Study on the Water-Saving Irrigation Technology in the Slope Vegetation Restoration of the Mining Area Dump

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Abstract: With the development and utilization of coal resources, the surface vegetation is destroyed and soil erosion is more and more serious. Open-pit coal mine on typical steppe causes very strong artificial erosion landform remodeling, especially mining dump slope, needing to take reasonable measures for its vegetation restoration. Irrigation is one of main means to ensure the vegetation growth on anthropogenic landforms, which can make up for a lack of atmospheric precipitation and coordinated uneven distribution of water space and enhance its competitiveness. The research focuses on different irrigation methods in the vegetation restoration of coal mine dump slope, which is slight spraying, drip irrigation and micro irrigation, where water shortages, lack of regular power and slope topography. Suitable irrigation methods are determined better to vegetation restoration and reconstruction through studying the characteristics of three irrigation methods, soil moisture content, vegetation coverage and biomass on the ground. Appropriate way of irrigation not only make more rational use of limited water resources, but also promote plant growth and protect coal mine slope, effectively reduce soil erosion.

Keywords: Hilly grassland areas, small watershed, soil and water loss, comprehensive control, model.

1. INTRODUCTION

Semi-arid grassland belongs to China's ecological fragile zone, with characteristics of dry climate, water resources shortage, loose soil structure, low vegetation coverage and strong wind erosion [1-2]. With further promote of the national energy base construction, large-scale coal mine development and construction grow with each passing day [3]. It brings a greater impact on the ecological environment and the production and life of the residents. A large number of open-pit mine drainage water causes different degrees decline of groundwater [4-5]. Water resources waste not only makes the drinking water difficulties but also aggravates the ecological degradation of the surrounding prairie. Therefore, the restoration and reconstruction of mining area, especially the artificial plastic slope vegetation becomes an important content. Irrigation is one of the main means to ensure development of water needed by the growth of vegetation. It can compensate for the lack of water vapor and the non-uniform of precipitation spatial distribution. It can also conducive to the normal growth of plants and enhance their competitiveness. For the artificial plastic special surface topography of the slope, due to the soil matrix or thin water Co., the traditional irrigation method can easily generate runoff or deep percolation, cause the waste of water resources, and it is even easy to form the phenomenon of slumping [6]. Thus, we must choose right irrigation mode. Thus it can be seen, carrying out scientific research in this area can provide technical support and scientific basis for the repair of China's large coal mine development zone of fragile ecological system. It has important scientific significance for regional ecological security [7].

2. GENERAL SITUATIONS OF STUDY REGION

The study area is located in Xilinhaote City of the Inner Mongolia Autonomous Region. The regional topography has obvious zonality. The terrain gradually decreases from the southeast to the northwest. The relative elevation is more than 600m, the altitude is from 902 to 1510m and the geographical coordinates is east longitude 115°32′41″-117°12′11″and north latitude 43°26′07″-44°39′05″. This area belongs to the semi-arid continental climate. The average annual precipitation is 350mm, it concentrates from June to August and it accounts for more than 70% of the annual precipitation. Its annual average evaporation is 1700 mm, and it is about 6 times of precipitation. It is windy in spring and the average wind speed is 3.5 m/s. The average annual gale day is 70 days and the instantaneous maximum wind speed of 36.60 m/s. Its soil is typical Kastanozems and dark Kastanozems, with organic matter content from 20 to 36.8 g/kg and the pH value is about 8. The soil nutrient status is lack of phosphorus, potassium rich and nitrogen medium. We select open-pit mine dumping site as test area in the northeast of Xilinhaote city. It is stepped landform of platform and slope distribution and its relative height is 100m, the length of each step slope is about 20m. The surface of slope is covered with soil and the slope angle is from

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32 degree to 34 degree. The soil bulk density in the test area is 1.36 g/cm^3 and the soil particle size is mainly greater than 0.05 mm sand [8].

3. RESEARCH METHODS AND TEST DESIGN

3.1. Selection of Irrigation Methods

The test area is located in semi-arid steppe region, water resource is very scarce, therefore, according to the test area layout and slope actual situation, we select three forms such as micro spray irrigation, drip irrigation and micro-moist irrigation [9-10].

3.2. Irrigation System Layout

3.2.1. Water Source Project and Pipeline Layout

The water storage tank is used as the irrigation water source, the volume was 15 m^3, and it is placed in the upper platform of the test plot. In order to prevent the emitter from clogging, the two stage filtration system with mesh type and centrifugal type is designed. The filter is connected with the water tank through the gate valve. DN63PE pipe is used in main pipeline of water conveyance, and DN25PE pipe is used in water distribution pipeline of each test plot. In order to accurately measure irrigation water, each test area is equipped with water meter and it is connected with the main pipe through the variable diameter three-way switch [11].

