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# A policy and technical measures for controlling soil and water loss in the Loess Plateau of China

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**Abstract**— Loess Plateau is the most serious region of soil and water loss in China and the world. The sediment carried into the Yellow River amounts to 1.6 billion tons every year. This paper reviews the factors and reasons for erosion in this area, and puts forward a comprehensive controlling policy on the basis of the principles of ecology and practise of Chinese scientists for 40 years. In conformity with the policy, a number of technical measures for controlling soil and water loss are suggested.

**Keywords:** Loess Plateau; soil and water loss; controlling policy; technical measure.

The Loess Plateau is located in the middle reaches of the Yellow River in China. It is bordered by the Qilian Mountains in the west, stretching eastward to the Taihang Mountains, and by the Great Wall in the north, extending southward to the Qinling Mountains. The whole loess region covers 8 latitudes (35°–41°) and 13 longitudes (102°–114°) with an area of more than 530000 $km^2$ and a population of more than 70000000.

The Loess Plateau is a special geomorphological element in China. It is covered by the thick quaternary period loess which has been mostly transported by wind for about 3 million years. The types of landforms in this region are various. There are loess Yuan, loess Liang, loess Mao and river valleys as well as rocky mountains.

The elevation of the Plateau is about 2000m in the west and northwest and 300–400m in the southeast. Generally speaking, it likes an inclined plane sloping from northwest to southeast.

*Present status of soil and water loss*

The soil and water loss in the Loess Plateau is very serious. The total erosion area approximates to 430000 $km^2$, and 270000 $km^2$ of them are serious erosion area with an erosion modulus of 2000–20000 $t/km^2.a$ and a depth of eroded topsoil of 0.2–2.0 cm/a (Fig. 1). A large number of sediment has carried into the mainstream and tributaries of the Yellow River, and resulted in sediment transport reaching as high as $1.6\times10^9$ t/a and average silt content of 37.6 $kg/m^3$ in the lower reaches. It ranks first among the big rivers of the world for sediment.

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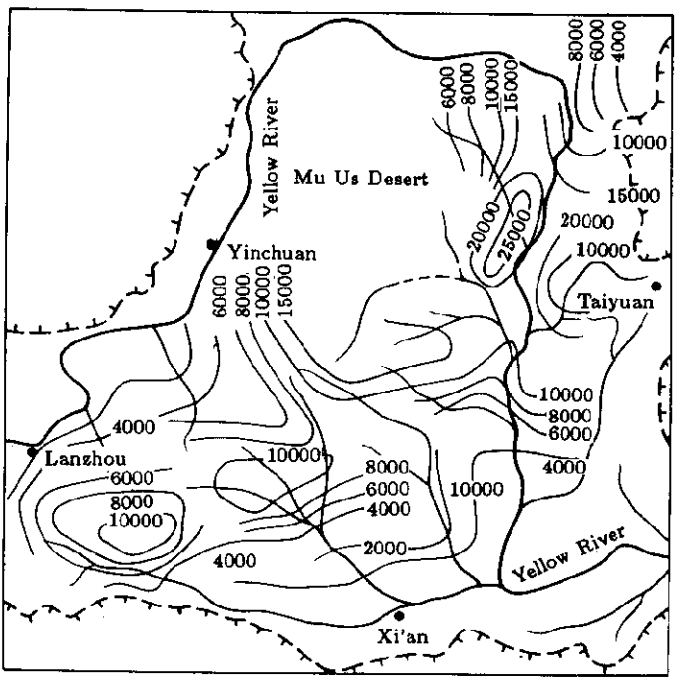


**Fig. 1** Soil erosion in the Loess Plateau ($t/km^2.a$)

The serious soil and water loss has increasingly deteriorated the ecological environment in this region. The development of agriculture, forestry and animal husbandry is adversely affected, and the lives and property of millions of people along the lower reaches of the river are threatened. It can be seen from follows.

1. Expansion of the acreage under gullies decrease of soil fertility

It is determined that the length of gullies averages 2–7 km in a $km^2$ of this region, and the area under gullies makes up 30–50% of the total area of land, sometimes amounts to more than 60%, gully head unceasingly stretching, gully section unceasingly expanding, thus resulting in devouring large fertile farmlands. The results of analysis showed that a ton of eroded soil contains 0.8–1.5 kg of N, 1.5 kg of P and 20 kg of K. On this grounds it is calculated that the amount of nitrogenous, phosphate and potash fertiliters lost in the region counts up more than $3.6\times10^7$ t/a.

