Rainwater Harvesting in the Loess Plateau of Gansu, China and Its Significance

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Abstract

China has been facing serious water shortage problems that caused great economic and environmental losses. The water condition is even much worse in the loess plateau of Gansu, located in northwest and north China, where runoff and groundwater is very scarce. Agriculture in this region relies mainly on rain and most of the people have suffered from thirst for centuries. This is one of China's poorest areas. To promote social and economic development and to improve peoples' lives, it is necessary to change the water condition. The only potential water source in this area is rain. Since 1988, efficient rainwater catchment techniques have been tested and from 1995 to 1996, the local government implemented a “121” rainwater catchment project, solving 1.2 million peoples water problems. Follow-up rainwater catchment irrigation projects have been carried out to change the basic agriculture condition of the area. Gansu’s experiences show that rainwater catchment and utilization (RWC) can provide an effective means to alleviate poverty and allow a breakthrough for dryland farming.

Introduction

China is one of the world’s largest countries and has enormous water resources. Ranking 6th in the world, the total precipitation on the continental is 6190 km³, which produces 2710 km³ of river runoff and 130 km³ of groundwater. However, owing to the large population, the water resources per capita are only 2300 m³, 1/4 of that in the world. The water resources available for cultivating land in China are 2100 mm, compared to 3500 mm worldwide. Moreover, the water resources are unfavorable distributed both spatially and temporally. Water resources per capita can be more than 20000 m³ in the southwest China but only 200 m³ to 300 m³ in the north. On the temporal aspect, China is known for its monsoon climate. The distribution of river
runoff is very uneven within a year or between years. Sixty to seventy percent of runoff is concentrated in the flood period from July to September. This kind of distribution pattern causes seasonal water shortage even in the semi-humid and humid area. It is predicted that along with the rapid growth of social and economic development and the increasingly demand on improving peoples’ lives, water scarcity will be much more critical in the 21st century.

The situation is even more serious in the loess plateau of Gansu province in the northwest China (Zhu and Wu (B), 1995, Zheng et al, 1995). Water is the key factor for development in China’s all over China, but in Gansu province the situation is very critical. This is one of the driest and poorest regions in China, with an area of about 100 000 km$^2$. The annual precipitation reaches 420 mm, however, owing to the deep loess soil layer, which is characterized by high vertical infiltration rate, and the very low humidity, most of the rain is absorbed by the soil and then evaporates in the air. The runoff coefficient is only 0.05. Due to the geological condition, groundwater is also very scarce. Water resources per capita in the area are only 230 m$^3$, 1/5 of that in the province and 1/10 of that in the state. The topographic condition is very unfavorable for water diversion from rivers to land. Crisscross distributed ravines and gullies and the high altitude of land make the water conveyance system and irrigation network almost impossible to build. The agriculture in this region mainly relies on rain. The unfavorable distribution of precipitation during the year causes frequent draughts and a very low crop yield. According to the annals and records, 634 draughts occurred in the past 1400 years, on the average, one every two years. In the last 41 years there were 36 draughts. The crop yield averaged 1000kg/ha. In a dry year, the yield does not compensate for the purchase of seeds. People were not able to plant cash crops due to the lack of water. Life in the area was very poor. Annual income for a 5-member family is as low as US $ 250-300. Moreover, most of the people in the region have never gotten enough drinking water. In most years, the local government has to dispatch trucks to transport water from far away to supply drinking water. Water shortage became the root of poverty and threatened the existence of human beings.

To help local people to get rid of poverty and to promote the socio-economic development, the key measure is to change the water condition. As pointed out before, the only potential water source in this area is rain. However, utilization of rainwater faces unfavorable condition. There is little rain in this semiarid area and it cannot produce runoff on the natural soil with very high vertical infiltration capability. Moreover, most of the rain cannot be used owing to the uneven temporal distribution pattern. It is estimated that 5%-8% of precipitation forms the runoff, 15-20% of rain is absorbed by the crops, the remaining 75-80% returns to the air without use. The low extent in use of rain forms a sharp contrast with the serious water shortage in the region. The local people have a tradition to use rainwater, as their drinking source, which can be traced to thousand years ago, but the water harvesting efficiency is so low that even the drinking demand cannot be met. To raise the rainwater utilization
efficiency and to meet the demand of poverty alleviation and social-economic
development, the Gansu Research Institute for Water Conservancy (GRIWAC) has
carried out systematic experiments on RWHU in this area and set up many pilot
projects to show the profit (Zhu and Wu (A), 1995). Based on these experiment and
demonstration work, a so called "121" rainwater catchment project (the government
supported each family to build one piece of water collection field, two storage and
one land to plant cash crop) had been initiated by the local government in 1995. The
project has successfully solved the drinking problem for 1.3 million people (260,000
families) and their 1.18 million livestock. Since 1997, a rainwater catchment and
irrigation project has followed up, aiming to supply water for supplemental irrigation
with a high efficient water saving method. The results were also proved to be
successful. RWHU has become a strategic measure for the social and economic
development in this semi-arid region.

