Application Effect's Research of Vetiver Eco Blanket in Pubugou Reservoir Fluctuating Zone

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ABSTRACT: To solve the ecological disasters in Pubugou Reservoir Fluctuating Zone, ecological blanket governance model is proposed in this paper, which may provide good early environment for plants' survival in fluctuation zone, and then play the function of greening and sustainable development to ensure the slopes' stability. Meanwhile, based on the result of vetiver ecological blanket in Hanyuan experimental zone, we find that three kinds of typical Fluctuating Zone slope's greening effect is good, which includes the dirt piling up slope, the whole lump of rock slope and the gravel piling up slope, and it gets an average coverage of 90.3 % as well as good strength. Due to the different geological conditions, the ecological blankets' governance effect differs from slope to slope. Using analytic hierarchy process to calculate the weight, we get the dirt piling up slope, the whole lump of rock slope and the gravel piling up slope's weights are 0.41, 0.17, 0.42, respectively, namely, the dirt piling up slope and the gravel piling up slope have good results overall, followed by the whole lump of rock slope.

Keywords: ecological blanket; fluctuating zone; slope; Vetiver; Pubugou reservoir

1 INTRODUCTION

In recent years, the ecological blanket slope protection technique has attracted increasingly attention with its good economic and social benefits [1]. Ecological blanket slope protection developed abroad over the past decade is a new composite slope plant protection measure collecting slope reinforcement and plant protection, which is a three-dimensional composite grass blanket structure through a special process plant fiber layer and grasses, and other nutrient soil mixture are polymerized to form [2], and is a new slope greening prevention technique providing a protective layer of soil erosion control and plant growth matrix, nutrients and moisture [3]. It not only can overcome the problems of traditional way that the production of turf volumes will damage farmland and regeneration vigor of turf volume will decrease after storage, but also can be produced the whole year and without taking up land [4]. Vetiver is a perennial with specially developed root system, which has strong soil and water holding capacity and is widely used in road, river bank slope protection and bioremediation project of heavy metals tailings, whose developed roots and the soil among the roots together form complex interaction system which can significantly increase soil shear strength [6,7]. According to the survey on the Mississippi by AIllinois Energy Professionals Association (ILEP) it is found that the using of land could cause the loss of 72 percent non-organic nitrogen, 56 percent phosphorus and 57 percent of the sediment. Deanna thought that we should consider protection and management of hydro-fluctuation belt before using [8].

Because reservoir hydro-fluctuation belt existing severe soil erosion, frequent geological disasters and damage to biodiversity and other issues, ecological environment restoration and reconstruction is urgent.

In this paper, according to experimental study of vetiver ecological blanket in Hanyuan experimental plot a comprehensive analysis of its height, coverage, color, the largest leaf width, population density and other growth indicators is made to evaluate practical application of ecological blanket. Simultaneously, this paper uses AHP to build judgment matrix and calculate the weight and by contrasting the treatment effect of three typical slopes on Pubugou reservoir hydro-fluctuation belt, and this paper can explore and verify the vetiver ecological blanket ecological restoration ability to hydro-fluctuation belt in order to provide a scientific basis for our reservoir hydro-fluctuation belt governance and promotion and application ecological grass blanket.

2 GENERAL SITUATION OF TEST AREA

Test area is located in the town of Fuquan, Hanyuan County Ya'an City (102°39'E~29°21'N), which is a subtropical monsoon climate between the north temperate zone and monsoon zone with four distinct seasons, with an average elevation 850~900m, annual average temperature 17.9℃, frost-free period 300d, sunshine 1475.8h, annual accumulated temperature 5844.7℃, and the average annual rainfall of 741.8mm.

