27 Ecosystem Rehabilitation on the Loess Plateau

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Abstract

The Loess Plateau is well known for its deep loess deposits and serious soil erosion. The region covers five provinces and 0.62 million km^2; 45% of the area is eroded and there is an average soil loss of 3720 tonnes/km^2/year. Since 1985, the comprehensive reclamation of the Loess Plateau has been listed as a key science and technology project in China. Eleven small catchments have been selected as experimental and demonstration areas for ecosystem rehabilitation in different regions of the plateau. After 15 years, each of the 11 catchments has formed a good model for local areas. A set of technologies to control land degradation has been developed. The average yield of farmland has increased by 100–300%, the area under crops has decreased by 30–70%, perennial vegetation cover has increased by 70–150% and soil erosion has decreased by 60–80%. The economic structure of the region has undergone major changes, with income from grain down from 80% to 30%. Other sources indicate that farmers' incomes are 5–10 times greater than previous levels.

The key task in the region is to improve land use. In the loess hill region, cultivated land occupies more than 40% of the total area, most of which is on steep slopes (more than 15°) and about 20–30% of which is on slopes of more than 25°. Only 12% of the region is forested, and only half of that forested area effectively controls soil erosion. Only 30.5% is grassland, of which almost 69% has deteriorated from overgrazing. Land use should consist of flat area cropping for subsistence; forestry in gullies to protect the local ecology; and fruit growing and animal husbandry on sloping land for income.

Results from the 11 trial areas indicate that small catchments can be ecologically rehabilitated, but that they must pass through three stages—restoration, stabilisation and sustainable development—taking 15–20 years. The prospects for the Loess Plateau are bright, but there is a long way to go.

黄土高原以其深厚的黄土沉积和严重的水土流失著称于世。黄土高原地区涉及 5 个省（区），62 万平方公里。其中水土流失面积占 45%，每平方公里平均每年有 3720 吨的土壤流失掉。从 1985 年开始，国家把黄土高原的水土保持综合治理列为重点科技攻关项目，在不同类型区选择了 11 个小流域作为国家生态恢复重建试验示范区。经过 15 年连续治理，这 11 个小流域均成为当地的先进样板。研究开发了一套防治土地退化的技术。农田的单位面积

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产量提高了 1-3 倍，林草植被覆盖度增加了 70-150%。土壤侵蚀减少了 60-80%，农民收入提高了 5-10 倍。土地利用和经济结构发生了根本变化，农耕地面积减少了 30-70%，种植业的收入在总收入的比例由过去的 80%以上变为 30%左右。

15 年的研究结果表明：调整土地利用结构是首要而关键的任务。黄土丘陵区农耕地面积占总面积的 40%，大部分是 15 度以上的坡耕地，20-30%的耕地的坡度大于 25 度。有林地面积只占总面积的 12%，其中能起到控制水土流失作用的林地只有 6.5%。草地面积只占总面积的 30.5%，其中 68.8%的草地由于超载放牧严重退化。根据 11 个试验示范区的研究结果，黄土高原的土地利用和产业调整的基本原则为平地为农耕地，实现粮食基本自给；沟壑坡地宜发展生态保护型林业；在坡地上发展草业和果，这将是该区商品经济潜力所在。

11 个试验示范区的实践表明，一个退化的小流域生态系统是可以通过有序治理达到恢复重建的，但要经过 3 个阶段，即恢复阶段、稳定发展阶段和良性循环阶段。一般需要 15-20 年时间。所以，黄土高原的治理前景是美好的，但需要付出时间和投入。

THE Loess Plateau, located in the middle reaches of the Yellow River, is the cradle of Chinese civilisation. Cultivation in this region started 6000 years ago. The national economy relies on the energy base of the Loess Plateau for its heavy and chemical industries. The plateau is rich in sunlight and heat energy, the soil layer is thick, and there are vast areas of land suitable for forestry, fruit trees and grass. However, predatory exploitation, wanton deforestation, overgrazing and other forms of malpractice caused by a population explosion have caused degeneration of the ecosystems on the plateau. As a result, local economies are underdeveloped. The Overview provides background information about the region; Figure 1 of the Overview shows its location.

People in the Loess Plateau region have struggled long and hard against soil and water loss. The government has increasingly paid attention to the region, especially in the past 50 years, and has made great efforts to improve conditions. Since 1985, state authorities have listed the control of water and soil losses on the Loess Plateau as key research topics.