**Technical aspects of the projects**

The RWHU project is mainly composed of 4 parts, namely, rainwater collection
fields, storage, water supply and irrigation system and agriculture facilities (Zhu and
Li, 1998).

1. In the traditional rainwater catchment techniques, the rainwater collection field is
mostly the natural soil, threshing yard and road, which has low efficiency in collecting
rainwater. The new system adopts seepage control measures for the rainwater
collection field. In the drinking project, the previous mud-straw roof was replaced by
cement tile and used for water collection. When the roof area or the rainfall is not
sufficient to produce enough water, the courtyard is lined with concrete slabs.
According to testing, rainwater collection coefficient (RCE) of these two kind of
material can reach 0.75 to 0.8. In general, 100 m² of roof and concrete yard is enough
to collect water for a 5-member family in the area with annual rainfall of 400 mm. For
the irrigation project, the nearby villages use the paved highway. For those who do not
have a highway passing by, compacted loess soil, threshing yards or village roads are
used but with low RCE ranging from 0.15 to 0.3. In some villages, the farmers divide
the field into 4 parts. Each year one part is covered with plastic film to collect water
for irrigating the other 3 parts. Then in the following years, the other 3 pieces of land
are used subsequently for water collection. Polyethylene film with thickness of 0.01
mm is used in one year of service life. The RCE can be over 0.9. Concrete slab is
sometimes used for the cash crop fields when the output can pay for the investment.

2. In most cases, a water cellar, an underground bottle-shaped tank is adopted for
storage. Many water collection fields are on the ground. Besides, water kept
underground will have low temperature thus maintaining good quality. In the drinking
project, storage is built inside the courtyard. The loess soil can sustain itself in a
vertical section as high as 5 m in dry condition. So, the wall of water cellar is just
pasted with cement mortar with a thickness of 3 to 4 cm, good enough for protecting
the soil from erosion and controlling seepage loss. The top and bottom of the cellar are built with plain concrete in an arch shape to support the overburden and water weight. When the soil is sandy, a plain concrete wall of 30 cm thick is needed instead of cement mortar. Storage capacity for drinking water supply ranges between 15 and 20 m$^3$, while for irrigation purposes, 30 m$^3$ storage is necessary for two applications in 1 mu (Chinese land unit, equal to 1/15 ha.) of land.

3. A hand pump, affordable for most farmers, is used for water supply for irrigation purpose. For irrigation, various methods are used according to the available fund but under a unique principle: highly efficient in water saving. At the moment, most farmers use manual hole irrigation. This is labor costly but very effective and cheap. In some region, the seeding machine equipped with tank supplies water through a pipe together with the seeds feeding into the soil during sowing. The water applied is only 6-8 mm but it can ensure the emergence and growth for more than 1 month. Other methods include irrigation under plastic film, pipe irrigation and water injection into the root zone by using a fertilizer injector. In case the fund is available, drip and seepage irrigation is used. To save cost, the movable and semi-movable system is adopted. In the latter case, the main pipe is fixed while the lateral pipe with emitters can be moved to irrigate crop line by line. To use the limited rainwater efficiently, the principle of supplemental irrigation is adopted. Water is applied 2 to 3 times at the critical growth period. In the area with annual precipitation of 400 mm, 45-75 mm is enough for one harvest to get a satisfactory yield.

4. To ensure an effective use of water and a high output, several agriculture measures are taken. The field is covered with plastic film to avoid evaporation loss. Sometimes, to increase the soil moisture around the plant, the crop is planted in the ditches between ridges, which is covered with plastic film. Then rainfall concentrated in the ditches will supply more water to the plant. Green houses for vegetable cultivation are now a common practice to make the highest benefit of the rainwater. The plastic roof of green house can also collect rainwater for the vegetables inside. According to some testing, RCE during flood season amounted to 0.8-0.9. Water collected from the top can basically meet the water demand in the area with annual precipitation of 400 mm.