During the running of Pubugou hydropower station a 60m hydro-fluctuation belt is formed in Hanyuan

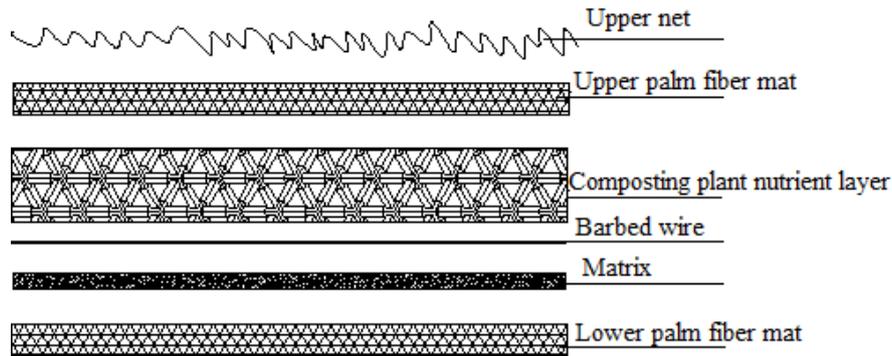* Corresponding author: nfq1965@163.com

Figure 1. Ecological blanket's structure

County reservoir area, which caused a reservoir bank pollution, geological disasters increasing, plant diversity and ecosystem damage and other issues, resulting in such as soil erosion, soil salinization, water pollution, pollutant precipitation and a series of serious harm. While the local ecosystem type diversity, complex geology and soil structure, harsh needs of ecological functions and other special conditions make it extremely difficult to be treated [8].

3 EXPERIMENTAL MATERIALS AND METHODS

3.1 *Experimental materials*

Vetiver (Vetiveria zizanioides), a perennial herb, grass family vetiver genus, almost can tolerate various heavy metals and agricultural chemicals with very rapid growth, which not only can grow in arid and semi-arid areas with annual rainfall only 200~300mm to survive, but also can grow normally in warm humid regions with rainfall 5000~6000mm [9]. Studies have shown that completely flooded vetiver can survive six months, and in the part of flooded conditions the net photosynthetic rate even better than the control group. Meanwhile, vetiver not only is little infected or spread of pests and diseases, but also has a strong ability to resist various disasters, and once planted successful, it will be able to survive for decades or even hundreds of years. The average value of tensile resistance or intensity of vetiver single root is 12.4N or 69.7MPa, and the root system deeply and widely distributed in the slope can greatly reduce the active earth pressure intensity on slope retaining wall (reducing the value of the total active earth pressure is greater than 15%) [11]. Furthermore, strong photosynthesis and rapidly growing of vetiver and absorption and transpiration of well-developed root system network can reduce water content and pore water pressure of the slope soil and enhance soil suction, thereby increasing the soil strength of the slope and enhancing the stability of the slope.

Vetiver, with flood, drought and disease resistance, rapid growth and an ideal mechanical effect of slope protection, is as a test material, which has strong economic environmental benefits applied in hydro-fluctuation belt.

3.2 *Ecological blanket structure of Vetiver*

Vetiver ecological blanket is made of polypropylene plastic mesh, upper fiber layer, layer of decomposed plant nutrition, barbed wire, soil layer and lower fiber layer, all of which quilt together to be regular hexagon. The structure is shown in Figure 1.

3.3 *Experimental method*

3.3.1 *Vetiver ecological blanket production*
First, we should clean up the site, and then clean up the turn tile of the lower palm fiber mat, soil, vetiver seeds, insurance agent, barbed wire, composting plant nutrition layer, upper palm fiber mat and upper reinforced polypropylene plastic mat, and finally use a nylon cord to link up layers together. Ecological blanket structure is shown in Figure 1.

3.3.2 *Experimental design*
In the test area we select three kinds of typical hydro-fluctuation belt slope as demonstration sites to govern using ecological blanket. Characteristics of three kinds of typical hydro-fluctuation belt slope are as follows:

Pilot 1: The whole lump of rock slope. Structural plane is huge, and slope is greater than 60 °. The rock mass has high integrity and weak weathering;

Pilot 2: Gravel accumulation slope. The content of gravel exceeds 70%. The soil is little between gravel, and the soil under gravel is thick with a slope of 30~45°.

Pilot 3: Soil accumulation slope. Soil is thick, with fluffy soil layer, unstable and prone to cause soil erosion.

