The Soil and Water Conservation Effects and Key Issues of Protective Cultivation in the Loess Plateau

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ABSTRACT

Putting into practice protective cultivation in the Loess Plateau, there is a need to understand the key concepts of soil and water conservation, preserving soil moisture, and use integrated technologies of agricultural techniques such as mulching, biologic techniques, engineering and chemical measures. Studies were conducted to determine the protective cultivation effects to preserve soil and water in the Loess Plateau, created systematized protective cultivation techniques including mechanical and agricultural practices locally adapted to the Loess Plateau.

The Loess Plateau is one of the regions in China with a long history of agriculture, specifically traditional dryland farming. Ancestors in the area had begun to till the land 6,000-7,000 years ago. They had reclaimed cropland with the most original measures, planted crops and created a whole suit of traditional dryland farming techniques that were suitable to the semi-drought regions.

The key of these techniques were to develop drought-resistant crop varieties, adopting a series of dryland farming planting and cultivation techniques, which still play an important role in present agriculture. Examples are a cultivation system which is mainly about preserving moisture, a rotation system mainly for crops and legumes, and a fertilizer mainly manufactured from organic substances.

Keywords: Loess Plateau, protective cultivation, soil and water conservation effect.

1. PROTECTIVE CULTIVATION IS THE REVOLUTION OF TRADITIONAL TILLAGE

1.1 Stages of Dry Farming on Losses Plateau

Intensive cultivation has always been the most traditional farming technique which has been playing a role in agriculture. In Loess Plateau, water shortage and poor land are the main factors that restrict the production food supply. Due to the low productivity of its land and the increasing population, it is impossible to carry on rotation in the Loess Plateau.

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People who are living there mainly lived on food production, who began plowing by driving cattle with iron tools in the Warring States Period. Then, they established the cropping systems which are mainly on plantation industry, i.e., food production plantation mainly on wheat, operated with a rotation of one-year-one-harvest and two-year-three-harvests. They relied on manure, straw and leguminous crops inverted crop rotation to maintain the land's fertility, and then a rotation system and farming technique based mainly on deep plowing and harrow deer repression. Drought prevention and water conservation were the main aims of intensive cultivation during their long-term practice; they learned to control factors of water and fertility through soil cultivation measures, a soil management system like "furrowing-harrowing- raking-pressing-hoeing".

Original agricultural production experienced an entirely ecological natural stage during which they fertilize the land by legume, reversing crop rotation and organic fertilizer and utilized animal and human power as energy. During this period, the annual input of phosphorus was $75kg/hm^2$ which was adapted with the $750kg/hm^2$ production. Since the 1960s, they still used the traditional tillage system involving deep plowing in summer and land leisure in autumn, which included some techniques such as deep plowing, harrowing, suppressing and middle plowing to enhance the soil's ability of preserving soil moisture.

Since the 1980s, mulching techniques were promoted while high-yield varieties resistant to drought were chosen. The input of material techniques were strengthened, then the two-year three-year harvest or 3-year- four year harvest *Gramineae* rotation mainly on wheat and maize and the *Gramineae* continuous cropping based on wheat and maize were formed. Then came the stage of applications of mulch, rain gathering, and conservation tillage.

1.2 The Traditional Dry Farming Techniques are Still Playing an Important Role in Agricultural Production

The precipitation in Loess Plateau is between 400 and 600mm annually, altering greatly every year due to the frequent drought and serious loss of soil and water. Learning from the long-term practice, researchers found that when the soil is rich with precipitation in a given year, harvest would be very good the next year.

To improve the soil's moisture ability, it is important that evaporation conditions in the soil be changed through decreasing potential evaporating speed on surface of soil, and improving soil-structure to enhance water-holding capacity of soil itself. The implementation of water-conservation techniques on the basis of bench terrace's achievement on water and soil conservation has played an important role in promoting continuous sustainable production and protecting environment.

(1) The most effective way to change soil evaporation is to apply mulch. Mulching can effectively raise land temperature, decrease evaporation and preserve soil moisture. Mulching could be done using straw, leaves, withered grass, organic fertilizers and screens, etc. With the obstruction of the straw stubble, rainfall and heat infiltration can be blocked, and soil and water conserved. Straw mulching can hold back rainfall evaporation and change soil moisture and heat conditions. The rotten straw increases the nutrition and organic matter of soil. Thus, straw mulching can do much in preventing drought and

desertification of land. In recent decades, mulching film, grass fiber film, emulsification pitch and medicament of soil-surface-temperature-raise and water-holding are used.

