Analysis on the Characteristics of Water Resources in the Loess Plateau

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Abstract

Water resources in the Loess Plateau are scarce, but in some areas, such as the gully, the water resources are nearly 3 times that of the plateau slope, which contains abundant arable land resources and the potential for increasing grain production. Checking out the local water resources is of great significance to agricultural production and economic development. This study summarized the characteristics and distribution of water resources in the Loess Plateau from three aspects: surface water resources, ground water resources and soil water resources, and clarified the quantity and transformation and utilization characteristics of water resources. The research results can provide decision-making basis for local agriculture and water conservancy departments to formulate policies and adopt agricultural development measures, and are of great significance to the sustainable development of regional agriculture and society.

Keywords

Groundwater Resources; Surface Water Resources; Soil Water Resources; Loess Plateau; Sustainable Utilization.

1. Introduction

The Loess Plateau is rich in land resources, but water resources are relatively poor [1], local water sources are abundant [2], and the contradiction between supply and demand is sharp [3]. The land area in this area accounts for 6.9% of the country's land area, arable land area accounts for 12.2%, and water resources account for only 2.2% of the country's land area. The average water volume per arable land area in this district is 3780 m^3/hm^2, and the per capita water volume is 634 m^3. The average water volume per arable land area and per capita water volume account for 14% and 26.4% of the national average water volume respectively [4]. The shortage of water resources seriously restricts the sustainable development of industrial and agricultural production in this area, and seriously affects the balance and restoration of the ecological environment [5]. Another feature of the water resources in this area is that the regional distribution and seasonal distribution are extremely uneven, and there are great changes within and between the years, which brings great difficulties to the development and utilization of water resources. Water resources mainly include surface water resources, ground water resources and soil water resources [6].

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2. Surface Water Resources

2.1 Overall distribution

In the arid and semi-arid Loess Plateau, precipitation is scarce and evaporation is vigorous. Free water surface evaporation is more than twice that of precipitation. Taking Yan'an City as an example, the annual average precipitation is 490-660 mm, the water surface evaporation is 950-1000 mm, and the relative humidity is 59%-68%. In summer, it is controlled by oceanic air masses, with large-scale rainfall, mostly thunderstorms, accounting for 52% to 58% of annual precipitation; autumn precipitation is concentrated in September, accounting for 23% to 30% of annual precipitation, mostly continuous rain; spring and winter the precipitation is relatively scarce. Due to uneven rainfall seasons, droughts and floods occur frequently. Drought is the main agro-meteorological disaster in this area. An average of 4 to 5 months of drought occurs every year. Heavy droughts occur frequently, affecting the growth of over-wintering crops and planting autumn crops, causing great harm; droughts are most severe in winter, followed by spring droughts, and autumn droughts least. Due to the scarce rain and snow in winter, the soil moisture is reduced, which affects the green growth of overwintering crops and the emergence of spring crops. Since the founding of the People's Republic of China, Yan'an City has experienced more than 20 heavy rainstorms and floods. The spatial distribution of average precipitation for many years basically shows a decreasing trend from south to north. Wuqi in the northwest and Yanchuan in the northeast have little rainfall, with an annual rainfall of about 450 mm. The southwest has more rainfall due to the influence of mountains and forests.

2.2 Water resources reserves

Water resources in the Loess Plateau show a sharply decreasing distribution law from southeast to northwest. From the perspective of surface water resources, from Tongren and Taohe Rivers to the mountainous areas south of the Weihe and Fenhe rivers, the annual average rainfall is greater than 600 mm, the annual runoff depth is more than 100-200 mm, and some areas can reach 400 mm. the most abundant water resources is in this area. Gaolan, Haiyuan, Tongxin, Dingbian, and the north of Baotou have a dry climate with sparse rainfall. The annual precipitation is less than 300 mm, and the annual runoff depth is less than 10 mm. especially in the Jingyuan and Yinchuan areas, the annual precipitation is less than 200 mm. The annual runoff depth is less than 5 mm, which is the region with the most water-poor water resources. The central loess hills and the Loess Plateau have an annual precipitation of 400-500 mm, an annual runoff depth of 20-50 mm, broken terrain and vertical and horizontal valleys, which are the areas with the most serious soil erosion. The mountainous area has less land and abundant water. The plateau area is very rich in land resources, but water resources are seriously insufficient, and the distribution of water and land resources is extremely unbalanced. There are five main rivers in Yan'an: Yanhe, Beiluo, Qingjian, Yunyan and Shiwang. The average surface water resources for many years are 1.3 billion m^3, equivalent to a runoff depth of 35.7 mm. The surface water resources in Baota District reached 112 million m^3, accounting for 8.53% of the total surface water resources in Yan'an City.