3.2.2. Power System

In the micro spray irrigation test plots, the irrigation area is irrigated by solar water lifting system. In the drip irrigation and micro-moist irrigation test plots, the irrigation area is irrigated by self- pressure. In order to ensure the uniformity of irrigation area, two pressure regulating gate valves are arranged in the middle and lower parts of the water distribution pipe respectively [12]. The micro nozzle is arranged in equilateral triangle, the distance between the Micro spray irrigation nozzles is 1m and the distance between the nozzles is 1m. The distance between drip irrigation pipes is 0.5 m and the distance between emitters is 0.3 m, and the dripper discharge is 1 L/h. The upper micro-moist tube spacing is 30 cm, the distance of middle and lower parts is 50cm and the micro-moist tube flow is 1000ml/m.

3.3. Layout of Test Plots

The test plots are established on the dump slope after covering soil for more than 3 years [13]. Each test plot area is 100 m^2 with the slope length 20 m and width 5 m. There is 0.5 m width brick trail between test plots which is convenient for observation and sampling. Each test plot is enclosed on both sides and top with color steel plate and steel frame. We layout a total of 10 test plots, including 9 test plots with irrigation measures, 1test plot without irrigation measures as a control area. Each plot is an independent one and there is water retaining ridge on the top of slope (platform edge) preventing soil and water loss. At the same time, in order to facilitate the study of soil erosion on the slope, the edge guide groove is provided in each test area. The lower retaining of the diversion trench wall is using the concrete pouring and it is buried underground part 30 cm and on the part of 40 cm. By

Table 1: Measures Configuration and Irrigation Methods in each Test Plot

No.	Gradient	Treatment Measures and Irrigation Methods
1	33	bare land (control)
2	33	Ecological bags arranged in one shape, the distance is 1 m and the grass is planted. Irrigation method is ground drip irrigation
3	33	Ecological bags shaped layout, their horizontal spacing is 0.5 m and vertical spacing is 1m, grass and shrub combination. Irrigation method is ground drip irrigation
4	33	Pasture mixed sowing. Irrigation method is micro-moist irrigation
5	33	It is laid by the planting belts all. Irrigation method is micro-moist irrigation
6	33	Ecological bags arranged in one shape, the distance is 1 m and the grass is planted. Irrigation methods are ground drip irrigation, micro-moist irrigation and micro spray irrigation.
7	33	Tamarix chinensis sand barrier + grass mixtures: the sand barrier is 1 m x 1 m grid, the permeability is 25%, and the grass mixed sowing. Irrigation method is ground drip irrigation
8	33	Ecological bags shaped layout, their horizontal spacing is 0.5 m and vertical spacing is 1m, grass and shrub combination. Irrigation method is ground drip irrigation
9	33	Pasture mixed sowing. Irrigation method is micro-moist irrigation
10	33	It is laid by the planting belts all. Irrigation method is micro-moist irrigation

using a guide groove to guide hole flow together in the middle of the wall and we design runoff collection pool at the bottom of the runoff in the District. The runoff pool is calculated according to the data of the study area of the nearly 30 rainfalls, the maximum rainfall 78.9 mm/d and runoff coefficient 0.65 using the maximum value of the bare soil. Finally, we determine that the runoff pool length × width× height =3.0 m×1.5 m×1.8 m, runoff pool for brick and concrete structure, with waterproof adhesive plaster. The sediments carried in the runoff are all collected into pool in the process of rainfall. Configuration of irrigation methods and measures in each test plot is shown in Table**1**.

4. RESULTS AND DISCUSSION

4.1. Vegetation Water Requirement Characteristics of Different Slope

Water requirement of vegetation is affected by many factors [14]. Because of the climate, soil, cultivation measures and hydrogeological condition, the water demand is different in different years. But the water demand in every growth period, evaporation between plants, leaf transpiration and the water consumption modulus all has the certain regularity, reflecting the characteristics of the physiological water requirement and ecological water requirement requested in grass growth period. Using the soil water balance method to calculate the water law and water demand of three kinds of optimizing grasses and provide a scientific basis for irrigation system and irrigation management decision. The project area belongs to the middle temperate arid and semi-arid climate zones, with low rainfall, shorter frost-free period, combined with the mine slope to restore vegetation as the main objective conditions, rather than high, therefore, we make a complete growth period in the process of test as a research cycle. The actual water consumption and water requirement rule of the three kinds of forage grass under the condition of non-sufficient irrigation are shown in Table **2**. Found in the testing process, under the condition of rainfall and irrigation, variations in soil moisture change rate on the slope is obviously greater than that of middle slope and it is greater than that on the low slope. At the same time, due to the temperature, soil moisture and its physical properties, the intensity of forage grass in water changes greatly along with the development process. Three kinds of forage grass of water demand intensity is more obvious along with the change of temperature, the change process of the temperature is low, high, low, the water demand intensity is also low, high and low changing process.