The Study Areas

Eleven experimental and demonstration areas (EDAs) were set up on the Loess Plateau on the basis of natural and social differences. Figure 1 shows the location of the experimental and demonstration areas; Table 1 shows the main environmental characteristics of the sites.

All EDAs represent seriously depleted ecosystems on the Loess Plateau. We have developed a set of technologies to control land degradation, as a result of which each EDA is expected to develop as a

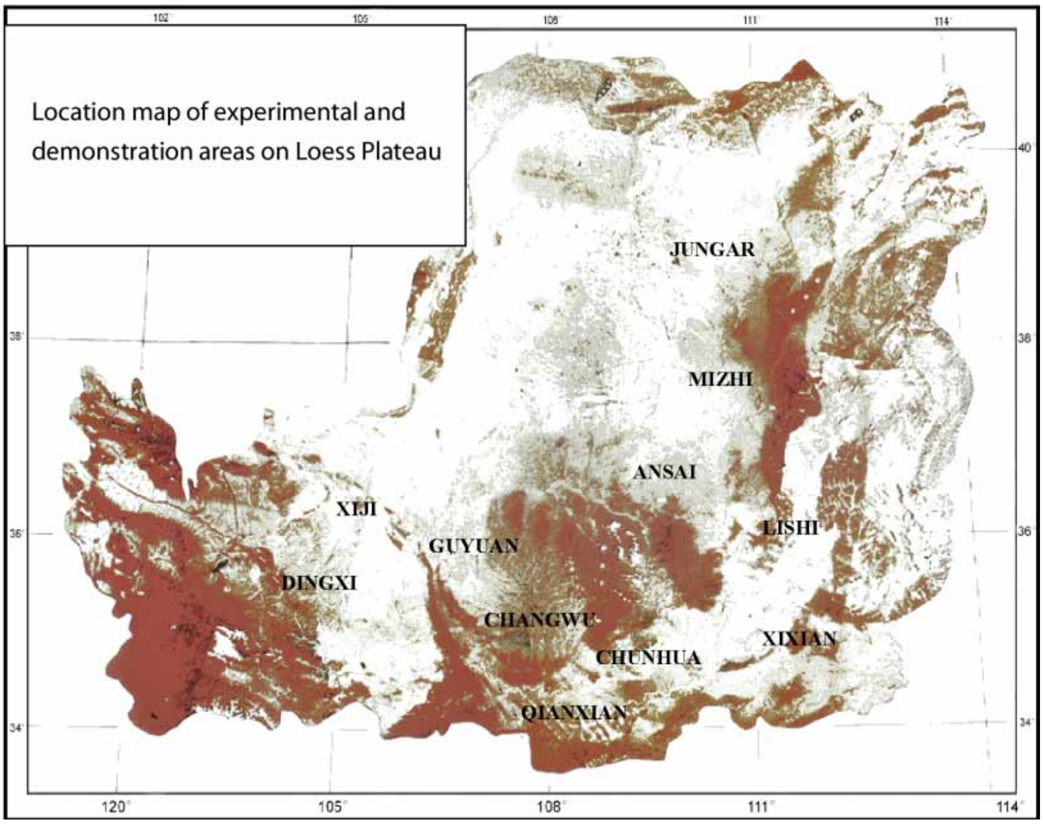

Figure 1. Location of experimental and demonstration areas on the Loess Plateau.

Table 1. Main environmental characteristics of experimental and demonstration areas (EDAs) on the Loess Plateau.

Type of region	Name of EDA	Area (km^2)	Annual rainfall (mm)	Annual average temperature (°C)	Population (persons)	Density of gully (km/km^2)
Windy and sandy	Jungar	7.7	344.2	5.3	330	2.37
Loess hill	Mizhi	5.6	422.0	8.4	586	3.00
	Ansai	8.3	497.6	8.8	407	3.06
	Lishi	9.1	484.7	9.0	1235	3.81
	Guyuan	15.1	472.0	7.0	785	2.16
	Xiji	5.7	402.0	5.3	491	3.32
	Dingxi	9.2	415.0	6.3	1564	1.57
Loess tableland	Changwu	8.3	584.0	9.7	1815	2.76
	Chunhua	9.2	600.0	9.8	2708	2.13
	Qianxian	8.5	590.0	10.8	1806	1.89
	Xixian	10.9	510.6	8.8	1211	1.46

Source: Database of the office of EDA project, Bureau of Resources and Environment, Chinese Academy of Sciences sustainable farming zone on a large scale. Each EDA has formed a good model for the local region.

