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# The impact of rainwater harvesting and supplementary irrigation on dryland agriculture in hilly and mountainous areas of northern Shaanxi

Yafei Ji

[1]Shaanxi Provincial Land Engineering Construction Group Co.,Ltd., Xi 'an, Shaanxi 710075,China.

[2]China Shaanxi Well-facilitated Farmland Construction Group Co., Ltd, Yanglin, Shaanxi,712100 China.

[3]Shaanxi Industry Innovation Center of Cultivated Land Protection and Quality Improvemen, Yangling Shaanxi ,712100 China.

## Abstract

**Shaanxi is a dryland and water-saving province. In order to effectively ensure the development of dryland agriculture in hilly and mountainous areas, the "four in one" mountain rainwater harvesting and irrigation project has been launched. This article introduces the basic situation of the rainwater harvesting and irrigation project, summarizes the main practices such as the integration of natural precipitation and well water, water source filtration, photovoltaic water extraction, post management and maintenance, and the development of full automation, and explores new paths for the development of high-quality agriculture on similar cultivated land in hilly arid and semi-arid areas.**

## Keywords

**Hilly and mountainous areas; Dryland agriculture; Four in one "; Rainwater collection and supplementary irrigation; Save costs and increase efficiency.**

## 1. Introduction

In order to explore feasible irrigation modes for the cultivation of miscellaneous grains and corn in similar plots in northern Shaanxi, suitable comprehensive water-saving technology models for rainwater harvesting and supplementary irrigation will be promoted in hilly and arid areas where irrigation facilities are difficult to construct, there is no power grid coverage, or insufficient farmland. This will ensure the water demand of crops in key growth periods, increase crop yields, and guarantee food security. After completion, taking corn planting as an example, the average yield per mu is 620kg, which is more than 200kg higher than the original planting method (dry planting).

## 2. The origin and iterative upgrading of comprehensive land consolidation in the whole region

### 2.1. Overview of the project area

Shaanxi Province is a typical arid and water-saving province in northern China, with a severe shortage of water resources. Over 60% of the province's land area is located in the arid and semi-arid regions of the Loess Plateau. Jingbian County is one of the counties (districts) on the Loess Plateau in northern Shaanxi Province. It belongs to a semi-arid region with scarce water resources, with an average annual rainfall of 395-400 mm. The average water resources per mu

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are 1/5 of the national average level. Dryland agriculture accounts for 58% of the total cultivated land area of 1.72 million mu in the county, and the low yield farmland area caused by water shortage is nearly 890000 mu, which has become the main factor restricting local grain production. To explore the development path of local agriculture, a "four in one" rainwater harvesting and irrigation project was launched in the mountainous area. The project area is located in the northwest of Shaanxi Province, southwest of Yulin City, 120 kilometers away from Yulin City. Its geographical coordinates range from 108 ° 17 ′ 15 ″ E to 109 ° 20 ′ 15 ″ E and 36 ° 58 ′ 45 ″ N to 38 ° 03 ′ 15 ″ N. Jingbian County is located on the southern edge of the Maowusu Desert, upstream of the Wuding River, and the Great Wall runs east-west. It borders Inner Mongolia Autonomous Region to the north, Ansai District of Yan'an City to the south, Hengshan County of this city to the east, and Dingbian County to the west, and is located at the border of Shaanxi, Gansu, Ningxia, and Mongolia provinces. The county is 91.3km wide from east to west and 116.2km long from north to south, with a total land area of 5088km$^2$.

The terrain of the project area is close to hills and gullies, and the beach is irrigated with groundwater to grow crops such as corn and sorghum, with a yield of over 600 kg; Slow sloping land and terraced fields are mainly dominated by drought, mainly planting crops such as corn, buckwheat, sorghum, etc., with a yield of 300-400 kg. They rely mainly on the weather for food, and in years of severe drought, there is almost no yield, only straw can be harvested for feed.

## 2.2. Project Overview

The "Four in One Rainwater Collection and Irrigation Project" will be implemented in the project area, covering an area of 500 acres. The nearby river channel water will be utilized to supplement water with machine wells. A soft water cellar of 3000 meters will be built on the mountaintop, and solar photovoltaic power will be used to extract water from the ditch, dam, and river channels to the water cellar, and then irrigate surrounding farmland with drip irrigation pipe network. The design concept is river channel photovoltaic water intake (machine well water intake) - water transmission pipe network - high-level soft rainwater collection reservoir - water distribution main pipe and branch pipe - drip irrigation belt. The main water-saving technologies used are photovoltaic water extraction and agricultural electricity supplement technology, pipeline water transmission technology, soft rainwater collection and storage technology, and terrace and field drip irrigation technology, jointly forming the "Four in One" rainwater collection and irrigation technology.

The project is divided into three parts, namely the water source lifting project, the soft rainwater collection reservoir project, and the water distribution pipeline network project; The main construction contents include one high-level soft rainwater collection system, 500 acres of field water supply pipeline network, supporting water outlet piles, valve wells, etc., one set of field head, one set of photovoltaic water pumping station and supporting facilities, one set of agricultural power well water pumping pump, and one set of intelligent water control system.