3. Groundwater resources

3.1 Groundwater recharge

Taking Yan'an as an example in the Loess Plateau region, the groundwater supply mainly comes from atmospheric precipitation and a small amount of surface water. Surface water replenishment includes the replenishment of water in rivers, channels, lakes and reservoirs. After the mountain river enters the plain, a large amount of surface water can seep into the ground to recharge the groundwater. Plain areas can be recharged laterally by rivers, turning surface water into groundwater. The water level of the river rises during the flood season, and more water can be supplied. Groundwater flows from high to low, from the upper reaches of the river valley. Therefore, low or downstream areas can be recharged by groundwater in high or upstream areas. The bedrock fissure water and karst water in the low hills of the Loess Plateau in Shaanxi Province can flow along the mountains to the north and south sides to replenish the groundwater in the loess area. The groundwater flowing to the north, along the stratum sloping to the northwest, continues to be deeply transformed into a replenishment source of deep confined water. The infiltration of pores and fissure water in the loess layer can become a supply water source for the fissure water of the underlying bedrock. The recharge of groundwater can be expressed by the infiltration coefficient [7]. In the loess hilly and gully area to the north of Yan'an, the ground is cut and broken beams and valleys are developed, steep slopes are deep, precipitation is concentrated and heavy rains, soil erosion is serious, and the infiltration coefficient is only 0.03 to 0.04; the Ziwuling and Huanglong mountainous areas to the south of Yan'an, vegetation Better, the evaporation is strong, and the infiltration coefficient is 0.05.

3.2 Types of groundwater

3.2.1 Pore fissure diving

Pore and fissure water is widely distributed in the loose overburden of the surface. Due to the difference in topography and composition, the phreatic reserve varies greatly. Loess hilly and gully area, ground cutting. The gully longitudinal model, the groundwater supply and storage conditions are poor, the water volume is extremely weak, only sporadic water is contained, and the spring flow rate is less than 0.5 $t \cdot h^{-1}$. The original loess area of Yan'an has a large thickness of loess. The inherent pores, cracks and pores of the loess are the water-conducting space of the loess, and there are relatively impervious layers in the lower part. Therefore, the original loess area of Yan'an generally contains more groundwater. The water richness of groundwater in the original area varies greatly with the size of the original area and the width of the original surface, and there is usually a distribution law that gradually increases from the original center to the periphery.

3.2.2 Pressurized water

There is a distribution of confined water below the loess layer, and the depth of the confined water head is generally 10 m to more than 100 meters, and some of it flows freely from the surface in the valley, and the spray height is more than 10 m. The Mesozoic is dominated by sandstone and mudstone. The medium-fine sandstone of the Yan'an Formation is thick and loose in structure. At structural fractures, it is often a good water storage layer with abundant groundwater. The spring water flow is generally 0.5~2.5 $t \cdot h^{-1}$, and the water output of a single well is 100 t/d.

3.2.3 Karst water

Karst water is mainly distributed in the low hills and hills in the southern part of the Loess Plateau. The Sinian and Ordovician thick massive limestones and the coal-bearing classic rocks of the Limestone intercalated by the Carboniferous Permian are found in fractures and karst areas. Karst water is concentrated in the deep, and the groundwater level is very deep, up to 200-500 m. The spring water flow is generally 5-50 t/h, and the larger one can reach 3200 $t \cdot h^{-1}$.

3.3 Groundwater resources

Groundwater in the Loess Plateau is Quaternary pore water, buried in Quaternary aeolian, alluvial loess, alluvial sand and gravel. The phreatic water is mainly supplied by atmospheric precipitation. There are local rich water sections at the confluence of large rivers and roads such as Ergou, which can replenish groundwater, which is of great open source value. The daily open source can reach 13,800 m^3, and the total annual open source is 5.051 million m^3. According to conditions such as topography, landform, geological environment, and depth of groundwater burial, groundwater resources in this area can be divided into three types of groundwater in loess plateau area, loess ridge area, and valley terrace area.