2. Silting up reservoirs and canals, destruction of water resources

According to the statistics of many years the deposits in the reservoirs builded by Shaanxi, Gansu, Shanxi and Ningxia provinces in the loess region average $25.1\times10^7$ t/a. A number of irrigation canals on mainstream and tributaries of the river as well as in mountain area has lost efficacy because of sediment deposit and bursting by mountain torrents, so there is a need to throw in lots of the labor force and financial resources for renovation.

3. Frequency of flood and drought, influencing the development of national economy

The drought in the Loess Plateau is frequent and serious due to soil and water loss. According to the statistics of observed data the area hit by drought in varying degrees, on an average, is about 733000 ha/a, and may reach 2330000 ha at most, while the flood has run rampant in the region of lower Yellow River which burst its banks 1590 times in all during the period of 2540 years from 602 B. C. to A. D. 1938, making the people fall into the calamity-ridden straits over a long time. The bed of the river is 4–10 m higher than ground at present, and its lower course has been known as "suspended". The dykes on both banks have been heightened once for 10 years on the average, and more than RMB 2000 millions Yuan have been expended in this connection.

In addition, the wind erosion in the Loess Plateau is also very serious. A vast expanse of Maowusu desert in the north intrudes southward 4–11 m/a, causing the sandification of vast stretches of farmlands

*Reasons for soil and water loss*

The soil and water loss in the Loess Plateau is determined by both natural and social factors. The natural factors are potential conditions, while the mankind socioeconomic activity pays a leading and decisive role in genesis and development of soil erosion and water loss.

1. Natural factors

(1) Topography The topography of the plateau is undulate, and the area is crisscrossed by gullies with slopes of 10-35 degrees. The distribution of Yuan, Liang, Mao and gullies with a depth of 100-300 m is intricate, the mountain and hilly region being usually subject to soil and water loss, and resulting in typical rolling area of ridges and mounds.

(2) Loess property The Loess Plateau has overburden of loess strata 100-200 m in thickness, of rather loose structure comprising more than 50% of grains 0.02–0.05 mm in size and 10–15% of readily soluble carbonates, and having the particular feature of vertical joints. Its resistance of erosion is extremely low, especially for farmland. All the aforesaid lead up to genesis of avalanche and sink hole in this region.

(3) Rainfall The distribution of rainfall in time and in space is very uneven in the plateau, ranging from an average of 200 mm in the northwest to 700 mm in the southeast. 60–70% of annual rainfall occur in the months June through September, after in the form of rainstorms. The heavy rains of short duration and high intensity (up to 1–3 mm/min) result in severe erosion. More than 80% of the total yearly amount of eroded soil may be washed during a several rainstorm.

(4) Vegetation Vegetation cover is instrumental in absorbing the energy of raindrops by way of intercepting them at the canopy, regulating runoff and improving soil structure, being a main natural factor for controlling erosion. However, there is only a few of natural vegetation surviving in the whole plateau at present, especially in the loess hilly region with a forest coverage of only about 3% and seriously degraded grasslands, and can not afford to be

instrumental in protecting soil on the whole.

2. Social factors

The social factors influencing the development of soil and water loss mainly are population explosion and irrational land management and inappropriate exploitation of natural resources such as reclamation of land on steep slopes, deforestation and stripping of grass, overgrazing as well as the plunderage by ruling classes and destruction in the wars of past ages. Under the action of these factors the plateau covered with luxuriant growth of trees and grasses has changed gradually into bare hills with a deteriorative ecological environment.

After liberation Chinese government has paid a great attention to prevention and control of soil and water loss in the plateau. There have been 100000 $km^2$ of area which are under the control for the last 40 years. However, the thing of control while destroying has occurred along with a rapidly expanding population and development of national economy. Irrational exploitation of mine, improper disposal of muck in road-building and borrowing of earth for kilns and so on, intensify new soil erosion.

*Policy of controlling soil and water loss*

In order to control soil and water loss and improve ecological environment in the Loess Plateau the Chinese government and scientific workers have gone through a tortuous way-practicing, recognizing, repractising and reknowing for 40 years, and a great progress in the theory and practise of controlling soil and water loss has been achieved finally.