(2) Plowing is a general agricultural technique in gathering and preserving soil moisture. During a long period of practice, the time spent for doing various operations such as "early plowing to store moisture, protective cultivation to keep moisture in summer, well managed to prevent moisture in spring and winter, harrowing to protect moisture after rainfall, and cultivating the land before seeding to protect basic moisture" is the sum of techniques to preserve moisture in dryland farming. Deep plowing can be divided into spring-deep-plowing, summer-deep-plowing, autumn-deep-plowing and winter-deep-plowing, of which the summer plowings can result in more positive impacts. To store up more rainfall, it is always good to do early deep plowing of the land before the rainy season with a depth of 20-25 cm. Deep plowing can thicken the depth of mellow soil which can help to accelerate decomposition of organic matter, to resume the fertility of land and decrease the harm caused by grass, worms, and diseases. For a cropland that is easily water-eroded or wind-eroded, the micro landform can be changed by altering run-off elevation till into transversal slope till, contour farming, increasing the roughness of the soil's surface, enhancing the soil's tarnish resistance and permeability, and decreasing surface run-off to preserve the cropland from erosion.

1.3 Protective Cultivation is a Revolution of Traditional Cultivation

For thousands of years, traditional plowing is the main method of dryland farming in Loess Plateau. This original way of tillage was inefficient as it destroys the environment. From the 1970s, mechanization tillage was introduced into agricultural production which resulted in faster plowing of the field, rapid weathering of the plowed soil, and quicker soil run-off causing serious erosion. Due to the unsuitable tillage, soil erosion and water loss became more serious resulting in an eroded area of about 50 per cent. The input of sand into the Yellow River was 1600 Mt. About 80 per cent of the farmland are in the eroded area. Agricultural production and human lives are badly affected.

Protective cultivation is seasoned with double requirements of environmental protection and improved production. It is a technique with accurate purposes. From the end of the 18^{th} century, the Americans started to migrate to West America where they reclaimed 90M grassland to plant crops. Due to drought, over-cultivation, and world storm, a great number of farmlands were destroyed.

In order to improve eco-environment and fertility, they created many techniques under those conditions, with the main consideration of preventing soil erosion and promoting water use efficiency. The most successful measure they had taken was protective cultivation that required few furrowing, no furrowing, and straw mulching which did well for soil and water conservation, and drought prevention.

Today, protective cultivation is implemented in about 60 million hectares worldwide and has shown many advantages of protecting the environment at low cost.

In China, protective cultivation was introduced, tested, demonstrated, and popularized, including few-tillage and no-tillage from the 1970s. Ways to deep plow with the plow pan broken; mulching, grass and crop rotation were introduced. Tools adapted to local conservation tillage were developed. Pilot studies on conservation tillage techniques were set up which were suitable to different types of drought areas, mainly those with few (no) tillage, furrowing drilling, mulching, intercropping and rotation. Of these techniques, soil and water conservation tillage was very typical. For example, contour planting, ridge planting techniques, rotation on grass land techniques, wheat intending with straw mulching, wheat straw and mulch film mulching, whole straw of maize mulching, no tillage of summer maize and mulching tillage, were popularized in some regions and showed remarkable benefits. However, no experiments were done or studies conducted related to mechanisms of decrease of run-off and sediment in implementing conservation tillage. No local technical conservation tillage systems were also implemented.

2. STUDIES ON WATER-PREVENTION EFFECTS OF STRAW MULCHING THROUGH SIMULATED RAINFALL

Studies were conducted to make use of rainfall in which straw mulching was applied to increase rainfall seepage and decrease soil erosion. The studies also determined different conditions of rainfall, soil groups, and slope gradient.

2.1 Materials and Methods

This experiment was carried in a simulated rainfall hall in the National Key Laboratory of the Loess Plateau Soil Erosion and Dry Farming by using side gush automatic simulated rainfall system. The sprinkler is 16 above; the velocity can reach to a degree of above 98 per cent when the drop reaches the land compared to natural raindrop. The trough used was 2m×0.5m×0.3m (length×width×height) and its gradient can be altered. Samples of runoff and sediments were gathered through an instrument mounted at the end of it.

The soil was Eum-Orthic Anthrosols in Yangling, Loessal soil in Yanan, and Aeolian soil in Yulin. Roots in the samples were eliminated by sieve of 1×1cm. Straws were cut into 5cm length, and mulched on the soil surface.