The thickness of the aquifer in the valley terraces is generally less than 10 m, the water level is several meters deep, the water output of a single well is generally 20 to 100 t/d, and the unit water inflow is generally 0.1 to $0.5 \cdot (h \cdot m)^{-1}$, which is a weak water cut. In the Jiandi zone, the aquifer thickness is 10-40 m, the water level buried depth is several meters to more than 20 meters, the water output of a single well is 50-200 t/d, and the unit water inflow is generally 0.5-3 $t \cdot (h \cdot m)^{-1}$, which is medium rich water. According to water samples taken from Nanniwan boreholes, the groundwater salinity is 0.866

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and 0.286 g·L^{-1}, and the irrigation coefficients are 20.6 and 20.5, respectively. The water quality is suitable for farmland irrigation. According to field surveys, the depth of groundwater in the Nanniwan area is generally 1~5 m, and the water output of a single well is 25 m^{3}·h^{-1}; the depth of groundwater in the pine forest area is generally 3 to 15 m, and the water output of a single well is 22 m^{3}·h^{-1}.

4. Soil water resources

4.1 Characteristics of soil water resources

Water resources in the hilly and gully regions of the Loess Plateau are inherently insufficient and unevenly distributed. Shallow groundwater is generally buried at a depth of 50-200 m, and there is a deep aeration zone between the water supply layer of the near-surface soil, and it is difficult for plants to use it. The loess layer is deep and loose, with good water holding capacity, and the 2 m deep soil layer can store annual precipitation. Therefore, as a precious resource, soil moisture is of great significance to dry farming and vegetation growth in this area [8]. The groundwater in the Loess Plateau is deeply buried, and precipitation is usually all stored in the soil to form soil water, and this deep soil storage is used to regulate the physiological water demand process of plants, which is called the soil reservoir effect. As a reservoir, soil has two conditions: storage capacity and water source. However, because the soil is a porous body with uneven distribution of internal pores, the ineffective water storage in the soil reservoir accounts for 33-50% of the total storage capacity. Among the effective water reserves, the actual amount that can be used by plants also varies greatly depending on the plant species, the pros and cons of growth, the rationality of the farming system, and the actual water storage capacity. Although the water holding capacity of the soil in this area is relatively high, due to weather and soil conditions, in fact, it is often in a state of low water storage capacity, and the water use efficiency is not high. This is especially obvious in farmland, where the soil water potential that can be used by ground crops is maintained to varying degrees in various places. In addition, the topography of the Loess Plateau is changeable and has good water conductivity. The soil moisture is affected by the slope direction and energy budget. The difference in soil moisture storage in different terrain parts is very obvious. Generally, the moisture conditions of the top and the upper part of the slope are poor. , Slope foot and ditch bottom are better. The representative soil in the region-loessial soil, due to its uniform texture, well-developed capillary pores, low suction and high water content, it has strong evaporation capacity, and the upward movement and evaporation of water is active. Therefore, the stable soil moisture level is very low, and although the soil reservoir plays a role in regulating the water demand of plants, the deep soil water storage is often in a state of deficit, and the regulation of the physiological water demand of plants is limited.

4.2 Soil water resources dynamics

The water balance can be simply expressed as: the amount of income-the amount of expenditure the amount of balance. Under non-irrigation conditions, income items mainly refer to precipitation, groundwater replenishment, and condensation; expenditure items refer to evapotranspiration, canopy interception, water leakage, surface and underground runoff, etc. of plant communities; balance is mainly reflected in the amount of soil water storage Variety. When the soil water storage increases, the soil moisture is in a positive compensation state, and the soil moisture is supplemented and restored to a certain extent; the soil water storage remains unchanged, indicating that the soil moisture budget is balanced; when the soil water storage decreases, the soil moisture appears negative compensation, and at the same time Because the groundwater in Yan'an is deeply buried, it cannot replenish the water consumption of the upper soil. It can only be supplied by deep soil storage. As a result, the soil is dry and the soil is prone to dry layers, which affects and restricts the growth and development of plants.

Soil water storage is the source of continuous water supply from the soil to plants. Since the storage form and energy state of water in the soil are inseparable, different forms of water storage have different degrees of difficulty for crop utilization, that is to say, they are not equivalent. Generally speaking, the effective water capacity of the soil is decisive for the carrying capacity of vegetation.

