

Thinking and Disposing Measures for Managing Slope Farmland in the Loess Plateau Gullied Hilly Area in Northern Shaanxi

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Abstract: Soil and water loss occurring in slope farmland in the Loess Plateau gullied hilly area in Northern Shaanxi badly damages the local land source and degrades the ecological conditions. A comprehensive management with various measures must be undertaken for controlling soil and water loss in slope farmland. Farming should be stopped and trees and grasses planted in steep slope farmland combing regulating land use and rural industry structure. The disposition of the management measures is that gentle slope land should be built into level terraces, contour shrub strips (plant hedges) greatly adopted and some practicable techniques largely extended such as inter-cropping of trees and grasses in terraces, fully mulching cash orchards, containing surface runoff and so on.

The Loess Plateau gullied hilly area in Northern Shaanxi is the major party of the Loess Plateau in China. It covers an area of 44,000km² in total, mainly distributing in the south along the Great Wall in Yulin city and the vast northern area and Qiaoshan and Huanglong mountains south of the Baota Section in Yanan city.

In the Loess Plateau gullied hilly area in Northern Shaanxi, there is crop land of 1,708,000hm² (including slope land of 1,468,000hm²), composing 38% of the total. Slope farmland is the main base for the local production of agriculture, forestry and animal husbandry. But soil and water loss occurring in it is very serious and badly limits the development of economic and agricultural production in this region. It damages the local land sources and continuously worsens the ecological conditions. Meanwhile, it also brings grave consequences to river harnessing. Therefore, an early and efficient management taken to control soil and water loss there is very important and practicable for improving the ecological and basic agricultural conditions, promoting a sustainable development of social economy and reducing sediment carried to the Yellow River.

Keywords: control measure disposition, slope farmland, the loess plateau gullied hilly area, Northern Shanxi

1 Soil and water loss is the essential factor to limit a stable ecological condition and sustainable agri- development in slope farmland

The loess plateau gullied hilly area in Northern Shaanxi is characterized by a scatted landform with intercrossing gullies and canyons. Loess is loose in property and has a poor erosion durability. In addition to over-cutting and cropping in history, vegetation the has almost been destroyed. Therefore, a very serious soil and water loss takes place frequently in the case of rainstorms. Annual sediment discharge in total is 666million tons, making up 41% of the annual discharge up to the Sanmen Gorge. Coarse sediment yearly depositing in the lower reach of the Yellow River watershed is 400million tons. As much as 140 million tons of it comes from Yulin City. So this area is mostly eroded and is the major source of coarse sediment to the Yellow River. Half of the sediment is produced from slope farmland. Slope farmland with a grade of above 15° is suffered from an intense erosion and is 1,023,000hm², composing about 64% of the total cropping land, and that with a grade large than 25° makes up 25% of the total. According the observations for many years, annual erosive modulus is 20,000t/km² and that of slope farmland with degree over 25° is as high as 30,000t/km². There, not only erosions in forms of sheets, splashing and rills frequently occur, but also special shallow furrow erosion is formed to develop into gullies and canyons.

Organic matter and inorganic mineral nutrition in soil seriously loses as soil and water loss takes place. It makes slope farmland deteriorated in fertility and lower in production. Due to serious erosion, The regional soil Heilu (a kind of black fertile soil) has lost at all. The existing soil only is immature loess. Its organic content is mostly under 0.5% , full nitrogen content is 0.03%-0.05%, storage of phosphorus and potassium is fairly high, but its efficiency is not high. So the loess there is a kind of poor soil.

Water loss is a remarkable character in the Loess Plateau gullied hilly area in Northern Shanxi. It is easy to form runoff by over seeping when intensity of rainfall is high. Runoff depth is above 100 mm, making up 1/3—1/4 of the efficient when annual precipitation is 500mm. Water loss from slope land is $225 \text{ m}^3 / (\text{hm}^2 \cdot \text{yr})$ — $450 \text{ m}^3 / (\text{hm}^2 \cdot \text{yr})$ in common and 900 m^3 in some cases. It must have to be dry or have a draught in coming spring and summer if there is little rainfall in autumn. Therefore, slope farmland is lower in productivity and yields only about $600 \text{ kg}/\text{hm}^2$. Serious soil and water loss worsens soil at all and is the main reason to make the agricultural production there hesitated for many years.

