

Rainfall Collection & Water-Saving Irrigation Project and Ecological Water for Small Watershed Soil & Water Conservation in Semi-Arid & Extremely Water Deficient Region

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Abstract: Henan Province, with the average annual precipitation of about 700mm, is one of water deficit provinces in China and the provincial average annual drought affected area makes up 6.4% of the national drought stricken area. How to use natural rainfall effectively is key to solving agricultural & ecological water in semi-arid & extremely water deficient regions. The paper describes the history and current status of development of rainfall collection and water saving irrigation (RC&WSI), puts forward the methods for demarcating semi-humid & extremely water deficient regions (EWDR) and discusses the necessity and feasibility of developing rainfall collection & water saving irrigation in extremely water deficient region. In the paper current ecological water consumption and ecological water demand of “the Tenth Five-year Plan Period” for small watershed soil & water conservation (S&WC) in Henan Province is calculated and three modes of rainfall collection & water saving irrigation that are suitable in Henan Province are recommended. It is concluded that developing of rainfall collection & water saving irrigation is an effective way to readjusting small watershed agricultural structure and solving ecological water demand for soil & water conservation.

Keywords: rainfall collection & water saving irrigation, extremely water deficient region, ecological water

1 The history and current status of development of rainfall collection & water saving irrigation project

Rainfall collection & water saving irrigation (RC&WSI) is an irrigation technique by means of collecting rainwater. As early as in late 1960s and early 1970s, a lot of pools and water cellars were built in many places of Henan. With the collected rainwater crops were sown in time and crop yield was increased. In 1980s along with extension of “roof rainfall collection technique for solving potable water in rural area”, the RC&WSI projects were constructed in mountain and rolling areas of Henan that greatly mitigated potable water shortage in those areas. In 1990s, RC&WSI technique was developed rapidly, a number of high quality demonstration projects with high tech adopted were built that effectively solved water shortage in the mountainous regions.

2 The method of demarcating semi-humid & extremely water deficient region

The provincial semi-humid & extremely water deficient regions are determined through quantitative calculation by adopting fuzzy clustering method, according to the provincial geographical feature indexes, climatic arid indexes and water shortage indexes. The above table shows that more than 90% of heavy soil erosion counties are located in the extremely water deficient regions.

3 The necessity and feasibility of developing rainfall collection & water saving irrigation project in the extremely water deficient regions

3.1 The necessity of developing rainfall collection & water saving irrigation project

Henan is a big agricultural province with a huge population, however, the water resource is quite insufficient. The provincial average annual water resource is 41.3 billion m³, with per capita and per mu water quantity of 471.3m³ and 399.2m³, about 1/5 of the national average level.

The provincial average annual precipitation declines from over 1,000mm in the south to less than 600mm in the north. According to the historical record, in the period of 500 years from 1450—1949, the province-wide drought occurred in 200 years, including 37 absolute drought years and 6 extraordinary drought years. In the 41 years after founding of the People's Republic of China, Henan provincial average annual drought stricken area was 1,286,000 hm², or 6.4% of the national average annual drought affected area. As for drought disasters, the most severe cases (in drought year, absolute drought year or extraordinary drought year) occurred in the extremely water deficient regions in the west, central and north Henan. In these areas, soil and water losses are most serious, however, the local climatic and soil conditions are suitable for growing crops and planting economic trees and fruit trees. The important issue is to solve crop and economic forest water demand as well as the ecological water for soil & water conservation. Surface water utilization rate in these areas is about 50% and there is still potential for water resources development. However, developing large or medium sized water projects in these areas is quite difficult and the cost will be higher. Therefore, development of rainfall collection (RC) project is quite necessary for mitigating water shortage, solving ecological water supply and increasing the farmers' income in the soil erosion areas.

3.2 Feasibility analysis on developing rainfall collection & water saving irrigation project

3.2.1 Analysis on the potential of developing rainfall collection and water saving irrigation

The average annual runoff depth of Henan provincial rolling regions is about 200mm. If rainfall collection works are built, the runoff coefficient could be increased. Provided the rainfall collection project on the area of 1hm² can intercept water of 3,000m³, so much water can irrigate 3 hm²~5 hm² farmland twice and increase grain yield by 1,500kg/ hm². Presently in Henan Province there are dry land of 1,333,000hm² and economic forest of 167,000hm² that are suitable for developing RC&WSI project. If RC projects could be built in the above-mentioned area, then the annual grain yield could be increased by 20 billion kg and the fruit yield could be increased by 500 million kg, thus the socio-economic benefit is quite remarkable.