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Therefore, it is necessary to study the field water holding capacity and withering humidity of the Loess Plateau. Water content, withering humidity in Yan'an area is almost completely determined by soil texture), soil bulk density and other soil moisture constants and physical parameters. The soil texture of the Loess Plateau is basically light soil, the soil bulk density is 1.25 g/cm3, the field water holding capacity is 19.3%, the wither coefficient is 5%, and the available water is 14.3%.

4.3 Estimation of precipitation and annual soil water volume

Water resources in the hilly and gully areas of the Loess Plateau are congenital insufficiency and unevenly distributed. The depth of groundwater is generally 50~200 m, causing soil moisture to be often in a state of deficit. Precipitation is the only supplementary source of soil moisture in this area. However, due to the special hydrological characteristics of the Loess Plateau, the depth of precipitation infiltration is generally within 2.0 m, and there is little deep leakage. Generally speaking, soil water resources are consumed by plant transpiration and soil evaporation, and restored by precipitation infiltration. In theory, the water volume maintains a dynamic balance. Therefore, precipitation restricts the annual soil water turnover in the Loess Plateau, and the soil provides most of the precipitation for plant growth. Therefore, precipitation is closely related to vegetation productivity. Because of the zonal and non-zonal distribution of precipitation, the zonal and non-zonal pattern of vegetation in the Loess Plateau has been established. Internal balance equation of soil water resources:

The amount of soil water replenishment is divided into total replenishment (W_s), natural replenishment (W_{sn}) and effective natural replenishment (W_{se}).

$$Ws = P - Rs - Pi + Eg + IR - PR \tag{1}$$

$$Wse = P - Rs - Pi + Eg \tag{2}$$

$$Wsn = P \tag{3}$$

P is annual rainfall, R_s is surface runoff, P_i vegetation interception and surface evaporation, E_g is diving rise, IR is irrigation, PR is replenishment of groundwater.

For grassland, Eg, IR, and PR can be ignored due to the deep soil layer and generally no irrigation and groundwater connection. So there can be:

$$W_s = W_{se} \tag{4}$$

For bare land:

$$Wse = P - Rs \tag{5}$$

Because interception is not all ineffective, especially in arid and semi-arid areas, it is almost all effective for dwarf vegetation, and 40-60% can be used as effective forest water supply to affect vegetation growth. The purpose of our research on soil water resources It is to study the amount of water consumed by plants and establish simulation models for water consumption and productivity. Therefore, when studying the soil water supply capacity—that is, the annual water supply capacity (W_{se}) of the soil to the plants, the interception part can be included in the soil water supply. Therefore, the above formula can be rewritten as

$$Ws' = Wsn' = Wse' = P - Rs + a \times Pi \tag{6}$$

A is the percentage of the effective part of forest and grass vegetation, 1.0 for grassland, 0.6 for forest and grassland, and 0.4 for forest. For bare ground, since there is no interception, a is 1.0.

5. Summary

In the Loess Plateau, the main factor affecting soil moisture properties is soil texture. Due to the aeolian characteristics of loess, its particle composition has obvious regional differentiation characteristics, so that the physical characteristics of soil moisture and soil moisture status show obvious regional differentiation characteristics, forming a unique soil moisture background. On the whole, the soil moisture status of the Loess Plateau is relatively dry, with low water content, and high water content in some watersheds. Precipitation is the basic source of soil moisture in this area. Due to the lack of total precipitation in this area, the source of soil water replenishment is insufficient, especially due to the impact of heavy rains, precipitation seasons and uneven inter-annual distribution, resulting in no water to replenish in dry years and soil erosion in wet years. Thus making it difficult to alleviate the drought.

The upward movement and evaporation of soil moisture are active. The most representative and most widely distributed soil type in the Loess Plateau is loessial soil. It has uniform texture; well-developed capillary pores, low suction and high water content, and have strong evaporation capacity. The texture of loess soil is generally sandy soil or light soil, and its texture becomes lighter toward the northwest, and its water holding capacity is weak. The soil moisture status of different topographical parts is obviously different. The soil evaporation and infiltration performance of the Loess Plateau is good, and it is very sensitive to the influence of heat, wind and other factors. At the same time, the topography of the area changes greatly, so it is very significantly affected by the aspect, slope and position of the slope. As a result, the soil in different topographical parts there is a very significant difference in moisture status. Generally, the soil moisture on shady slopes is better than that on sunny slopes, and the ditch foot is larger than the ditch slope, the slope and the top, and the top is the worst; the ditch and slope are controlled by the slope. The slope is the greater, soil moisture is the worse.

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