Summarising the experiences and lessons of many years, we have come to the conclusion that it is impossible to control soil and water loss thoroughly, improve destroyed ecological environment obviously and ameliorate economic conditions considerably even turn "malignant circle" into "good circle" by any mono-measure in the plateau. We must regard the Loess Plateau as a big system in accordance with system-engineering method on the basis of the principles of ecology, and put into practise a comprehensive controlling policy, proceeding from the actual condition in the plateau. The policy is "combining the control of slopes with the control of gullies", "combining biological measures with engineering measures", "combining control with exploitation" and "combining ecological benefit with socio-economic benefit". Every measure, method and benefit in the four combinations should be helped forward each other interactively to realize the coordination, balance and steady development of population resource-environment-economics.

It is known that watershed is an elementary unit for soil and water loss which takes place gradually from ridge to bottom. The results of investigation have indicated that 63% of eroded material come from slopes, and rest of 37% from gullies and landfalls, so the controlling measures must be arranged both on slopes and in gullies. Planting trees and grasses should be used mainly with the integration of leveling land for protecting slopes from erosion. It is determined that the woodland, grassland and terraced fields may reduce soil loss by 98.8–99.8%, 97.8% and 95% respectively (Table 1). Building dam system is regarded as a primary measure

for protecting water courses from erosion, for example, in Wangmao water course with a length of 3.75 km and an area of 5.97 $km^2$ in Shuide county, Shaanxi province the protective system made up of 42 dams has been built: it has obstructed, on an average, 6781 $m^3$ of sediment per km per year during the period from 1953 to 1981.

**Table 1** Function of different types of vegetation in controlling soil and water loss (after Hou, 1988)

| Type of vegetation | Slope | Amount of runoff | | Amount of soil loss | |
|---|---|---|---|---|---|
| | | mm | Decreased by % over farmland | $t/km^2$ | Decreased by % over farmland |
| Farmland (*millet*) | 28 | 175.9 | | 2824 | |
| Grassland (*Astragalus adsurgens*) | 27 | 53.3 | 74.8 | 77 | 97.8 |
| Shrub (*Caragana microphylla*) | 24 | 21.7 | 87.7 | 4 | 99.8 |
| Woodland (*Robinia pseudoacacia*) | 28 | 20.7 | 88.3 | 34 | 98.8 |

It is necessary to emphasize the combination of ecological measures with engineering's because of importance as the vegetation is in preventing soil erosion, it is difficult to establish, if it has not got help of engineering, either the survival rate of plant is low, or the plants grow badly. Furthermore, the function of vegetation cover is unobvious in its infancy, and only after passing a certain period the benefits of which the vegetation is can be manifested; while the engineering construction plays an important role in controlling soil loss from the first days of its existence, but without the help of bilogical measures it is subject to be bursted and silted up. Thus, both ecological and engineering measures must be combined each other with the purpose that engineering measures help biological ones, and biological measures protect engineering ones timely.

Practise of many years has also indicated that the controlling is difficult to get the desired result, if it is not combined with the exploitation of natural resources, with the shaking off poverty and the achieving prosperity of local people. In other words, the controlling tasks should be linked with the economic benefits of farmers; with the development of local economy making the ecological benefits reside in the economic benefits to realise the persistent utilization of natural resources, increase commodity production steadily and turn poverty into prosperity in the country. There have been 3150000 farmers family which have contracted for controlling and exploiting to 250000 small watersheds with an area of more than 24500 $km^2$ in the middle

reaches of the Yellow River at present. Wang Changhai, one of these farmers' family in Ningxiang county, Shanxi province, contracted to a small watershed in 1983, has afforested the barren hills of 170 ha and got a income of RMB 12700 yuan in five years. Thus not only the soil and water in the watershed are conserved, but also the farmers' life has got some improvement. It may be seen that both controlling soil and water loss and vigorously developing economy in the region of soil and water loss, this is an effective way of controlling the plateau.

*Technical measurers of soil and water conservation*

The great progress has been achieved in the theory and practise of soil and water conservation along with the development of socioeconomy and science and technology. In the recent 10 years and more, especially, a number of new technical measures of soil and water conservation have been studied by the Chinese scientific workers and have been widely taken in the production.