## 2.3. Economic evaluation

By constructing rainwater harvesting and irrigation projects, the basic agricultural production conditions in the project area have been greatly improved, enhancing the ability of agricultural production to resist natural disasters. The average yield per mu of corn planted in the project area has been tested to be 620kg, which is more than 200 kg higher than that of corn planted in dry fields in the local area, and an increase of more than 240 yuan per mu; Simultaneously achieving 20% reduction in fertilizer and 20% reduction in labor, with significant cost savings and efficiency gains. Irrigation mainly relies on surface water, supplemented by groundwater, and can also collect rainwater, greatly saving groundwater resources and effectively alleviating the problem of groundwater overexploitation in Jingbian County in recent years. After the implementation of the project, the land utilization rate was improved, the rational use of water resources was achieved, the industrial and planting structures were optimized, the

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development of the local agricultural economy was accelerated, farmers' income was increased, their living standards were improved, and their irrigation concepts were changed. The project fully utilizes the various advantages of the rainwater harvesting and supplementary irrigation mode, drives the development of various production specialties, and achieves a virtuous cycle of large-scale production, intensive management, and brand effect in the project area's agriculture.

## 3. Main methods

The main water sources in the project implementation area are machine wells, rivers, and reservoirs. Water is pumped to the high-level rainwater collection reservoir in the project area, and the rainwater collected by soft rainwater collection can be used to achieve high-pressure self flow replenishment in multiple irrigation areas. High pressure self outflow outlets are set up on the reservoir, and facilities such as filters, control valves, remote digital ultrasonic water meters, etc. are installed. Head valves are externally used and protected. All low-level fields are irrigated using gravity self flow water supply. The entire irrigation network is divided into four levels, with water distribution pipes leading water out of reservoirs and transporting it to the fields; The branch pipes are arranged parallel to the contour lines, and an opening and closing gate valve is set at the head of the branch pipes as a wheel irrigation area. Two way or one-way outlet plugs are designed on the branch pipes according to the plot, and each outlet plug controls about 5 acres of land.

### 3.1. Integration of natural precipitation and well water for use

There are currently 2 organic wells in the project site, with a depth of 420m after on-site investigation. The current pump depth under the well is 150m, with a pump power of 30 kW and a flow rate calculated based on a pump outlet diameter of 90mm. The existing pump supplies water to irrigate an area of 150 acres, and there is currently no interruption or sand leakage during normal use. Based on this, it is estimated that the water flow rate should not be less than 30 m '/h. Connecting the well to the soft rainwater collection system can reduce the risk of agricultural crop failure or crop failure caused by insufficient groundwater sources.

### 3.2. Water source filtration

Drip irrigation under plastic film is water-saving, fertilizer saving, and labor-saving. The drawback is that the drip head is prone to scaling and blockage, and strict filtration of the water source should be carried out. The filtering measures adopted at the Laozhuang Village project site in Ningtiaoliang Town are to design a filtering wall at the river water intake of the photovoltaic water lifting system, with crushed stone in the middle of the two layers inside and outside the steel cage.

The water source of this project is relatively clear, with little sediment content and no obvious floating objects, so a disc filter is installed at the outlet of the water cellar. If the sediment content of the water source is high, sand and gravel filters and disc filters should be installed for secondary filtration. There is one sand discharge outlet installed on each side of the water tight bottom, and a valve is installed. After a long period of use, sediment will settle at the bottom, and the silt needs to be cleaned regularly.

### 3.3. Photovoltaic water extraction

Although there are rivers, canals, or reservoirs around the hilly and mountainous areas without power grid coverage, they are unable to solve irrigation problems due to the lack of electricity facilities. This project constructs a photovoltaic water lifting system that uses solar energy as a power source to drive water pumps to directly draw water from reservoirs or rivers. After manual operation, the system can operate fully automatically without the need for manual

supervision, making it easy to maintain and safe and reliable. If the budget is sufficient, batteries can be installed to store solar energy, so that water can be pumped even when there is insufficient sunlight.

### 3.4. Post management and maintenance

Due to the involvement of numerous pipelines and wires in this project, as well as its high level of specialization, safety hazards are prone to occur. Therefore, all equipment and pipelines need to be managed by dedicated personnel and undergo regular maintenance in strict accordance with usage regulations to extend the service life of the equipment; Timely repair of problems to improve project economic benefits while ensuring safety production.

Photovoltaic power plants and soft rainwater collection facilities must be equipped with safety measures, enclosed, and equipped with danger warning signs to prevent accidents such as electric shock and drowning caused by people approaching, ensuring safe production. Facilities and equipment that are not waterproof, dust-proof, rust proof, sun proof, or corrosion-resistant should be manually intervened, and appropriate facilities should be constructed to provide protection, meet the requirements for outdoor installation and use, and extend their service life.

### 3.5. Developing full process automation

After manual startup, the photovoltaic water lifting system can automatically supply water as long as there is sunlight, but it will stop on cloudy days without sunlight. The only drawback is that it needs to be manually turned on. At present, there are specialized apps on the market that can achieve remote switch control after installation on mobile phones.

The current design of water cellar effluent and field irrigation projects is entirely manual operation. It is understood that the effluent pile can now be upgraded to an electromagnetic valve type to achieve mobile control. With the application of 5G technology, it is believed that the "four in one" full automation will be realized as soon as possible.

## 4. Project significance

This project aims to promote and apply photovoltaic pump stations, soft rainwater collection reservoirs, and rainwater collection and storage water replenishment technology in mountainous areas, effectively improving the infrastructure of mountainous farmland. On the premise of promoting the concept of "insufficient irrigation" water use, it explores feasible irrigation modes for mountainous crops to be irrigated with "life-saving water" to solve the bottleneck drought of mountainous crops, improve the survival rate of dryland crops, and ensure the growth of key growth periods. After the implementation of the project, water and fertilizer have been raised up the mountain, doubling the grain yield. The arid hilly and mountainous areas that have relied on the weather for many years have transformed from "rain fed agriculture" to supplementary irrigation agriculture, and exploring a new path for the development of high-quality and best agriculture in similar farmland in the arid and semi-arid hilly areas of northern Shaanxi.

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