According to the 2.2.1 process produce ecological

blanket. Pilot 1 uses a thick ecological blanket (5cm lower palm fiber mats, 2cm nutritious soil layer, 3cm composting plant nutrition layer, 0.5cm upper palm fiber mat). Pilot 2 and Pilot 3 use thin ecological blanket (2cm lower palm fiber mats, 2cm nutritious soil layer, 5cm composting plant nutrition layer, 0.5cm upper palm fiber mat).

3.3.3 *Analytic hierarchy process (AHP)*

The basic principle of AHP is to put study complex problems as a large system, through analysis of several systematic factors, the separation of the ordered hierarchy among the interrelated factors. Then the experts judge objectively each factor of each level and quantitatively present the corresponding importance, and establish a mathematical model to calculate the relative importance weight of all factors of each level and make the sort. Finally, according to ranking results, we conduct planning decisions and make selection of measures to solve problems. Experimental evaluation target u, there are i (i= 1,2,3, ..., n) affecting factors, and the importance weights of which are respectively (i = 1,2,3, ..., n), where,

$$\omega i > 0 \text{ and } \sum_{i=1}^{n} \omega i = 1 \qquad (1)$$

Namely,

$$u = \omega_1 p_1 + \omega_2 p_2 + \cdots \omega_n p_n = \sum_{i=1}^{n} \omega_i p_i \qquad (2)$$

Due to the influence of factors on the target u meaning the weight is inconsistent, we required need to construct the importance weights ratio of each factor on the target u (the relative importance) judgment matrix A, and the importance weights of each factor of target u can be calculated by solving the matrix eigenvalue, namely to obtain a normalized feature vector.

3.3.4 *Data analysis*

Using quadrat survey to investigate the status of the plant growth, each ecological blanket sets four 10 × 10cm2 plots, and we need to measure height, leaf width, density, coverage of herbs, sort the data and take the average. We use SPSS 21.0, Matlab 2012b to make statistical analysis of all data, and make comprehensive assessment greening effect of the ecological blanket on hydro-fluctuation belt, and use the Analytic Hierarchy Process (AHP) to compare treatment effect of ecological blanket on three typical kinds hydro-fluctuation belt slope.

4 RESULTS AND ANALYSIS

4.1 *Results and analysis of the Hanyuan experimental area*

Test time of Hanyuan experimental zone is from December 9, 2014 to February 7, 2015. The experimental data are shown in Table 1.

Note, NT means ecological blanket used at dirt pilling up slope, ZT means ecological blanket used at whole lump of rock slope and LS means ecological blanket used at gravel piling up slope.

Table 1 shows that at the early observation (0~9d), for three kinds of ecological blanket used at slope, there is no significant difference in color, average height, average leaf width, disease resistance. For density and coverage, ZT is obviously smaller than NT and LS, and the difference between NT and LS is very small. The strength of ZT reaches normal results at the first 9d, significantly better than the weaker strength of LS and NT. At the mid-observation (9 ~ 12d), for all the three slopes, the color of ecological blanket gradually deepened, resistance continued to improve, strength increased, the differences in color, disease resistance and strength of each other are increasingly obvious. At the end of observation (30~60d), the color and coverage are stabilized, and the difference among NT and ZT and LS is more significant. The average height and average width of the three are still in a growing state, with the most significant in ZT. All the density is still reducing, and differences between ZT and NT and LS become more apparent. The resistance and strength of the three in the growth stage achieve optimal state.

In the observation period of 60d, for the vegetation cover is very effective in reduction of soil and erosion runoff, mighty eco-blanket coverage can better get moisture and prevent slope erosion and soil erosion by rain, so the most important indicator of fluctuating zone management is the coverage. At the end of observing, eco-blanket coverage is up to 90.1% on average (minimum coverage of 75.1%), and the most important index in fluctuating zone management can meet the requirements of green-fluctuating. At the late observation, ecological blanket strength is good, with the average density of 0.82/cm^2, tending to be stabilized, which meets the general requirements of governance. In addition, resistance slope in three kinds of ecological blanket is good, and the color attains dark green, with an average width of up to 9.8mm; vetiver has a certain adjustment period after being transplanted to the environment, which shows the trend of first drop and then upward, and the final average height of three types of eco-blanket is 15.5cm. In summary, the effect of eco-blanket treatment to three kinds of fluctuating slope is good.