Project benefit

1. The "121" project has preliminary solved the drinking water problem for 1.2 million people (Gansu Bureau of Water resources, 1995). In a normal year, each day one person can get 10 liter and the large animal can get 30 l/day. For the human beings, this is a low quota. But, taking the local condition into consideration, it is realistic and is happily accepted by the local people. It can be expected that with economic development, people will be able to enlarge rainwater catchment systems through their own forces thus improving water supply. The RWHU system has proved to be reliable. In the year of 1995, the draught was particularly severe. Families who had built a RWHU system had enough water for their own use and were even able to help
those who didn't have the system. The water quality is also generally accepted. According to tests, rainwater is a clean source even after it has been stored in an underground tank over half year. The only two problems are a little turbidity and the colon bacillus. The local people are advised to boil the water before drinking. Furthermore, before the RWHU project was built, the inhabitants had to fetch water from far away. Investigation showed that each family spent an average of 70 working days to carry water. Since women and children were the ones fetching water, they were happy about the changes.

2. While the RWHU drinking project satisfied the basic needs of the local people, the irrigation project opens up ways for economic developments and general life improvements. The supplemental irrigation water, although in small amount, has a miraculous result on the crop yield. According to an experiment, 2 application of 10 m$^3$/mu (15 mm) each can increase the yield of wheat in plastic film covered field by 100 kg/mu (1500 kg/ha.). The water use efficiency (WUE) reached 1.1-1.4 kg/m$^3$ (including natural rainfall), irrigation water productivity (IWP, yield increase per irrigated water) amounted to 4-6 kg/m$^3$. For corn, because there is enough rain in the late growth period, the results are more significant. The same application can increase the yield by 200 kg/mu (3000 kg/ha.). WUE and IWP reached 3.5 kg/m$^3$ and 10 kg/m$^3$, respectively. The even larger benefits brought by the RWHU project are the possibility to grow cash crops to increase farmers' income. In this area, owing to the dry and cold weather (the altitude in most areas is over 2000 m), the fine vegetables cannot grow. As soon as the farmers got water from rain, they try every way to make full use of the valuable resources. Green houses to grow vegetables and raise pigs have become increasingly popular. In a 300 m$^2$ green house, income from vegetable sale amounted to about US $1,000. Thus the investment is returned within one and half year. The production value per irrigated water reached US $6/m$^3$. If each family owns a green house, their income can be doubled. So the RWHU project is an effective way to eradicate poverty.

3. The RWHU project is also beneficial to the environment. The soil erosion intensity is very high in this region. The annual eroded soil for each square kilometer of land amounts from 5,000 to10,000 tons. Up to now, it is estimated that more than 80 km$^2$ of rainwater collection field has been built, which can reduce the soil erosion by 500,000 tons of sediment every year. More important though when crops and trees are grown, there will be more ecological diversity in this semiarid mountainous area. Tiled roofing of houses and concrete lining of courtyards and the cultivation around the houses enable the farmers to enjoy their residential environment. The RWHU projects have been changing the face of this impoverished countryside.

**Main experiences**

1. The project has followed the participatory principle from beginning to the end. Farmers have contributed a lot to this project. They provided labor, local material and its transportation. The government subsidized a small part, mainly for cement. According to some rough calculation (Wu et al, 1995), for the drinking project of a 5-
member family, the total cost is about 1023 Rmb yuan (US $124). The subsidies from government were 400 yuans (US $48) and the farmers contributed the remaining 61%. For the irrigation project, the farmers shared more than 80% of the total input. This kind of input mechanism has the advantage of not only reducing the government fund, but also makes the farmers the project masters. This will be beneficial for the maintenance and the sustainable operation of the project. The farmers made these contributions, of their own will. In the very beginning of the project, farmers were not so confident in the project profit. The pilot projects were firstly built in some "scientific" farmers' home with their share of input. Only after one-year demonstration, the nearby farmers saw the benefit. They rushed to apply for the subsidy. They even borrowed money from the bank to build their RWHU system when the government fund was not available.