3.2.2 Technical analysis

In the rolling regions of Henan Province the average annual precipitation is about 780mm and rainwater resource is reliable. With the better conditions for rainfall collection, the works could be built by taking advantage of local favorable land form and can intercept rainwater of 300mm—400mm. The local farmers have a tradition of rainfall collection & utilization and rich experiences in building water cellars and dry wells. The technique of building small water collection works is simple and the locally produced cement, sand and stone can be used for water collection works building. Moreover, the management & maintenance of such works are also easy. This kind of small water works could be built, owned, maintained and used by single household, thus such works are especially suitable for the farmers who are living separately in mountainous regions.

In the light of "Henan Provincial Rainfall Collection and Water Saving Irrigation Project Development Planning", in "the Tenth Five-year Plan Period" Henan Province will develop an area of 85,800hm² by applying WSI with collected rainwater, solve potable water supply to 287,000 persons. About 215,000 RC works are planned to be built, with a gross investment of 2.54 billion yuan, including 0.855 billion yuan for RC works, 1.183 billion yuan for water storage works and 0.502 billion yuan for WSI works. The funds will come from state finance, local finance and farmers, with the local finance and

farmers' funds as the major proportion. After completion the annual benefit of the works will reach 0.453 billion yuan and the benefit-cost ratio will be 2.34. The investment return period is 8 years. With the remarkable economic benefit, it is feasible to develop RC&WSI project in the extremely water deficient regions.

4 Small watershed ecological water for soil & water conservation and the mode for rainfall collection & water saving irrigation project

4.1 Small watershed ecological water for soil & water conservation

The ecological water demand for small watershed soil & water conservation means the water demand for terraced field (the original sloping land) irrigation, irrigation of forest for soil & water conservation and economic forest (grass) after taking comprehensive improvement measures in soil erosion areas. The RC&WSI project alone can not meet the ecological water demand in a broad sense, inter-basin water conveyance and other measures might be more effective. However, it is absolutely possible to provide ecological water for soil & water conservation in a small watershed by means of developing RC&WSI project.

The ecological water demand for soil & water conservation can be calculated according to the norm and improvement area of each measure in comprehensive control of soil & water loss. The test data shows that in the extremely water deficient regions, the wheat and corn of the terraced field will be irrigated four times with irrigation norm of $150\text{m}^3/\text{hm}^2$ if micro irrigation is applied, while applying low pressure pipe irrigation technique the wheat and corn will be irrigated twice with irrigation norm of $375\text{m}^3/\text{hm}^2$. The annual water duty of terraced field is $600\text{m}^3/\text{hm}^2$ — $750\text{m}^3/\text{hm}^2$, annual water duty of the forest for soil & water conservation is $150\text{m}^3/\text{hm}^2$, the economic forest water duty is $225\text{m}^3/\text{hm}^2$ and the sown grass is $75\text{m}^3/\text{hm}^2$.

In the light of "Henan Provincial Soil & Water Conservation and Ecological Construction Planning", by the end of 1998 Henan Province had improved soil erosion area of $28,500\text{km}^2$, including transforming $472,500\text{hm}^2$ sloping land to terrace in the extremely water deficient regions, $955,600\text{hm}^2$ of forest for soil and water conservation, $148,700\text{hm}^2$ economic forest, grass planting of $135,200\text{hm}^2$. It is planned that by the end of 2005, the soil and water loss improvement area should be $34,870\text{km}^2$, of which the newly increased terraced field should be $94,000\text{hm}^2$, forest for soil and water conservation should be $214,700\text{hm}^2$, economic forest area should be $65,700\text{hm}^2$ and grass planting area should be $2,300\text{hm}^2$.

Table Annual Water Consumption for Each Measure

Measure	Water Duty (m^3/hm^2)	Improvement area by the end of 1998 ($10,000\text{hm}^2$)	Improvement area by the end of 2005 ($10,000\text{hm}^2$)	Water Used at the End of 1998 ($10,000\text{m}^3$)	Water Demand at the End of 2005 ($10,000\text{m}^3$)
Terraced Field	675	47.25	56.66	31,896	38,246
Forest for Soil & Water Conservation	150	95.56	117.04	14,335	17,556
Economic Forest	225	14.87	21.44	3,347	4,826
Sown Grass	75	13.52	13.76	1,015	1,032
Total		171.20	208.9	50,593	61,660

The table above shows that by the end of 2005, ecological water for soil and water conservation (SWC) will be 110.67 million m^3 more than that by the end of 1998.