After the founding of new China, the central government has paid much attention to conservation work in the Loess Plateau and undertook slope land management in a vast scale. According to the statistic by the end of 1998, level terraces built is $336,000 \text{ hm}^2$, being averaged $0.12 \text{ hm}^2/\text{person}$ and the area with conservation tillage such as level ditch and furrow cropping is about $200,000 \text{ hm}^2$. They have taken an important part in controlling erosion and developing agri-production in slope farmland. Since implementing the new policies of opening and reformation, the local farmers raise their realization of commerce. They stopped grain farming to plant cash trees of apple, pear, Chinese date, nut use apricot and so on in slope farmland of $200,000 \text{ hm}^2$. Obviously it is put in the important place to meet the requirement from farmers' food and help them get rid of poverty for managing slope farmland in these years.

The management of slope farmland is still in a primary stage. Although effort for half a century has been made, there are no conservation measures adopted and soil and water loss occurring in 70% of slope farmland. Productive potentiality of land sources has not been brought out at all. The backward production method of extensive farming is widely use to extort a harvest from nature in the most area though the techniques of increasing yield is continuously developed and extended. Slope land is cultivated with crops. It makes a vicious circle of the more land is cropped, the poorer the local farmers get and the poorer they are, the more land is going to be cultivated. Soil and water loss is intensified and ecological conditions are getting worse. Productivity of land and the whole ecosystem is falling down. The development of agriculture and economy in this region is badly influenced.

In recent years our county takes the construction and protection of ecological as cutting -in point for the West development. Input is raised to implement the construction of ecological conditions with the stress of soil and water conservation. Erosion control in slope farmland is stepping into a completely new stage with a target of promoting a harmonic development between economy, society and ecological conditions when the policies are practiced such as stopping farm to plant trees and grasses for conservation, contracting land by individuals, providing grain as a form of relief and so on.

2 Thinking and disposing measures for managing slope farmland

2.1 Following natural laws to strengthen conservation and the construction of ecological conditions

Soil and water loss in slope farmland in the Loess Plateau gullied hilly area in Northern Shanxi is mainly formed by surface runoff in rainstorms. Therefore, The first thing for managing slope farmland is to grasp the pattern of runoff movement on slope, scientifically regulate, control and use it and maximally control soil and water loss. On this basis, land sources should be rationally opened and grasses and trees instead of crop should be planted in steep slope farmland when a stable grain production is established as early as possible. It will obtain the target of obviously improving agri-production and ecological conditions, rationally regulating the structure of rural industry and making the farmers have a rich live. So, natural laws should be followed, the backward method of extensive farming should be changed and conservation and the construction of ecological condition should be strengthened. Slope farmland should be considered as a soil and water loss unit to produce runoff as well as an economic unit including the

structure of agriculture, forestry and animal husbandry. According the natural resources of water, fertilizer, light, temperature, etc various measures should be optimally disposed to form a system of comprehensive protection and development on account of the distribution law of different landforms such as the tops, slopes, edge lines of hill mound, gullies and valleys.

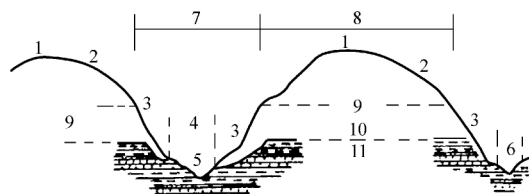


Fig.1 Cross section map of hilly and Gully region in loess plateau

1. tops of ridge & mound, 2. slopes of ridge, 3. slope of gullies and valleys, 4. valley ground land,
5. gully bank, 6. river bank land, 7. land of gully & valley, 8. land between gullies,
9. edge lines of valley, 10. Loess & old loess, 11. sandstone & shale.

Biological, engineering and tillage measures should be taken into account in managing slope farmland. The target of managing and opening slope farmland can be realized only through optimally disposing and implementing comprehensive measures step by step. The successful practice of managing slope farmland for years proves that only single measure used will not work well.