2. The project implementation took the procedure of experiment, demonstration and training and then extension. It took 4 years for GRIWAC to finish the feasibility study of the project and to establish pilot projects (Zhu and Wu (A), 1995). Thirty-three testing plots were set up to test the RCE of different materials for water collection field under various rainfall conditions. Data of more than 50 rainfall gauges were collected and yearly RCE for different rainfall and field situation was worked out with simulation models. Economic evaluation was conducted to verify the benefit. The North Hill Region in Yuzhong, a county close to capital of the province, was taken as a demonstration base. At the same time, training for the agro-technicians were conducted. More than 200 courses were held and technical guidelines were issued, which later became a provincial specification (GBWR and GBTS, 1997). Only when the above jobs achieved good results, the decision to extend this technique was made. After another 3 years of demonstration and small scaled extension, the "121" project was in place. This procedure ensured a scientific decision-making.

3. Although farmers undertook 60-80% of the total input, the remaining part still amounted to much. To achieve the goal of the "121" project — solving 1.2 million people's drinking problem, one hundred million yuans (US $12 million) of subsidies were needed. The government could only raise 70 million yuans. The government and media mobilized a donation movement for the project. A total of 53.28 million yuans (US $6.4 million) was collected from all over, ensuring the smooth execution of the project.

Conclusions — significance of RWHU

1. At the household level rainwater catchment systems can provide an effective means to alleviate poverty of which water shortage is often the root cause. Particularly in many arid hilly areas, people have little access to water from river or groundwater sources and frequent droughts cause low and unstable crop yields. People in these regions have suffered from chronic water shortage for centuries. RWHS enable people to get a clean, reliable and cheap water source using simple techniques at a household level for domestic use and irrigation, resulting in raised agricultural production and an overall improvement in people’s lives (Zhu and Wu (B), 1995).
2. RWU can also provide a breakthrough for dryland farming (Zhu and Liu, 1998). For a long time, people tried many methods to increase rainwater use efficiency to raise crop yield within the scope of rain-fed agriculture. However, the effects were limited, especially during recurrent droughts such as those typical of the mid-1990s when crop yields dropped seriously in most dryland areas. In the past, the principles of dryland farming have been to adopt cultivation methods or create a microenvironment (meteorological, soil, etc.) that enables the crop to adapt to the rain condition to a maximum extent. The approach used with rainwater catchment system is a thoroughly new idea, and that involves the control and regulation of precipitation to meet the crop demand. Results with rainwater catchment projects for providing supplementary irrigation in dryland areas have been extremely promising and it is expected that RWHU will play an increasingly important role in enhancing food production in areas of rain-fed agriculture in the future, particularly in mountainous regions. The facts also show the great potential of a combination of RWHU and agricultural water conservation in the development of rural areas.

3. RWCS are also becoming a new trend for water resources engineering (Zhu and Liu, 1998). In the past in China and in many other countries, attention was paid mainly to the surface and subsurface water exploitation and less to precipitation itself. Most modern water resources projects have been characterized by their large scale, concentrated development of water resources, complicated water diversion and distribution systems, high input, long construction cycles to bring profit. However, in the vast, remote and mountainous areas, the local people can hardly benefit from these huge projects owing to the long distance, unfavorable topographical conditions and the high costs for water supply. For these areas, the best solutions are decentralized and simple ones that involve the use of appropriate technology. Rainwater is available in all areas, whereas rivers and groundwaters are not generally available. RWHU has the advantages of requiring no water conveyance, low input for its exploitation, and simple construction and management techniques. This makes it ideal for the scattered, impoverished inhabitants in the mountainous areas of developing countries such as those in northwest China. Moreover, such developments help to reduce dependence on large water resources projects and groundwater exploitation with their numerous ecological and environmental problems threatening the sustainable development of whole regions. Owing to their decentralized nature and small scale RWU technologies are environmentally friendly.

4. The new RWHU techniques being adopted represent a major innovation in the concept of water resources development in China and even the world. Precipitation is the origin of all water resources, however, in China and elsewhere, the term water resources is often equated with river runoff and groundwater. As shown above, runoff coefficient in the loess plateau of Gansu province is only 0.05. It is unreasonable not to regard the other 95% as water resources when the water shortage is so serious that even the existence of human beings was threatened. Although the intensity of precipitation is low as compared with river runoff, it can be intensified by artificial concentration measures to meet the purpose of water supply (Zhu and Li, 1998). Rainwater can be concentrated enough spatially and temporally to become a necessary
supplement to the surface and subsurface water. Such is the process of turning rainfall into a usable resource (Mou, 1996). Research and development into these practices could create many new ideas and methodology of water resources evaluation and utilization and could even result in the evolution of a new and independent branch of water science (Liu and Mou, 1998).

References