Main Achievements of the Program

During the past 15 years, the 11 EDAs have undergone great change. The average yield of farmland has increased by 100–300%. Grain yield has increased from 5737.5 kilograms per hectare (kg/ha) to 8196 kg/ha; average personal income has risen from 218 yuan/year to more than 2000 yuan/ year (US$1 = 8.0 yuan). The amount of reclaimed land has increased from 46.1% to 80.2%. Research achievements have been applied to up to 10 million hectares of farmland, with some 5.55 billion yuan in increased crop value.

The project has not only improved the regional economy and farming practice on the Loess Plateau, but also promoted rehabilitation of the regional ecosystem. Some 150,000 km^2 of eroded land has been controlled by various conservation measures. The flow of sediments into the Yellow River has been reduced by about 300 million tonnes/year. By the end of 1995, reclamation had already led to an increase of 53.9 million tonnes in the aggregate grain yield over the previous 10 years. Increases in crop yield through the prevention of soil erosion and flood containment have resulted in economic returns of 180 billion yuan according to 1995 prices. Statistics from more than 2000 small watersheds showed that in each of the past 20 years, more than 4% of the eroded area has been controlled by soil and water conservation engineering on the Loess Plateau (before the 1980s, the figure was less than 1%) (Li Yushan 1996; Yang Wenzhi et al. 1992).

Land Use

Improving the land-use structure

The Loess Plateau has a long history of cultivation but natural and social factors have resulted in severe land-use problems, in particular a low proportion of vegetation cover and severe soil erosion and desertification.

Proportion of cultivation and vegetation cover

In loess hill areas, cultivated land occupies more than 40%, most of which is on steep slopes, with about 20–30% on slopes of more than 25°. There is little vegetation cover and the grassland is severely degraded, with less than 50% grass cover in most areas. For example, in south Nixia, grass yield is less than 500 kg/ha. Recent investigations have suggested that forested areas account for 12% of the whole region, of which only 6.5% can effectively control soil erosion. Most regions have only 30.5% grassland, of which 68.8% has deteriorated to some extent from overgrazing (Yang Wenzhi et al. 1992; Li Rui et al. 1992).

Soil erosion and desertification

The Loess Plateau suffers severe soil erosion and desertification. The long-term average sediment load of the Yellow River is about 1.6 billion tonnes per year, most of which comes from the plateau. Table 2 shows the main types of soil erosion on the Loess Plateau; Table 3 shows the intensity of the erosion.

Principles of rational land use

Experience, environmental characteristics and the nature of the land-use problems on the Loess Plateau suggest that the following principles should be considered for land-use planning in this region.

Table 2. Types of soil erosion on the Loess Plateau.

Soil erosion type	Area (km^2)	Proportion of total area (%)
Water erosion	289,300	46.36
Wind erosion	156,500	25.08
Water and wind erosion	178,200	28.56

Source: Tang Keli (unpublished lecture notes on soil erosion and conservation in China for the 2nd International Training Course on Soil and Water Conservation, September 1993).

Consider the economic benefits and ecological effects together

Human impact on the environment is continually increasing as the population increases and more demands are placed on land resources. If ecological effects are neglected during cultivation, land degradation and environmental deterioration will be more severe. Considering the economic benefits and ecological effects together will bring land reclamation and cultivation into ecological balance. On the other hand, soil conservation measures are unlikely to be followed by farmers if economic benefits are neglected.

Look at the integrated structure of land use

We must look at the overall regional economic arrangements as well as comprehensive land use. As mentioned above, semiarid regions have a variety of land-use types, which tend to be distributed in regular patterns. For example, in the hilly area, land types are in the following order: hilltop; land with a gentle slope (< 8°); steeply sloping land (15–35°); gully slope land (< 30°); gully terrace land (< 5°); and gully bed. Land-use arrangements must match the structure of the land type.

Remember that the overall function is bigger than the sum of the parts

This is one of the principles of systems engineering. Land use must match local conditions and there are mutual benefits between different land uses. For example, imagine that there are three hills to be used for planting crops, grass and trees. There are at least two ways to proceed. One is to plant crops on one hill, grasses on another and trees on another; the other is to plant grasses on the top, crops on the middle part (with gently sloping terraces), and trees on the lower part (the gully slope) of each hill. The first method means that one hill will produce grain, another forage and another wood. The results are the sum of the parts: 1 + 1 + 1 = 3. In the second method, the three kinds of uses can provide mutual benefits: the grassland on the top can protect cropland from water and soil erosion; trees on the lower part can control gully erosion. The results are more than the sum of the parts: 1 + 1 + 1 > 3. The second method is known as the integrated (or 'inlaid') method (Ju Ren et al. 1992; Song Guiqing and Quan Zhijie 1996). The key to realising this principle is to correctly handle the relationships between the subsystems and to establish a coordinated environment.