The scientific researches on introduction, selection and mutation breeding of fine species (varieties) of plant have been made, and some good drought-resistant and high yield species (new varieties) suited to the conditions in the Loess Plateau, such as *Astragalus adsurgens, Onobrychis viciaefolia, Caragana microphylla, Hippophae rhamnoides, Salix mongolica, Robinia pseudoacacia* and others, have been selected out, thus enriching the species resources for afforestation of the plateau and raising the per unit area output of production.

In order to speed up the restoration of vegetation, an experiment on the aerial sowing of trees and herbs was carried out. A total area of 4700 ha was seeded between 1975 and 1984. During this period the aerial sowing of *A. adsurgens, C. microphylla, H. rhamnoides* and *Pinua tabulaeformis* has been successful (Table 2), particularly for *A. adsurgens*, on the average, there were 45000—50000 triennial-tetrennial plants per ha, which survived and the production of fresh grass averaged 9750—18750 kg/ha, an amount of which is 8—10 times greater than the close by natural vegetation. It has opened a new way for the large scale restoration of vegetation and for the conservation of the plateau. Up to now the aerosowing area in this region has been extended to 270000 ha.

From early 1980s on the basis of widespread practise and intensive study of individual technical measures the scientific workers from Northwestern Institute of Soil and Water conservation, proceeding from the idea of establishing a high-effective and multi-function ecosystem in which the regional resources, environment, population and economy are in coordinated development, using the method of systematic engineering and uniting the "four combinations" as an integral whole with consideration for all "three benefits", have put forward a controlling model of optimum eco-economic structure of agriculture, forestry and animal husbandry to rationally use land, effectively control soil and eater loss and secure a stable and further rise in rural economy. According to the model, an experiment for example has carried out in Shanghuang village, Guayuan county, Ningxia from 1983. The practise showed that the model would be a successful one. It can combine the protection of resources and environment with their

**Table 2** Results of the experiment on aerial sowing of *A. adsurgens, C. microphylla, H. rhamnoides and P.tabulaeformis*

| Species | Seed quantity, kg/ha | Shooting status in the first year sowing | | Survival status of seedlings in the third or fourth year after sowing | | |
|---|---|---|---|---|---|---|
| | | Average num. of seedling, per ha. | Rate of seedlings, % | Average number of plants, per ha. | Survival rate, % | Rate of area with seedlings, % |
| *A. adsurgens* | 2.25 | 206300 | 25.5 | 45000–50025 | 21.0 – 27.6 | 47.8–54.0 |
| *C. microphylla* | 13.80 | 3275 | 1.5 | 3195–4410* | | 48.8–58.2 |
| *H. rhamnoides* | 7.47 | 10937 | 2.3 | 3465 | 31.7 | 36.6 |
| *P. tabulaeformis* | 9.75 | 9245 | 8.5 | 3705–5730 | 52.7–53.2 | 47.8–49.0 |

* The number of *C. microphylla* seedings in the third and fourth year is more than the first year as we missed to account for small seedlings.

utilization, the control with the exploitation, the ecology with the economy and the short-term benefits with the long-term benefits organically to reach the goal of both renewing ecological environment and turning poverty into prosperity. The pattern established by the model in the proportion of using land is: farmland—24%, woodland —20% and grassland—56%; the step in carrying out the model is: grass and shrub should first be planted, and assisted with necessary engineering measures on slopes and in gullies; and the technique is a complete system of technique, taking fertilization as the dominant factor. The results of the experiment for 3 years are: farmland has decreased by 29%, woodland has increased by 10 times, artificial grassland has increased by 40 times, sediment has decreased by 50%; the per unit area of grain has increased by 2.1 times, the number of raised livestock has increased by 100%, net income has increased by 6.4 times and, on the average, everybody has got grain of 518kg, RMB of 355 yuan and firewood of 900 kg per year.

Recently, a kind of gully reclamation practices in the Xingzi River Basin of the Loess Plateau is described. A number of silt-trap dams have been built and formed a dam system in small catchment to control flood and sediment. Two kinds of damming techniques—Chinese sluicing siltation and sluicing siltation by means of a monitor— are the most effective. Survey results indicated that peak flood and silt discharge in a main gully were decreased by 65%–90% and 70%–94%, respectively, in some catchment with a complete dam system. Amount of arrested sediment in dam system is 11400 t/km$^2$a, which is about 80% of annual mean sediment yield in the catchment.

All aforementioned measures and examples have provided scientific basis for implementation of the whole controlling policy in the Loess Plateau.

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