The intensity of rainfall was 120mm h^{-1}, the gradient was 10 per cent. The amount of mulching straw was 0, 1000, 2000, 3000, 4000; 5000kg.hm^{-2} and the coverage were 20 per cent, 40 per cent, 60 per cent, 80 per cent, and 100 per cent, respectively.

2.2 Results and Analysis

Implementing protective cultivation with straws and mulches results in increased roughness coefficient, holds the rainfall energy, and greatly decreases spatters to soil surface. Then, soil separation and diffusion can be reduced while the seeping capacity of the soil will be enhanced. The velocity and quantity of runoff and the effect of erosion were reduced, so erosion could be finally prevented.

2.2.1 Influence of Runoff by Straw Mulching

Straw mulching can stave runoff forming and its original time, while the percentage of straw mulching is higher than the lag of the runoff, will be longer (Table 1). In the condition of 120 mmh^{-1} rainfall intensity, 10 per cent gradient and 100 per cent straw mulching, the lag of original time of runoff was 15 minutes after comparison. When the rainfall intensity and the gradient were the same, original time increased with straw mulching percentage. The reason of the original time lags was the straws' absorption of water which extended the interaction time between soil and water and increased infiltration.

Table 1: Difference of Original Time, Time Lagged between Different Straw Mulching Ratios, and Comparisons.

Disposal	CK	20 Per cent	40 Per cent	60 Per cent	80 Per cent	100 Per cent
Original Time（s）	93	109	457	544	693	989
Lagged Time（s）	0	16	364	451	600	896

The higher the mulching ratio, the distinct the reduction on runoff would be. When the ratio was 20-40 per cent, the effect was not distinct; when the ratio was 60-80 per cent, the reduction was 10-30 per cent; when the ratio was 100 per cent, the reduction was above 40 per cent. Only when the ratio was more than 40 per cent, then, erosion can be prevented effectively.

Table 2. Average Quantity of Runoff and Percentage of Reduction in Different Straw Mulching Ratios.

Disposal	CK	20 Per cent	40 Per cent	60 Per cent	80 Per cent	100 Per cent
Average Quantity（cm^3/min）	1479	1432	1420.8	1319	1030.9	849.1
Percentage	0	3.17	3.99	10.82	30.36	42.60

In the condition of 120mmh^{-1} rainfall intensity and 10 per cent slope gradient, the mount of cumulated rainfall seepage was more than that compared with the quantity of cumulated rainfall which was less than 20 mm. Infiltration of different mulching materials were not distinct. When the cumulated rain was more than 20mm, the infiltration rates were diverse. Straw mulching can remarkably increase the mount of rainfall seepage. There was a positive relationship between mulching ratios and seeping quantities. When the ratio was 40 per cent, cumulated rainfall seeping quantity increased by 37 per cent. When the ratio was 100 per cent, seeping quantity increased by 113 per cent. Thus, straw mulching can increase seepage and reduce soil and water loss remarkably.

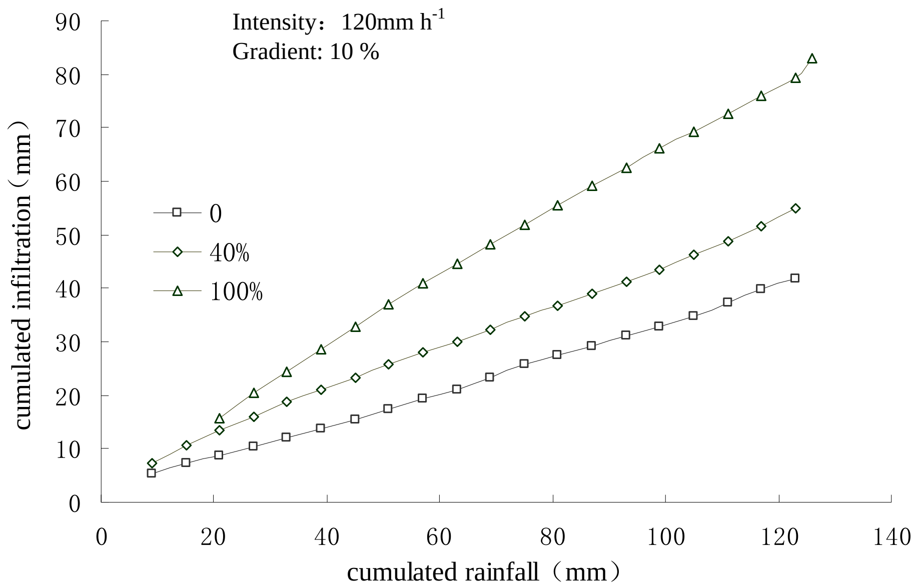


Fig. 1. Comparisons of Cumulated Seeping Quantity among Different Mulching Ratios.