Table 3. Intensity of soil erosion on the Loess Plateau.

Grade of erosion	Amount of soil lost through erosion ($t/km^2/year$)	Area (km^2)	Proportion of total (%)
Very slight	< 1,000 (500)[a]	99,434	15.94
Slight	1,000 (500)–2,500	192,348	30.83
Moderate	2,500–5,000	40,622	6.51
Severe	5,000–10,000	111,384	17.85
Very severe	10,000–15,000	94,162	15.00
Extreme	> 15,000	86,049	13.79

[a] The figure in brackets refers to rocky mountain regions, not the loess region
Source: Tang Keli (unpublished lecture notes on soil erosion and conservation in China for the 2nd International Training Course on Soil and Water Conservation, September 1993).

Combine land use with land construction

Land degradation — soil erosion, desertification, salinity, soil deterioration and so on — occurs easily on the Loess Plateau. The situation is exacerbated because the poor economic situation means that there is little input to the land. We recommend the following techniques to reduce soil degradation.

- *To transform steeply sloping land into level land.* Steeply sloping lands are widespread in the Loess Plateau. They are known as 'three losses land' because they tend to lose water, soil and fertiliser . Terracing and dam lands[1] are effective in improving conditions. Some problems can be solved by conservation measures such as reduced ploughing.
- *To enrich the soil.* Loess soil is a young soil with low fertility, so it must be enriched in order to get higher yields. We recommend rotation cropping (for example, grass–crop–grass–crop or grain–beans–grain–beans, etc.) and increasing the amount of farm manure and chemical fertiliser.
- *To develop limited irrigation.* In arid and semiarid areas, water is an important limiting factor for agricultural development. Water conservation and optimal water use are key measures for increased agricultural production.

Techniques for Maximising Land Productivity

Grain is essential for people's survival. In the past, people have resorted to every possible means to provide farmland to obtain grain, including deforestation. Deforestation has led to the destruction of ecosystems, causing chronic and increasing impoverishment. To change this scenario, we must increase grain output per unit area, and transform the primitive practice of extensive cultivation — and its concomitant notorious low productivity — into intensive cultivation. Yields will increase and the environment will be rehabilitated if all land resources on the plateau are used rationally in the balanced development of various farming undertakings, including crop plantation, fruit production, forestry and animal husbandry. Increasing grain yield is the main objective of our work on the plateau, in order to eliminate poverty among the local inhabitants and boost the rural economy. The grain production target on the Loess Plateau is 400–500 kg per capita, at which level the local people will have a slight surplus of grain. Our experiences in the experimental zones prove that such a target may be reached within five years if input is increased sufficiently and if key agronomic instructions are available at the right time (Li Yushan 1996).

Any increase in grain yield depends on the planted crop strain, the amount of good basic farmland, agronomic measures taken for crop cultivation, etc. In order to cope with natural conditions and the current grain-planting situation on the Loess Plateau, the key to increasing grain yield lies in an improved water supply for farmland irrigation and in fertiliser application.

Increasing the amount of applied fertiliser and farmyard manure is especially important. The level of fertiliser application on the plateau is about 32% of the national average. Initially, chemical fertiliser was used to increase yields from medium (0.75 t/ha) to high (1.5–2.25 t/ha) levels. In the experimental areas, yields doubled or tripled when chemical fertiliser and farmyard manure were applied together. At a demonstration point in Dingxi Prefecture, for example, yield increased by 79.9% when the amount of chemical fertiliser was increased by 166%. Similarly, when the amount of chemical fertiliser at a demonstration point in Changwu County was increased by 144%, a yield of 5.25 t/ha was achieved, an increase of 99.5%. On average, the application of 1 kg of impurity-free

[1] Dam land is a kind of flat land at the bottom of a gully, formed by the deposited soils eroded from the slope.

fertiliser to Loess Plateau farmland will increase grain yield by 6–10 kg (Li Yushan 1996).