2.2 To promote sustainable development of agriculture by stopping farming to plant grasses in steep slope farmland

Slope farmland is the essential production factor on which the vast farmers live. An economic benefit must be made when farming is stopped and trees and grasses are planted in slope farmland.

The gullied hilly area in Northern Shaanxi with precipitation below 500mm is part of dry and semi-dry area. The types of its natural vegetation should belong to grassland and shrub community. The precipitation can only meet the demand by the growth of draught tolerant herbage and shrubs. Pure arbor wood was operated and grown into "the little old" because of water shortage in soil.

For recovering vegetation, planting grasses is a cut way as it costs little in laboring and input, produces benefits quickly and widely. According the data observed by the Soil and Water Conservation Institute of Yanan City, wash erosion almost did not take place when grass coverage in grassland reached 75%. In addition, grass root plays a role to conserve water sources, beauty surrounding sense and regulate micro-climate. So stopping farming to plant trees and grasses in slope farmland is the only efficient approach to improve the worsened ecological conditions there.

Animal husbandry in a major form of breeding sheep is the leading traditional industry and an essential party of ecosystem in Northern Shaanxi. Grassland source has been seriously damaged and the productivity is lower to result in a slow development of animal husbandry due to the production activities of overgrazing, continuously opening slopes for farming, shifting dropping and so on for a long time. Planting grasses will lay a material foundation for animal husbandry development, also is an important mean to control soil and water loss, improve soil and increase grain production.

Contradictories in all sides can be solved by a start of planting grasses. It can be undertaken at same time that animal husbandry will be developed, farmers will get rid of poverty and have a rich live and capital farmland will contribute a stable production with a high yield while grasses instead of grain crops are cultivated in slope farmland. So, grass is the connecting between agriculture, forestry and animal husbandry in Northern Shaanxi. Wuqi County has an area of 3,791km² and a population of 120,000. Overgrazing and land-opening for a long time worsens the conditions of ecology and production and intensifies soil and water loss. Since 1998, the county has carried out the strategy of developing grass industry. Cultivation of commercial herbage has been driven to develop and quality herbage bases have been established according to the principle of forming a balance between herbage production and domestic animal breeding. Grasses have been cultivated in 770,000hm² in 3 years. Animal husbandry has been developed by indoor sheep production. At present, 100,000 heads of sheep(Xiaoweihanyang, a

good variety) are fed. Many farmers who were not engaged in feeding sheep are willing to stop farming to plant grasses for sheep. Ecological condition there is getting better obviously thanks to planting grasses instead of crops in vast slope farmland. The coverage of grasses and trees in the whole county is increased from 19.2% in 1997 to 49.6% today.

2.3 To promote the comprehensive development of agriculture, forestry and animal husbandry through regulating land use and the structure of rural industry

An irrational development and overusing of slope land is the main reason of ruining vegetation, intensifying soil and water loss and lowering productivity. Gentle slope land can be built into level terraces for the production of crops, fruits, cash plant and so on. Crop farming should be stopped and grasses and trees should be planted in the slope land with degree above 25° (or below 15° in the area where population density is small).

The input for managing slope farmland was increased and scientific results in many types were applied in production while the policies on rural economic reformation were carried out in the 10 years from the early 80's to the middle 90's. In that area appeared many model villages and Xiangs (township) where the farmers got rich by controlling erosion to improve ecological conditions and developing dominant natural resources. The models of developing rural economy are primarily formed in types of forestry - fruits and grass-animal husbandry. For an example, there are 100 family households having a population of above 500 and an area of 713hm² in Miaogou village in Baota district, Yanan City. The village already had farmland of 500hm² and each person only produced 150kg yearly in average before 1982. They had a poor life as they undertook production depending on loans and had food provided by government. The village made great effort to regulate its land use and industry structure since 1984. It stopped farming to plant cash trees of apple, pear, apricot, peach, etc and locust and other local arbor trees to form a protection. Meanwhile, grain production was raised by science and techniques application. With 10 years' effort, grain production by per person rose to 500kg while the farmland was reduced to 120hm² in 1994. The village managed cash forest in size of 200hm² yielding fruits of above 1million kg and became rich as nut income reached 4,000 / farmer in a year.