2.2.2 Effect on Runoff Process by Straw Mulching

When the rainfall intensity was 120 mm·h-1 and slope gradient was 10 per cent, the start runoff in bare fallow was higher. As time passed, the runoff increased, and reached maximum and moved to stability gradually. When covered by 20 per cent, the runoff decreased but was not significant (Fig. 2). The more coverage proportion, the smaller was the runoff.

Under the conditions of 40 per cent coverage, runoff was reduced; with 100 per cent coverage, surface soil crust and runoff will be greatly reduced and infiltration increased.

2.2.3 The Effect of Straw Mulching on the Process of Sediment Produced

Sediment concentration is a key indicator to estimate soil erosion. The start sediment production was higher in the bare fallow treatment, then sharply reduced, and reached stability (Fig. 3). Low straw coverage proportion has an unimportant role in preventing soil erosion. The sediment concentration was always rare when covered proportion was 100 per cent; its sediment production decreased by 80 per cent than the bare fallow treatment. When coverage proportion was 100 per cent, the runoff and drop falling power were smaller, erosion intensity was lower, and it was better to control soil erosion.

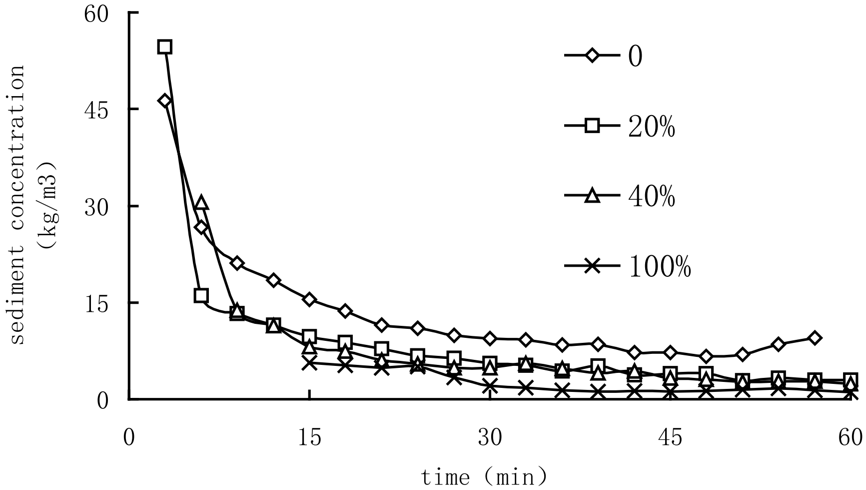
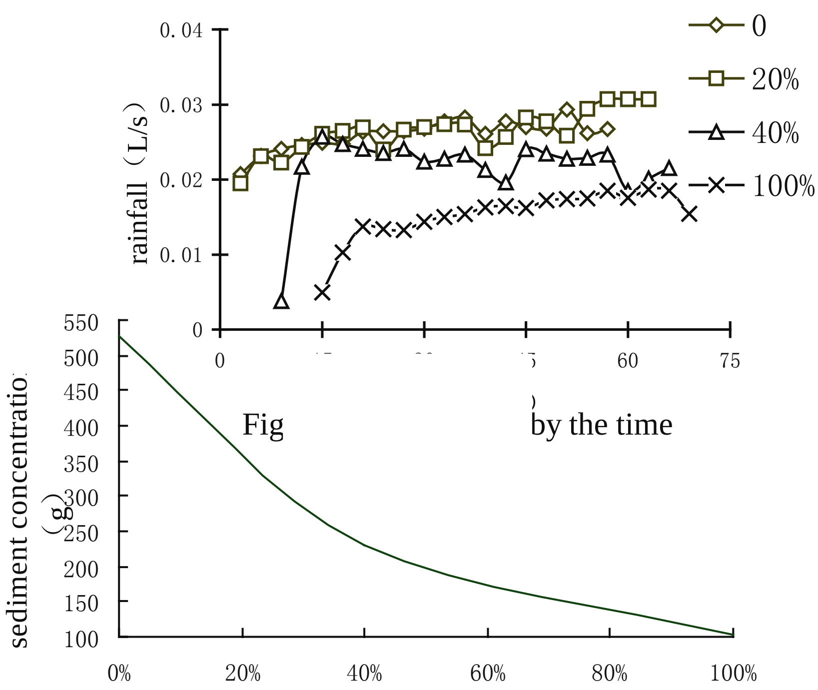