For nonirrigated farmland, yields are increased primarily by collecting water from seasonal rainfall. When there is sufficient water, fertiliser plays a key role in increasing yield up to a certain point, but above this point water is again the decisive factor for further increases in yield. Over many years, our work has shown that it would be impossible to break the ceiling of 3 t/ha for dryland wheat yield by simply increasing the amount of fertiliser applied. It is also necessary to increase the water supply; for example, by collecting runoff from seasonal rainfall, using plastic film to suppress evaporation from the ground surface and making more effective use of available water. Farmland tests in the demonstration zones in Luochuan, Guyuan and Changwu counties showed that these measures could be both feasible and effective. For example, in Guyuan County, when 40 m^3 of water (one-quarter to one-third of the amount of water required for the whole crop) was applied to spring wheat just before the tillering stage, the yield increased from 2.175 to 3.915 t/ha, three-quarters of the yield in fully irrigated crops. In this case, the water use efficiency is about 42 kg/ha using 1 m^3 irrigation water. On the other hand, there is considerable potential to make better use of local precipitation. In semiarid areas of the plateau, 25–30% of natural precipitation is absorbed by individual crops in transpiration, 10–20% becomes runoff on the ground surface and flows away, and the remaining 55–65% evaporates. Rainwater can be used more effectively by collecting runoff and reducing surface evaporation with plastic film.

Stages of Ecosystem Rehabilitation of Catchments

In Ansai County in northern Shaanxi Province, we restored a tiny watershed to its original state by mending and rebuilding the depleted ecosystem and ensuring that any further development would be sustainable. The watershed was a barren and depopulated gully in Zhi Fanggou in the hilly heartland of the plateau that had been plagued by serious water loss and soil erosion. From the 1940s to the 1990s Zhi Fanggou underwent 40 years of land degradation followed by 20 years of restoration. Before the drive, farming was a primitive kind of extensive cultivation; the grain yield was 0.6 t/ha and income as pitifully low as 222.1 yuan (about $27.80) per person per year. After the reclamation drive, the proportion of uncultivated land went down from 51.5% to 18%. The proportion of forest and meadow increased to 41.2%. By 1995, there was 0.18 ha/person of farmland, 0.47 ha/person of woodland, and 0.14 ha/person of artificially created pastureland; the average per capita income was 1658 yuan. Almost all peasant households now have their own television sets; 40% own colour television sets. Every village has its own ground-based equipment for receiving satellite-relayed television signals. Hence the countryside has undergone a radical change in appearance (Lu Zongfan et al. 1997). The experimental zones have become high-level models for comprehensive reclamation of the plateau; they also provide a base for theoretical exploration and an exemplary agrotechnological system for water and soil preservation.

The Loess Plateau is a backwater of the Chinese hinterland, plagued by poverty, underdevelopment, and serious water loss and soil erosion. Our work in Zhi Fanggou for the past 20 years suggests that in order to ensure that the Loess Plateau has a bright future it is best to focus efforts on sustainable ecological development rather than just on economic return. In line with this approach, in the context of stability and progress in the local farming system, we recommend the following three stages to develop ecoagriculture on the plateau while maximising water and soil preservation (Lu Zongfan et al. 1997).

Restoring the ecosystem

The main task of restoration is to increase vegetation cover by returning some cultivated land to forest. The ecological benefits are likely to be seen earlier than economic benefits, although the gap between the two is decreasing and the effectiveness of the investment increases as the original vegetation is gradually restored. At present, restoration is hampered by the difficulty of communicating the complex technological information that forms the basis of any restoration to the local people who carry it out.

Making sure the ecosystem is stable

The newly restored ecosystem is weak and relative unstable. It may revert to its previous state unless care is taken. It is therefore very important to maintain a balance between ecological benefits and economic return. A timeframe of 5–10 years is usually practical for both ecological and economical benefits.

Making sure the ecosystem is sustainable

As the ecosystem becomes sustainable, people's natural and social attributes reach harmony. Both family planning and the rational exploitation of natural resources become conscious actions, with well-defined goals among the local inhabitants. The ecoagricultural system will be more complicated but will function more efficiently. Farming practice and business management are based on scientific and technological data and information resources. Our studies at Zhi Fanggou suggest that the following parameters should be regarded as standardised targets for appraising the three stages in developing an ecosystem rehabilitation in a small catchment: the area of controlled land, the basic amount of farmland and cropland per capita, and the yield (see Table 4).

Table 4. Stages and targets of ecosystem rehabilitation of a small catchment.

Stages	Time (years)	Area controlled (%)	Basic farmland (ha/person)	Cropland (ha/person)	Yield (t/ha)
Restoration	10–15	40	0.07–0.1	0.5–0.8	0.6–0.975
Stabilisation	5–10	60	0.1–0.13	0.4–0.53	0.96–1.35
Sustainable development		80	> 0.17	0.27–0.4	1.875–2.25

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