The techniques for agri-production increase is continuously developed, improved and extended in the 10 years. But, the Northern Shaanxi can not be lifted out of poverty and backwardness in economy essentially due to extensive farming used widely. Besides extensive farming in capital farmland, animal husbandry has a low productivity because grassland is overgrazed and is not constructed with new input. Cash fruit forestry does not yield high because of lacking the input of necessary techniques though it develops fast in these years. Therefore, terrace construction should be quicken to early obtain the target that each person will have 0.13 hm²-0.17hm² of capital farmland while farming is stopped and grasses and trees are planted in a vast slope farmland. Meanwhile, effort should be contributed to get quality, efficient and high-yield production by practicing intensive farming in the capital farmland and in cash forestry properly. About 20% of the land can meet food requirement and yield a remarkable income. Grasses and trees instead of crops can be planted in above 70% of the slope farmland. Not only ecological condition will be improved, but also good conditions will be provided for developing animal husbandry, fruit forestry and its other industries concerned as vegetation is recovered. Finally a good circle will be formed for a sustainable development of agriculture, forestry, animal husbandry and ecological economy.

3 Frame of disposing measures for managing slope farmland

Vast farmers and technicians dealing with slope farmland management for a long time have accumulated a wealth of experience. The disposition of conservation measures is going to be rational as natural laws have been further learned. These efficient successful experiences have been popularized and applied in managing slope farmland in large area.

According to my opinions, the marks for conservation effects are followings. First, runoff formed on slope surface is rationally regulated and rainfall is contained locally to seep into the ground. Soil is well protected and soil and water loss controlled. Second, it can provide farmers with a rich life to closely combine a rational use of land sources and regulation of rural industry structure. Third, vegetation of

grasses and trees is increased greatly to green slope land again and remarkably improve ecological condition. The frame of disposing measure for managing slope farmland in Northern Shaanxi is proposed out according the above opinions and the existing scientific and technical achievements and working practice for many years.

3.1 Transforming gentle slope land into level terraces with stable high yield

Transforming gentle slope land into level terraces is an essential measure to promote rainfall to seep into the ground locally, reduce soil and water loss, raise soil's ability to conserve water and fertilizer and crops' ability to resistant to draught. According to research data, runoff loss is reduced by 22.5mm—49.5mm, reduction of nitrogen, phosphorus and potassium loss from soil is 70.6%, 37.2% and 24.5% of the total output from field, respectively and organic matter in soil in terraces through fertilizer application and maturation is increased by 1 to 4 times when slope land is transformed into terraces. It is proved by practice that stopping farming to plant trees and grasses on slope farmland can be effectively promoted only when control of soil and water, improvement of ecological and agri-production are undertaken together while terrace building is taken as a breach.

The middle and lower parts of hill slope are gentle, have higher temperature and are favorable to dry material accumulation of fruits and grain crops. So, gentle slope land near to villages should be transformed into level terraces to meet the food requirement by farmers. Broad level terraces built by machine may have an earth bank to be planted with shrubs. In this way, field bank is protected as well as vegetation and quality fields are increased. To make terraces quality must extend a set of safe production system for applying fertilizer, inter-cropping green manure, introducing quality varieties, covering film, collecting rainfall and so on after constructing terrace.

3.2 Countor shrub strips (plant hedges) are the skeletons for managing hill slopes

A hill slope generally goes between 10° — 35° . Except gentle slope land for building terraces, other slope land are all built into a reversed slope terrace in counter line with a slope intermission and planted. Shrubs of caragana, Salix cheilophila Schneid, Amorpha fruticosa, etc, are closely planted in the terraces or their banks to form a close shrub community in counter line(shown in Figure 2). Strip shrub planted in slope farmland shortens runoff line and speed. Soil and water loss is greatly reduced as the runoff in slope land is contained by shrub strips one after another. According to observation, runoff reduction is about 30%, sediment reduction is above 50%. After the establishment of a shrub strip, about 20% of vegetation is added to slope farmland and a shrub networks is created in hill slopes. It remarkably changes the situation of rare vegetation in hill mounds and slopes.