Fig3 sediment concentration changes with time

2.2.4 Relationship between Coverage and Runoff and Sediment Concentration

When the slope gradient was 10 and rainfall intensity was 120 mm·h-1, the cumulated runoff will be changed by an equation (y=-2.2139x2+8.9312x+80.422, R^2=0.9735) as the coverage proportion increased, and sediment concentration changed like a power function, y=135.13x-1.2047 (R2=0.8958). When the coverage was 2000kg/hm^2, the runoff decreased by 4 per cent, the sediment concentration decreased by 50 per cent. When the coverage was 3000kg/hm^2-4000kg/hm^2, the runoff decreased by 10-30 per cent. When the coverage was 5000kg/hm^2, the runoff decreased by 40 per cent, the sediment concentration decreased to 80 percent.



coverage rate

Fig4 Sediment changes with different coverage rate

2.2.5 Effect on Runoff and Sediment Production by Different Stubble Length

The cumulated runoff has been increased as stubble length decreased. Under the conditions of 10° slope gradient and 120 mm·h-1 rainfall intensities, and 5-15cm stubble length, the runoff did not change significantly. When the stubble lengths were 10 cm, 15 cm, 25 cm and 30 cm, the runoff decreased by 3.6 per cent and 11.3 per cent, 25.3 per cent, and 45.8 per cent.

The runoff changed by quadratic polynomial curve, where
y =- 2.9679x2 +11.988x + 91.478 (R2 = 0.9995).

When stubble length was less than 25 cm, it would be unavailable to reduce soil erosion.

Sediment production increased with stubble length reduction. When the length was less than 10cm, it will be useless to control soil erosion. The relationship between sediment concentration and stubble length was the index function, y = 2630.1e-0.6222x （R^2 = 0.9668）.

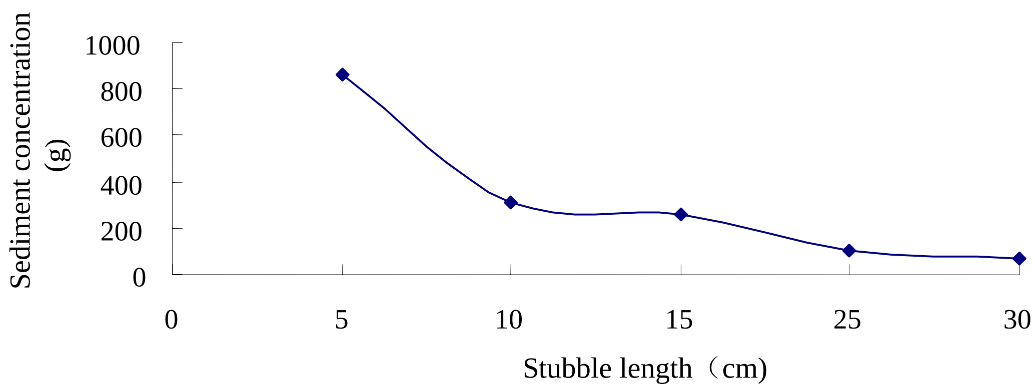


Fig.5. Sediment Changes with Different Stubble Length.

2.2.7 The Different Infiltration Capacities and Erosion Resistance in Different Soil Groups

During the rainfall process, infiltration intensity of Aeolian soil was the largest, followed by Loessal soil, and the Eum-Orthic soil. The sediment