Table 2: The Water Consumption of Different Vegetation Growth Period

Vegetation	Growth Period	Days	Daily Water consumptions Rate(mm)	Stage Water Consumption Intensity(mm)	Water Consumption Intensity During Growth Period(mm)
Alfalfa	seedling-stage	16	2.0	32.0	357.2
	lichen-branch	30	3.4	102	
	budding	40	4.5	180	
	flowering - pod	24	1.8	43.2	
Astragalus Adsurgens	seedling-stage	15	1.8	27.0	358.3
	lichen-branch	31	3.5	108.5	
	budding	38	4.6	174.8	
	flowering - pod	24	2.0	48.0	
Elymus Dahuricus	seedling-stage	13	2.2	28.6	371.0
	lichen-branch	34	3.6	122.4	
	budding	40	4.7	188.0	
	flowering - pod	20	1.6	32.0	

4.2. Adaptability Evaluation

Under the specific conditions of irrigation water source, plastic slope, soil and other conditions, 3irrigation methods are analyzed and evaluated through experimental observation, and their advantages and disadvantages are compared, including water requirements, power, energy consumption, investment costs, etc., as shown in Table **3**. As can be seen from the table, the three irrigation methods have their own advantages and disadvantages, and the overall evaluation of micro-moist irrigation is the best, followed by drip irrigation and micro spray.

4.3. Benefit Analysis and Evaluation

The purpose of artificial plastic landform irrigation is to restore vegetation on the slope surface [15]. Therefore, the selection of vegetation coverage, vegetation height and vegetation aboveground biomass can reflect the irrigation benefit in general. The vegetation coverage and vegetation height are positively correlated with the above ground biomass of vegetation, and the benefit is analyzed and evaluated only by the aboveground biomass of vegetation.

It can be seen from table **4** that the aboveground biomass of the three irrigation methods is obviously different, and that the No. 7 plot is the highest, except for the control area, the 4 district (micro-moist irrigation) is the lowest. On the whole, the benefits of drip irrigation are better than that of micro irrigation (the aboveground biomass is not big, but the irrigation water productivity is lower than drip irrigation), and the micro-moist irrigation is the worst.

4.4. Irrigation Regulation Technology

4.4.1. Irrigation System

For irrigation schedule of forage growing period, water balance equation can be set up for planned wet layer.

Table 3: Performance Comparison of Three Irrigation Methods

Item	Micro-moist irrigation	Micro spray irrigation	Ground drip irrigation
Water source	No needing complex filtration system, it can be directly irrigated by simple filter screen.	The filtration system is necessary for purifying the suspended impurities in water.	A complex filtration system is needed to purify suspended impurities in water by various means.
The power	Self- pressure can satisfy	Need power to drive equipment	Self-pressure can satisfy
Energy consumption	Minimum	Highest	Highest
Blocking condition	Not easy to jam	Easy to jam	Easy to jam
Application level	Application is simple, without professional knowledge	Application is complex, needing professional training	Application is complex, needing professional training
Construction level	The construction is simple and no professional construction team is needed	Needing professional construction team and professional commissioning	Needing professional construction team and professional commissioning
Water saving	The most water-saving, saving more than 50% of drip irrigation	More water-saving,40% to 60% less than traditional irrigation	More than 70% water saving than traditional irrigation
Comprehensive investment cost	Minimum	Highest	Higher

Table 4: Vegetation Aboveground Biomass in Different Plots in Different Months

Month	Aboveground Biomass of Vegetation in Different Test Plots(g/m^2)									
	1	2	3	4	5	6	7	8	9	10
5	26.0	61.4	62.7	27.4	58.0	43.4	68.0	65.4	28.7	66.0
6	34.7	82.7	90.7	38.7	90.1	65.4	104.1	97.4	43.4	99.4
7	42.0	102.7	103.4	57.4	112.1	97.4	140.7	125.4	60.7	132.1
8	54.0	138.7	155.4	76.7	157.4	125.4	172.1	158.8	82.7	170.1
9	58.7	157.4	160.8	70.7	172.1	128.1	192.1	179.4	80.0	187.4