4.2 The mode for rainfall collection and water saving irrigation project

In the extremely water deficient region in north Henan mountainous area, average annual precipitation is 629mm, with uneven distribution over-year or in a year. Drought is serious because of

water shortage. This area is a transitional belt from Taihang Mountain to North China plain, with the feature of complicated topography and thin soil, mostly brown soil, over the rock base. The major crops include wheat, corn and cotton. The major trees of economic value include apple, hawthorn, pear, jujube and Chinese prickly ash, etc. The locally produced sand and gravels are enough for building RC&WSI works. Different types of RC works should be built according to local specific condition. In mountainous areas, dry wells (for collecting rainfall), water cellars and water tanks are more suitable, while in rolling areas dikes are better. Water tanks should be built at the mouth of gullies or by the side of highway, with the highway as the runoff plat or intercepting torrential flood as water source. The volume of a dry well or water cellar is usually 50 m^3 — 60 m^3 and can irrigate 0.07 hm^2 — 0.24 hm^2 farmland. One water tank can impound water of $3,000\text{ m}^3$ — $5,000\text{ m}^3$, irrigating 4 hm^2 — 5.34 hm^2 farmland. The bed and wall of water tanks should be built with 50# grouted stone and 1:2 cement mortar pointing. The dry well should be bedded with 0.25 m thick lime soil and compacted for seepage prevention and well wall should be protected with lime soil for seepage control. The water cellar bed and wall joints should be disposed with cement mortar pointing.

The Average annual precipitation of the extremely water deficient regions in western Henan mountainous area is 621mm. The uneven distribution of the precipitation over-year and in a year often causes drought. Belonging to loess rolling area and gully, the dominant soil includes brown soil and loess. Wheat and corn are the major crops. The cash crops include cotton, oil crops, tobacco and vegetables. The economic trees include apple, jujube, pear and apricot, of which apples, jujube and apricot make up the majority of the provincial total production. The area has the features of topographic relief, full of gullies, thick soil layer, greater temperature difference and long sunshine hours that are suitable for development of economic forest and cash crops growing. In this area, the major RC works include water cellars, dry wells and dikes, mostly made of grouted stone and concrete structures. The prevailing WSI practices include drip irrigation, percolation irrigation and hole irrigation.

The central Henan extremely water deficient region involves the rolling areas in central Henan and west to the Beijing-Guangzhou railway line. The topography of the area to the north of Shaying River is similar to west Henan mountainous area, thus the rainfall collection mode is something like that adopted in west Henan mountainous area. In the area south to the Shaying River is similar as Nanyang Basin, therefore dikes are built for rainfall collection there.

In the light of specific condition of Henan province, the following three modes of RC&WSI project should be developed and popularized:

Mode I: water cellar (or dry well) + micro irrigation + economic forest or cash crops;

Mode II: water tank (pool) + low pressure pipe irrigation + crops or cash crops;

Mode III: dikes + low pressure pipe irrigation + crops or cash crops.

5 Conclusion and recommendations

In comprehensive improvement of small watershed soil and water loss in the extremely water deficient regions, ecological water should be ensured first. The RC&WSI is an effective way to mitigating small watershed ecological water shortage. In recent years, in the arid mountainous and rolling areas in Henan Province local farmers built RC&WSI projects to develop economic forest, plant fruit trees and grow cash crops, and their income was increased. In development of small watershed RC&WSI projects, the local farmers consciously readjusted agricultural structure and adopted high tech in agricultural production for better benefit. It fully proves that development of RC&WSI project is practicable in arid mountainous regions and conforms to the interests of the local farmers.

The lump sum investment of RC&WSI project is higher, while in most hilly regions the local farmers economic condition is not good, therefore the effort should be made to ensure irrigation of economic forest, cash crops or field crops first. In the area with better economic conditions more rainfall collection works should be built to supply irrigation water for forest and grass for soil & water conservation. In designing of small watershed soil and water conservation projects for extremely water deficient regions, the local bearing capacity of water resources and the potential of water resources development & utilization should be expounded and evaluated. The area of trees and grass planting and the area of farmland should be determined according to water resources potential, so that the essential

crop water requirement could be ensured. It is recommended that in implementation of the west development strategy, the state should put more investment into developing RC&WSI projects. This is an effective way to improving the western China ecological environment and increasing farmers' income. Added to that, the research on RC&WSI technique should be strengthened.

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