4.2 *Selection of the evaluation factors*

Analyzing the many lawn evaluation factors, combined with ecological management results of fluctuating requirement, it establishes the evaluation system of ecological blanket's governance drawdown slope (see Figure 2).

Table 1. The greening effect of ecological blanket in typical Fluctuating Zone slopes

| Type of slope	Index	0d	3d	6d	9d	12d	15d	20d	25d	30d	45d	60d
Dirt pilling up slope (NT)	Color	Pomona green	Light green	Yellow green	Pomona green	Medium green	Medium green	Medium green	Bottle green	Bottle green	Deep green	Deep green
	Density (cm^2)	4.1	4.1	4.3	4.5	5.4	4.5	4.4	2.7	2.4	1.8	0.9
	Average height (cm)	11.2	9.8	8.6	8.4	8.6	9.4	10.1	10.3	11.1	13.9	15.6
	Coverage (%)	71.3	66.8	53.1	52.4	67.5	79.6	84.2	88.3	93.3	96.7	97.1
	Resistance	Better	Better	General	Better	Better	Good	Good	Good	Good	Good	Good
	Intensity	Weak	Weak	Weak	Weak	General	General	Better	Better	Better	Good	Good
	Management Fee (yuan/m^{2}year)	9	9	9	9	9	9	9	9	9	9	9
	Average width (mm)	—	—	—	2.1	2.4	2.8	3.5	3.8	4.5	6.9	9.8
The whole lump of rock slope (ZT)	Color	Pomona green	Light green	Yellow green	Pomona green	Pomona green	Medium green	Medium green	Medium green	Medium green	Bottle green	Bottle green
	Density (cm^2)	4.1	3.7	3.6	4.1	4.3	3.5	3.1	2.1	1.5	0.5	0.46
	Average height (cm)	11.1	9.8	8.7	8.5	8.9	9.7	10.3	10.6	11.3	13.5	15.8
	Coverage (%)	51.3	46.8	33.1	35.4	49.5	59.7	64.2	68.3	70.3	74.7	75.1
	Resistance	Better	Better	General	Better	Good	Good	Good	Good	Good	Good	Good
	Intensity	Weak	Weak	Weak	General	General	Better	Better	Better	Good	Good	Good
	Management Fee (yuan/m^{2}year)	10	10	10	10	10	10	10	10	10	10	10
	Average width (mm)	—	—	—	2.2	2.6	2.9	3.7	4.1	4.8	7.1	10.4
Gravel pilling up slope (LS)	Color	Pomona green	Light green	Yellow green	Pomona green	Medium green	Medium green	Bottle green	Bottle green	Deep green	Deep green	Deep green
	Density (cm^2)	4.1	4.1	4.3	4.6	5.3	4.5	4.3	2.6	2.4	1.8	1.1
	Average height (cm)	11.1	9.7	8.6	8.3	8.4	9.1	9.7	9.9	10.7	12.9	15
	Coverage (%)	71.3	66.7	53.2	52.5	67.9	82.9	90.1	93.7	95.3	97.7	98.6
	Resistance	Better	Better	General	Better	Better	Better	Good	Good	Good	Good	Good
	Intensity	Weak	Weak	Weak	Weak	General	General	Better	Better	Better	Good	Good
	Management Fee (yuan/m^{2}year)	9	9	9	9	9	9	9	0	10	10	10
	Average width (mm)	—	—	—	2.1	2.2	2.5	3.2	3.5	4.3	6.8	9.2
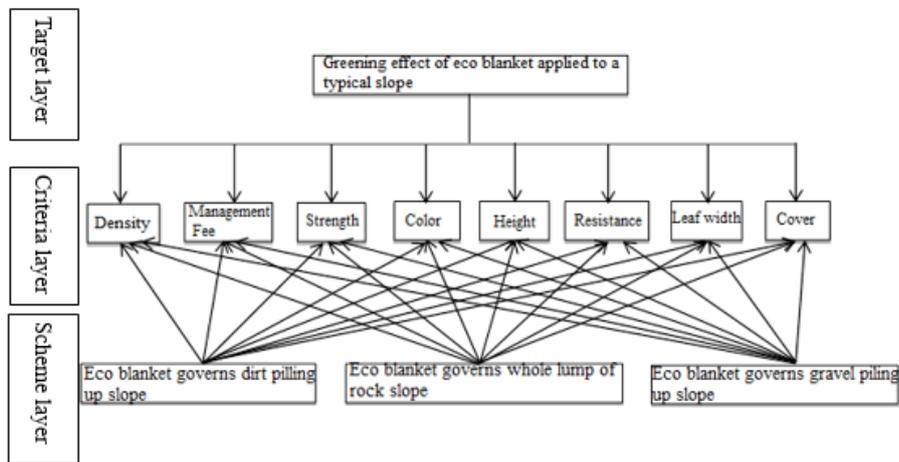
Figure 2. Ecological management's level analysis figure of fluctuating zone