Table 6: Slope Drip Irrigation Schedule of Alfalfa

Month	5	6	7	8	9	Total
Rainfall(mm)	25.0	44.7	48.0	45.0	41.0	
Water requirement(mm)(mm)	32.0	104.0	135.0	80.6	5.6	357.2
Irrigation amount(mm)	0.0	72.0	72.0	48.0	0	192.0
Irrigation times (times)	0	3	3	2	0	8
Irrigation quota(mm)	192.0					

Table 7: Slope Drip Irrigation Schedule of Astragalus Adsurgens

Month	5	6	7	8	9	Total
Rainfall (mm)	25.0	44.7	48.0	45.0	41.0	
Water requirement (mm)(mm)	23.4	98.1	133.6	93.2	10.0	358.3
Irrigation amount (mm)	0	48.0	72.0	48.0	0	168.0
Irrigation times (times)	0	2	3	2	0	7
Irrigation quota (mm)	168.0					

W_t-W_0=W_T+P_0+K+M-E (1)

In the formula (1), W_t-W_0—water storage in the wetted layer of the soil plan at the beginning of the period and at any time of T. W_T—the amount of water added due to the increase of planned wetting layer. K: groundwater recharge during the period of T, the groundwater recharge in this project is neglected. M—irrigation water quantity in t. E—crop water requirement within T, E=et, e for water demand intensity. P_0— the effective rainfall during growth period can be calculated according to the formula P_0=αP, α is the rainfall coefficient, as shown in Table **5**.

Table 5: Reference Table of Rainfall Coefficient

Daily rainfall (mm)	α
<5	0
5 ~ 30	1.0
>30	0.8

According to above calculation, in the dry year (90%) three kinds of forage slope irrigation water-saving irrigation system is shown in Table **6**, **7** and **8**.

4.4.2. Irrigation Regulation Technology

Irrigation is one of the main means to ensure the growth and development of vegetation on the slope [16]. It can make up for the lack of atmospheric precipitation and uneven distribution of water vapor in the space, which is conducive to the normal growth of plants and enhance their competitiveness. For the slope vegetation, the hot summer without rain is the biggest test. Because the soil layer or the substrate is thin and the water storage is limited, irrigation is the primary work for daily maintenance.

(1) The irrigation mode should choose micro irrigation method. Micro irrigation is a modern fine and efficient water-saving irrigation technology, with the characteristics of water saving, energy saving, adaptability, irrigation and fertilizer. Irrigation efficiency is higher, generally it can reach more than 90%. The flow of micro irrigation emitters is not too large, which reduces the size of droplets and prevents the formation of overland runoff during irrigation.

(2) Irrigation time: according to the slope vegetation and weather conditions, we should choose the best time of the day watering. Morning and evening watering, evaporation is the smallest, while watering at noon, evaporation is large, but also easy to cause vegetation leaves burns. At night watering, the slope vegetation will be wet overnight, leaf and stem wetting time is too long, the pathogen is easy to infect, causing disease, and spread at a faster speed. So the best