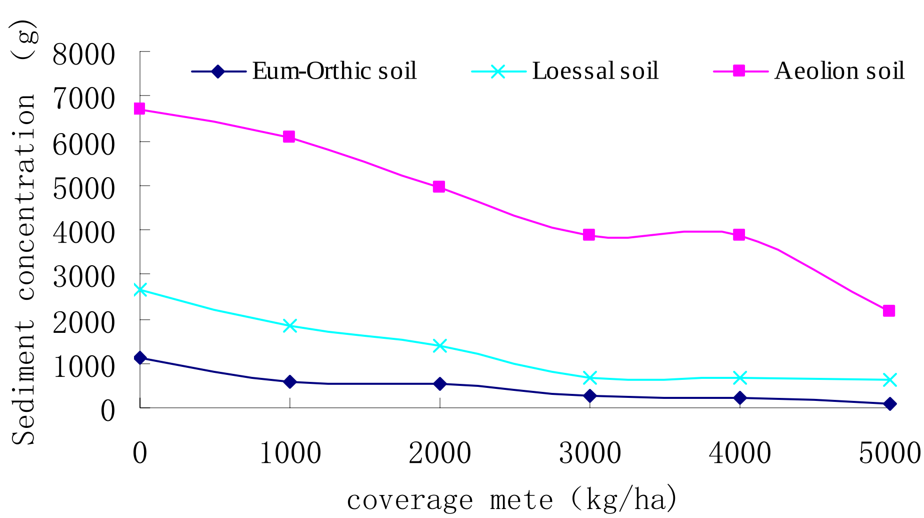


Fig6 sediment changes with different soil concentration change was the same with the infiltration intensity. Erosion resistance was reverse to infiltration intensity or sediment concentration. When the soil was covered, sediment production was changed in the same way.

Based on the relationship between straw mulching and infiltration, runoff and sediment production, straw mulching will increase the infiltration by 37-113 per cent, and the runoff reduced by 3-40 per cent, and soil erosion lessened by 10-80 per cent. When straw mulching proportion was less than 40 per cent, it was useless for erosion control.

3. THE NEW EMERGING ISSUES OF DRYLAND FARMING IN THE LOESS PLATEAU

(1) The development of agricultural techniques in dryland has been gradual. The Loess plateau has large areas which have been transformed from low produce stage into high produce stage. This situation has risen continuously along with productivity. Agricultural production has already been in a stage which enslaved agriculture to weather conditions, not only limited by material and energy, but the narrowed rainfall resources. The deficient water supply was the main factor which influenced crop yield in the dryland. Making full use of the limited rainfall recourses was a breakthrough step in dryland farming.

(2) The tendency of deep soil desiccations weakened the modulation ability of soil and water, and increased the crop yield wave. The product quality has been down, and the resources wasted.

(3) The crop yield wave in dryland farming was due to the annual and seasonal rainfall changes. Precipitation and the regulated ability of soil reservoir directly decide the soil productivity. The application of dryland farming science and technology cannot eliminate its volatility, and make the yield fluctuate at a higher level. “Subsidized shortfall with bumper harvest” is still one of the main countermeasures of agricultural produce in dry farming.

4. SET UP TECHNOLOGY SYSTEM OF PROTECTIVE CULTIVATION IN THE LOESS PLEATEAU

In the Loess Plateau, the basic farmland rely mainly on level terraced field which has already controlled soil erosion, promoted the efficiency of the limited water resource, increased production and revenue and have had positive meanings to the agriculture of promoting the technology.

The Loess Plateau dryland farming is around holding, protecting, effectively using, through the comprehensive application of technology such as various agronomy, covering, biotechnology, engineering and agriculture chemistry, and developed to combine the system of water-saving farming cultivation. Dryland farming technology can economize on and protect water, develop farming techniques of no-tillage and minimum tillage whose principles are straw mulching and plastic-covering. Dryland farming technologies have created systematized modern agricultural protective cultivation techniques, including mechanical and agricultural combination with local adaptation in the Loess Plateau.

(1) Protective cultivation is the choice of dryland farming and mechanized dryland faming technology. Popularization of the technology of mechanized protective cultivation on a large scale, such as deep plough and loose mechanized; returning straw into field, according to the crop variety; and finishing "ditch-fertilize-seed-ridging-covering" in one time drive the complete network association of other individual technologies.

(2) Protective cultivation technology system that collected rainfall and drought resistance was established. Combining agricultural machinery and agronomy, a micro water harvesting technology was set up, such as "groove ridge alternate, ridge with membrane, ditch plant, runoff on ridge and collect in groove". Collected moisture can be divided into topography water, field collect water, field collect water and root district micro water harvesting, ridging, cover membrane, concentrated rainwater on the relatively large area on limited plot, infiltrated into deep soil. Execute no-tillage and minimum tillage agriculture to avoid narrow passage caused by the soil living organisms destroyed, improve soil structure, and strengthen or resist the ability for raindrops spatter lose wind erosion.

(3) Protective cultivation technology system which is combined plastic film with straw was established. Due to its increasing temperature, and preserving soil moisture, the technology of covering play an important role in the area of insufficient heat and water resources. On the basis of covering, wheat high stubble gathering was popularized, along with wheatgrass cover , maize straw return field , ditch plant ridge build technology, grow grass cover cultivation technique to improve the protective cultivation technology system, and perfect the technology system of water-collecting strengthening, groove-ridge planting, and mulching.