4.3 Judgment matrix construction

According to experts' assignment and l~9 & reciprocal scaling method, we can construct judgment matrix. In order to determine a reasonable weight values, consistency test is required for judgment matrix. Judgment matrix A-B can be constructed as follows

$$A = \begin{pmatrix} 1 & 5 & 1 & 2 & 6 & 3 & 4 & 1/2 \\ 1/5 & 1 & 1/5 & 1/4 & 2 & 1/3 & 1/2 & 1/6 \\ 1 & 5 & 1 & 2 & 6 & 3 & 4 & 1/2 \\ 1/2 & 4 & 1/2 & 1 & 5 & 2 & 3 & 1/3 \\ 1/6 & 1/2 & 1/6 & 1/5 & 1 & 1/4 & 1/3 & 1/7 \\ 1/3 & 3 & 1/3 & 1/2 & 4 & 1 & 2 & 1/4 \\ 1/4 & 2 & 1/4 & 1/3 & 3 & 1/2 & 1 & 1/5 \\ 2 & 6 & 2 & 3 & 7 & 4 & 5 & 1 \end{pmatrix}$$

$$B1 = \begin{pmatrix} 1 & 3 & 1/2 \\ 1/3 & 1 & 1/4 \\ 2 & 4 & 1 \end{pmatrix} \quad B2 = \begin{pmatrix} 1 & 1/2 & 2 \\ 2 & 1 & 3 \\ 1/2 & 1/3 & 1 \end{pmatrix}$$

$$B3 = \begin{pmatrix} 1 & 2 & 1/3 \\ 1/3 & 1 & 1/5 \\ 3 & 5 & 1 \end{pmatrix} \quad B4 = \begin{pmatrix} 1 & 3 & 2 \\ 1/3 & 1 & 1/2 \\ 1/2 & 2 & 1 \end{pmatrix}$$

$$B5 = \begin{pmatrix} 1 & 1/3 & 1/2 \\ 3 & 1 & 2 \\ 2 & 1/2 & 1 \end{pmatrix} \quad B6 = \begin{pmatrix} 1 & 4 & 1/2 \\ 1/4 & 1 & 1/5 \\ 2 & 5 & 1 \end{pmatrix}$$

$$B7 = \begin{pmatrix} 1 & 1/4 & 1/3 \\ 4 & 1 & 2 \\ 3 & 1/2 & 1 \end{pmatrix} \quad B8 = \begin{pmatrix} 1 & 5 & 3 \\ 1/5 & 1 & 1/4 \\ 1/3 & 4 & 1 \end{pmatrix}$$

4.4 Test and results analysis

Table 2 shows CRk <0.1, namely, judgment matrices B1, B2, B3, B4, B5, B6, B7, B8 have passed conformance testing, and the matrix A-B has satisfactory consistency.

Combining Table 2 and normalized eigenvectors of A, ωa = [0.20 0.04 0.19 0.12 0.03 0.08 0.05 0.30]^T, the consistency test results calculating the total sort level is CR = 0.03 < 0.1, so the total sort level has passed the consistency test, and the weights in Table 2 can be used.