Table 8: Slope Drip Irrigation Schedule of Elymus Dahuricus

Month	5	6	7	8	9	Total
Rainfall (mm)	25.0	44.7	48.0	45.0	41.0	
Water requirement (mm)(mm)	46.6	110.2	144.5	69.7	0	371.0
Irrigation amount (mm) [1] Suying Li, Peter H, Verburg, Shihai Lv, Jingle Wu, *et al*. Spatial analysis of the driving factors of grassland degradation under conditions of climate change and intensive use in Inner Mongolia, China. Regional Environmental Change 2012; 12(3): 461-474. [2] Shidong Li, Xiangyang Hou, Ping Li, Yating Dai, Xiliang Li, *et al*. Ecological Protection and Establishment Projects. Contemporary Ecology Research in China 2015; 375-408. [3] Cui Guo-wen. Characteristics of the Inner Mongolia Autonomous Region coal industrialization process and suggestions for the development of "12th Five-Year". China Coal 2010; 36(9): 5-8. [4] Hang Chen, Zhongyi Liu, Zailin Huo, Zhongyi Qu, Yuhong Xia, *et al*. Impacts of agricultural water saving practice on regional groundwater and water consumption in an arid region with shallow groundwater. Environmental Earth Sciences 2016; 75: 1204. [5] Lina Mi, Honglang Xiao, Jianming Zhang, Zhenliang Yin and Yongping Shen. Evolution of the groundwater system under the impacts of human activities in middle reaches of Heihe River Basin (Northwest China) from 1985 to 2013. Hydrogeology Journal 2016; 24(4): 971-986. [6] Francesco M, Antonio G and Gianluca G. Effect of water-saving irrigation regime on whole-plant yield and nutritive value of maize hybrids. J Sci Food Agric 2013; 93: 3040-3045. [7] Xianqiang Tang, Qingyun Li, Min Wu, Wenjian Tang, Feng Jin, *et al*. Ecological Environment Protection in Chinese Rural Hydropower Development Practices: A Review. Wate, Air, & Soil Pollution 2012; 223(6): 3033-3048. [8] Lin-hua Sun and He-rong Gui. Establishment of water source discrimination model in coal mine by using hydrogeochemistry and statistical analysis: a case study from Renlou Coal Mine in northern Anhui Province, China. Journal of Coal Science and Engineering (China) 2012; 18(4): 385-389. [9] Quinones-Bolanos E, Zhou H and Soundararajan R. Water and solute transport in pervaporation hydrophilic membranes to reclaim contaminated water for micro-irrigation. Journal of Membrane Science 2005; 252: 19-28 . [10] Jiang Jun-yan and Wang You-ke. Effect of different treatment of drip irrigation on growth of potato. Agricultural Research in the Arid Area 2008; 26(2): 121-128. [11] Lu Li-hua, Hu Mao-kun and Li Yan. Effect of irrigation treatment on water use efficiency and yield of different wheat cultivars. Journal of Triticeae Crops 2007; 27(1): 88-92. [12] Zhang Jun, Niu Wen-quan and Zhang Lin-lin. Experimental study on wetting source characteristics of micro irrigation line source infiltration. Soil and Water Conservation Science of China 2012; 10(6): 32-38. [13] Ma Zhan-dong. Experimental study on regulation of surface runoff by several soil and water conservation measures. Soil and Water Conservation in Shanxi 2008; (1): 16-18. [14] Lijuan Li, Jiuyi Li, Liqiao Liang and Yumei Liu. Method for calculating ecological water storage and ecological water requirement of marsh. Journal of Geographical Sciences 2009; 19(4): 427-436. [15] Liu Wei-min and Xing Wan-yu. Study on soil removal technology of Shengli east two open-pit mine. Opencast mining technology 2009; (4): 14-16. [16] Pascual Romero and Adrián Martinez-Cutillas. The effects of partial root-zone irrigation and regulated deficit irrigation on the vegetative and reproductive development of field-grown Monastrell grapevines. Irrigation Science 2012; 30(5): 377-396.	24	72	96	24	0	216.0
Irrigation times (times)	1	3	4	1	0	9
Irrigation quota (mm)	216.0					

watering time should be in the morning, in addition to meet the slope vegetation needs of water every day, until the evening leaves dried, to prevent the breeding of pathogens.

(3) Irrigation water quantity: each irrigation amount of slope vegetation should refer to the established irrigation system. In hot summer, if the irrigation water is too small, soil moisture is beneficial to weeds, but unfavorable to the slope

vegetation. If the soil layer is thicker than 15cm, it should be at least 15cm above the wetted depth.

(4) Irrigation method: the study shows that with the increasing of the slope, soil or substrate thickness and water holding capacity decrease gradually, we should get in the high slope begin to move to the lower slope, increase the height of the watering time, it can improve the soil water content of slope. When the conditions permit, gap irrigation should be used, and the amount of irrigation should be divided according to the proportion of 5:3:2 on the slope, middle slope and lower slope.

CONCLUSION

Whether it is from the slope soil water changes or the biomass aboveground, three irrigation methods of large opencast coal mine in arid and semi-arid steppe vegetation landscape artificial plastic slope restoration in the ground, drip irrigation is irrigation method suitable for the construction, low investment cost, the operation is relatively simple and obvious water-saving effect. However, the accuracy of the test results is affected to some extent due to the constraints of water source conditions, repeated number of test plots, and measures allocation of various residential areas. From the qualitative point of view, micro irrigation is one of the best irrigation methods in the restoration of artificial plastic landform slope in large opencast coal mine in arid and semi-arid grassland area with water shortage. But according to the test results, the effect of micro-moist irrigation is poor. Mainly due to the following two reasons, firstly the flow of micro moistening tube selection is too small, it can not meet the water requirement of vegetation and evaporation. Secondly, micro moistening tube should have the appropriate working pressure head (8 < m), according to the test, in the limiting case, the lower part of the slope soil moisture was significantly higher than in the middle and upper slope. But because of the micro moistening tube bearing capacity, it affects the micro-moist irrigation effect to a certain extent.

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