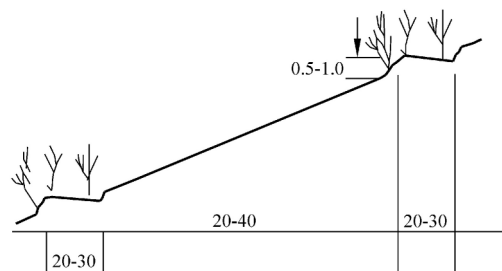


Fig.2 Cross section sketch map of countor shrub strips (plant hedges)

Land between strips can be rationally used with a plan according to the local conditions when shrub strips are established. A part of the land is in short time planted with grain crops in conservation tillage of level ditches and furrows, another part is cultivated with cash trees of apple, pear, apricot and so on, the rest is planted with grasses for developing animal husbandry. It is the biggest character of this measure that it can fast establish a forest networks and a comprehensive protecting system on slope land by forming a complete set with field roads and water storage works. Based on the data observed from

Dazuimao Runoff Plot in Suide County, erosion on slopes of gullies and valleys can be reduced by 70% if runoff is contained on slopes of hills and mounds.

3.3 Plant strips of close shrub communities are cultivated along the edges of mounds

A mound edge is the dividing line between a mound and gully slopes and is a turning zone for runoff on slopes where an intense back erosion often takes place. Shrubs of caragana, seabuckthorn, etc are planted along the edges of mounds to form a biological strip with close shrub communities to prevent gully banks from clapping and gully heads from advancing. In addition, it adds a green defense to slope land.

3.4 Stopping farming to plant shrub forest on gully slopes

The size of a gully slope is usually as equal as 30% — 40% of a small watershed. It is characterized by a scattered erosive landform. Its slope is 25° to 45° where an intense erosivity is produced by discharge formed through mound slopes and runoff from gully slopes. It cuts gullies and their slopes to make a serious gully erosion and gravity erosion. Annual erosion modulus is above $20,000\text{t}/\text{km}^2$. At present a fairly part of gully slopes is cropped. Farming should be completely stopped and shrub forest mainly consisting of caragana and seabuckthorn should be planted in this steep slope land with engineering measure for land preparation. A gentle slope land can be constructed into level step terraces or fish-scale pits for fruit trees plantation.

In this way, the measures being a complete set for each other to control erosion are rationally disposed to form an effective complete system of protection to contain runoff by one after another works in sections. Not only soil and water loss can be maximally controlled and vegetation can be earlier recovered, but also sustainable agri-production can be obviously promoted. It is favorable to arouse the conserving enthusiasm of the mass and helps to synchronize the construction of ecological conditions and poverty alleviation for the farmers.

4 Greatly extending 3 technique measures

4.1 Technique of inter-cropping trees and grasses in interval slopes in contour lines

The gullied hilly area in Northern Shanxi is in arid area and lacking of water. The factor of water should be fully thought about when man recovers vegetation. Besides selection should be made for the local varieties of trees and grasses, which are resistant to draught and poor soil there, natural precipitation should be fully and rationally used because it is the key factor to vegetation recovery.

Inter-cropping of trees and grasses in interval slopes in contour lines is popularized in vast area in Wuqi, Zhidan and Suide counties. Its operating steps are as followings. A step with a reversed slope is constructed in width of about 1.5m in a contour line. It is cultivated with dry resistant varieties of shrubs and some cash trees such as *Amorpha. fruticosa* L. or apricot in given spacing. A slope spacing between two steps is generally 6 m — 7 m, determined according the slope degree. Herbage of alfalfa is planted on its slopes (shown as Figure 3). After a rainstorm, the soil in the slope is not easily sluiced and runoff is not produced because of grass protection. A part of rainfall in a case is contained to seek into the slopes and the rest goes down to the steps.

Inter-cropping of grasses and trees forms a stereo grassland in well intercrossing of strips by a man-made runoff regulation and a stereo cropping. Its crowns in various layer cover the ground. They not only efficiently store water and protect soil from erosion, but also play a remarkable role in promoting and developing the production of forestry and animal husbandry. According to the research by the Soil and Water Conservation Institute, Academia Sinica, 46.6mm of water is short in a year for the growth of fruit trees planted in level terraces, making 9.1% of their requirement. An inter-cropping in interval slopes contains runoff produced between slopes to supplement water application to plants. In this case, natural precipitation basically meets the demand from the fruit trees' growth.