Combining Table 1 and normalized eigenvectors of A ωa, the repairing effects weights computing eco blanket right to the overall objective are as follows:

(1) The overall objective weight of eco blanket to dirt pilling up slope is 0.41.

(2) The overall objective weight of eco blanket to whole lump of rock slope is 0.17.

(3) The overall objective weight of eco blanket to gravel piling up slope is 0.42.

At AHP, the greater the weight is in governance objectives of the program layer, the better the effect. From the experimental results, we can see the weight T3> T1> T2, the treatment effect of soil slope and the gravel slope is significantly better than rock slope, the reason may be that the plant roots can absorb moisture and nutrients in the soil and gravel slope, and in rock slope there is difficulty in finding a nutrient source. The ecological effect of dirt pilling up slope is slightly better than the blanket treatment at gravel pile slope.

For normalized eigenvectors of A matrix ωa, ωa1, ωa3, ωa8 are significantly greater than the other values, and we focus on evaluation of density, intensity and coverage in Hanyuan experimental zone governance. In Table 2, when K = 1, ω31> ω11> ω21, namely, the plant density in dirt slope is the largest, followed by gravel slope. When K = 3, ω33> ω13> ω23, which shows ecological blanket strength in dirt slope is maximum. When K = 8, ω18> ω38> ω28, which shows the cover at gravel slope is the largest, and eco-blanket cover at rock slope is relatively small.

Application of AHP results shows that, multi-factor and comprehensive evaluation method can include multiple indicators of rich information, but also has a scientific and rational mathematical method which can more fully and accurately reflect the actual fluctuating zone governance, while AHP analysis of ecological blanket is basically consistent with the practical effect of the treatment in Hanyuan experimental area.

5 DISCUSSION

(1) Current fluctuating zone management mainly uses spraying, geotextile mat and planting grass slope and revetment raw plant. However, spraying slope is not suitable in steep slope areas and long-term immersion areas. Simultaneously, geotextile mat most uses thermoplastic resin as raw material, which is easy to form secondary pollution. Due to the presence of different construction technology, the thin matrix material, the thickness of the substrate material thick and so on, planting grass slope is inappropriate in fluctuating zone promotion. Vetiver blanket construction in Eco-fluctuating zone governance is simple, and is effective in wind, sun, and soil moisture conservation and ecological blanket has greater strength, long-term preservation, long life and post-maintenance costs low. But it is easy to degrade.

(2) According to the above experimental results of AHP calculation, ecological management of vetiver

Table 2. Judging matrix maximum eigenvalue, the normalized eigenvector and consistency check table

K	1	2	3	4	5	6	7	8
ω_1	0.32	0.30	0.23	0.54	0.16	0.33	0.12	0.63
ω_2	0.12	0.54	0.12	0.16	0.54	0.10	0.56	0.09
ω_3	0.56	0.16	0.65	0.30	0.30	0.57	0.32	0.28
λ_k	3.02	3.01	3.00	3.01	3.01	3.02	3.02	3.08
CI_k	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.04
RI_k	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
CR_k	0.02	0.00	0.00	0.00	0.00	0.02	0.02	0.08

Note: ω_{mn} means the m-th row and the n-th column in the table, e.g. ω_{11} is 0.32.

eco blanket for fluctuating zone is feasible. The main mechanism of ecological governance is to use this medium of eco blanket for seeds sprouted and growing to provide a good environment. Vetiver life is more than 50 years, with a strong anti-ecological adaptability and ability, the underground part has developed in the root system, with depth penetration. Root can grow in weathered rock or gravel when applying to fluctuating zone without having seeding year after year or every other year.

(3) Based on the study of Hanyuan experimental area, vetiver eco-blanket treatment with three typical fluctuating slopes is practicable. After 60d's growing, the average color of plants is up to be dark green, with an average coverage 90.1%, the capacity of solid soil and slope strengthens, and the disease resistance, height and density can all reach a good level. But fluctuating zone types are different, the water level elevation and geological conditions of the same type in different regions are quite different. Therefore, exploring more effective ecological blanket plant and designing more appropriate structure of ecological blanket according to the fluctuating zone type still needs further study.

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