertilization techniques were derived from one research project of the National Key Technologies Research and Development Programme of China during the 9th Five-Year Plan.

Political ownership, collaboration and approval

How has the project secured support from political-level stakeholders and aligned its activities with wider development agendas to trigger further collaboration opportunities?

Yan'an government, together with CAS, initiated and executed the mitigation action in Yangou watershed. Also, the project was aligned with the policy of central government: Grain-to-Green policy.

The three key project stakeholders had different motivations in the project, namely: i) government wanted to achieve its political goals of increasing the income of local residents and restoring local ecosystems; ii) scientists wanted to establish their evidence base through the project activities; and iii) local communities benefitted from the increased incomes and improved ecosystems.

Achieving co-benefits and balancing trade-offs

How were the costs and benefits external to the project taken into consideration, e.g. on employment, environment, health, poverty levels, food security etc? Explain how the project aimed to maximizing external co-benefits from project activities and avoid/minimizing external costs and damages.

There are multiple benefits of Yangou watershed interventions, besides the mitigation of soil erosion and water shortage. The benefits include: i) the expansion of non-agricultural vegetation; ii) the restoration of native vegetation over large areas; iii) biodiversity conservation; iv) increased food production; v) diversified livelihoods; and vi) increased local job opportunity

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[‡] This analysis is based on the "principles of good practice" developed by the EU/FP7-funded project AfriCAN Climate (2011-2014). These principles represent critical cross cutting issues shared by the majority of climate change projects, regardless of focus, scope and scale. They are intended to encourage critical reflection and help project developers and decision-makers draw out relevant lessons. Source: http://africanclimate.net/en/good-practice/8-principles-good-practice

from infrastructural construction and revegetation. The project provides a win-win situation where both ecosystem conservation and economic development are supported.

However, some trade-offs and long-term negative impacts have also been identified. For example, in order to compensate for the decline of croplands, the project included the activity to increase the crop productivity. In addition, some experts are worried about the problem of 'water trap' at the source of watersheds, such as Yangou, that the overuse of water in Yangou may reduce the water flow to the lower part of the river basin. Also, restoration of the vegetation, especially artificial reforestation in this semiarid environment, may increase the evapotranspiration of the ecosystem – a factor that directly contributes to the appearance of a dry soil layer (Wang et al., 2011). These possible problems need to be addressed.

Monitoring and Evaluation

How has the project demonstrated its impacts in terms of achieving objectives, outcomes, and outputs? Explain how M&E plans were developed, and how effectively they have been applied.

Monitoring and evaluation exercises were carried out by scientists from ISWC, CAS and MWR. The goals were to: i) improve the capacity of preventing soil erosion; ii) mitigate water shortage; iii) increase the grain productivity; and iv) increase the income of local communities. Corresponding to the goals, activities below were conducted.

(1) *Soil erosion and stream flow*. A sediment gauge infrastructure was established at the outlet of Yangou watershed to monitor the sediment-laden flow and stream flow. The monitoring results were made available in 1998, 2001, 2003, and 2010. (2) *Change of land use*. Three investigations of land use were taken separately in 1997, 2003 and 2009 (Xu et al., 2012). (3) *Grain productivity*. Monitoring of the grain productivity was conducted before (1997) and after (2000) the application of productivity-promotion techniques. (4) *Change of income sources*. The industrial structure and their economy output during 2000-2005 were monitored.

References

Dang X, Liu G. 2009. **Economic response to the small catchment management of Yangou catchment in the loess hilly region of northern Shaanxi province**. *Research of Soil and Water Conservation*, 16(5):116-120 (in Chinese with English abstract).

Gao Y, Feng Q1, Liu W, Lu A, Wang Y, Yang J, Cheng A, Wang Y, Su Y, Liu L, Ma Q. 2014. **Changes of daily climate extremes in Loess Plateau during 1960-2013**. *Quaternary International*. Retrieved from http://dx.doi.org/10.1016/j.quaint.2014.08.052.

Gauvin C, Uchida E, Rozelle S, Xu J, Zhan J, Yin R. 2010. **Cost-effectiveness of payments for ecosystem services with dual goals of environment and poverty alleviation**. *Environmental Management*, 45(3): 488.

Ju T J, Liu P L. 2007. **Investment and coordination problems of high strenth eco-environment reconstruction in Yangou Basin of loess hilly region.** *Chinese Journal of Eco-Agriculture*, 15(3): 179-182.

Li Z, Cao W, Liu B, Luo Z. 2009. **Current condition and dynamic changes of soil erosion in China**. *China Water Resources*, 7: 8-11.

Liu C, Sui J, Wang Z. 2008. **Changes in Runoff and Sediment Yield along the Yellow River during the Period from 1950 to 2006**. *Journal of Environmental Informatics*, 12: 129-139.

Liu C, Wu B. 2010. **Grain for Green Programme in China: policy making and implementation?** The University of Nottingham, China Policy Institute, Briefing Ser 60: 1–17. Retrieved from http://www.nottingham.ac.uk/cpi/documents/briefings/briefing-60-reforestation.pdf

Liu J, Li S, Ouyang Z, Tam C, Chen X. 2008. **Ecological and socioeconomic effects of China's policies for ecosystem services**. *Proceedings of the National Academy of Sciences of the United States of America*, 105(28): 9477.

Liu P, Xu Y, Tian J, Ju T, Xu X. 2005. **Ecological and Environmental Construction in the Yangou Watershed of the Loess Plateau: Models and Benefits.** *Research of Soil and Water Conservation*, 12(5): 88-91 (in Chinese with English abstract).

Lü Y, Fu B, Feng X, Zeng Y, Liu, Y, Chang R, Sun G, Wu B. 2012. **A policy-driven large scale ecological restoration: quantifying ecosystem services changes in the loess plateau of china**. *Plos One*, 7(2), e31782. Retrieved from http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0031782

Ministry of Water Resources of PR China. 2008. **Standard for Classification and Gradation of Soil Erosion SL 190-2007**. China Waterpower Press, Beijing, China.

Wang S, Liu D, Deng X, Liu P. 2001. **Multi-technology and experimental demonstration for steady and high yield of crop in Yan'er Watershed.** *Agricultural Research in the Arid Are*a, 19(4):26-31 (in Chinese with English abstract).

Wang S, Liu D, Liu P, Deng X. 2001. **Demonstration and spread on stabilizing grain output in extremely dry year in Yangou watershed.** *Bulletin of Soil and Water Conservation*, 21(6):80-82 (in Chinese with English abstract).

Wang Y, Shao M, Zhu Y, Liu Z. 2011. **Impacts of land use and plant characteristics on dried soil layers in different climatic regions on the Loess Plateau of China.** *Agricultural and Forest Meteorolog*y, 151(4):437-448.

Xie J X, 2001. **Revegetation in the Yangou Watershed: a meso scale research and demonstration**. *Scientific News Weekly*, 31 (in Chinese).

Xu X, Lu P, Ju T, Shi X, Yu M. 2012. **Effects of soil and water loss control on reducing runoff and sediment transport in Yangou watershed of Loess Hilly region**. *Transactions of the Chinese Society of Agricultural Engineering*, 28(3):113-117 (in Chinese with English abstract).