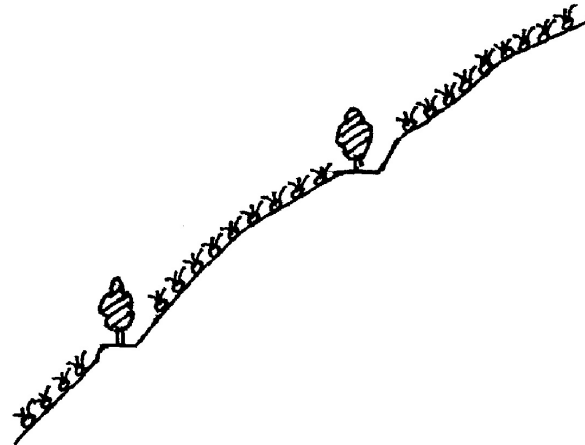


Fig.3 Sketch map Inter-cropping of grasses and trees forms

4.2 Techniques of fully covering an orchard

Some cash trees such as apple, chine date, pear and so on are suitable to grow in the gullied hilly area in Northern Shaanxi. They are one of the major sources for the local farmers to get rich. In recent years, the farmers are stressing in adjusting the rural industry structure. They have planted fruit trees instead of grain crops in a large area of farmland. The fruit trees of pear, chine date, apricot and etc have yielded in a vast area and become one of the leading industry in the local economy.

These cash trees mostly grow in an arid orchard without any irrigation system. In order to solve water problem, step terraces had been built before an orchard was established. They contain about 10% of runoff. Only fish-scale pits are dug for planting trees in slopes in most case and have a low water containing capacity. It is easy to yield a runoff to cause erosion during a rainstorm. In addition, an orchard is bare when the trees are young. The soil without plant cover is lower in conserving water and higher in evaporating. Based on the data, 50% of natural precipitation is evaporated.

In recent years, it has been proved that technique of covering orchards is the only effective approach to solve the problems of soil and water loss and draught in slope orchards because it can conserve natural precipitation in soil to maximally reduce evaporation.

The techniques popularized for orchard covering are as followings. One is to sow low creeper leguminous herbage under fruit trees. Use of solar energy and ground coverage of plants is increased as well as fold and green manure added. Based on the data, an orchard with grass coverage can store water 40mm higher than that by a bared orchard. Organic content rises by 1.7g/kg and full nitrogen is raised by 0.35g/kg. Second is to mulch an orchard. Crop straws or some cut down herbage such as Sweetclover, Crownvetch, Coronilla, alfalfa and etc are used to cover orchards in the land with slope above 25°. A rainfall is locally contained to seek into soil. According to the data, water storage rises by 900m³ - 120m³/hm². Rotten straws and leguminous herbage add huge organic matter and nutrition to soil. Sweetclover can fix net nitrogen of 225kg in a year when fresh grass of 37,000 kg/hm² is obtained yearly. The yield of a unit area rises by about 30% to the orchards with mulching.

4.3 Storing ground runoff

The surfaces of yards and roads are hard. They are a weak permeable or impermeable structure. Runoff and sluicing are easily produced there. According to the data, the depth of runoff there is usually 109mm and they are the critical resources of soil and water loss. Long time ago, the farmers there created a water cellar, a measure of storing ground runoff. In these years, the local farmers constructed a lot of water cellars in the suitable places along roads and in orchards. Runoff by rains is stored to water fruit trees, vegetables in green houses and to be used as water supply for man and domestic stock life. It has led in a good result.

Runoff storing plats were built in 8 hill mounds in Zhaojiamao small watershed. 8 large water cellars have been constructed and have a capacity of 3,400m³ and 45small cellars set up and have got a capacity of 3,100m³. They are the water resources for drop-irrigating apricot and vegetable orchards in size of 13.3hm². An irrigation system with a water well and cellar community on ground and water pipe net under ground have been established in Gaonian small watershed in Zhizhou County. Although a serious draught occurred there in the year of 2000, vegetable grown in green houses of above 40 households in the village still got a good harvesting.