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Preliminary Experimental Study on the Soil Conservation and Slope Protection Effect of Vetiver

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Abstract

In this paper, the biological and engineering mechanical properties of vetiver were discussed. The focus was on the experimental study of vetiver's effect on soil conservation and slope protection at Caiji Water and Soil Conservation Pilot Site of Lankao County in the middle reaches of the Yellow River. The effect of vetiver and the richness of soil nutrients were discussed and the improvement of shear strength and erosion resistance of vetiver was studied. The ultimate goal was to explore the effect of vetiver on soil conservation, slope protection and soil improvement, as well as to provide a reliable principle and practical engineering ground for other areas suitable for protecting slope with vetiver, which will play a far-reaching exemplary role.

Keywords: vetiver, Lankao section of the Yellow River Basin, slope protection and soil conservation, slope treatment, soil and water conservation

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INTRODUCTION

Soil erosion is one of the most serious ecological and environmental problems in China. It is estimated that there are 1.6 billion tons of silt rushing into the Sanmenxia Canyon of the Yellow River per year, which is equivalent to the ploughing layer of 5.4 million mu (1 mu = 666.7 square meters) of cultivated land (Guo 1995, Kaifeng Yellow River Bureau under the Henan Yellow River Bureau 2017, Yan 2013, Zhang and Wu 2012). The ecological environment is destroyed, the surface vegetation is getting less and less and the land use is unreasonable. Soil erosion is becoming increasingly serious and in particular, Caiji region of Lankao County in the middle reaches of the Yellow River suffers the most. Heavy rains occurring frequently in summer and scarce surface vegetation result in the easy washing away of the beach soil by rain. That is why the Yellow River Basin suffers the most from soil erosion and it is imperative to address the current soil erosion in the Basin (Denget al. 2016, Li 2009, National Research Council Vetiver grass: a thin green line against erosion 1993, Xiao and Zhang 2017).

How to better protect river banks? Is there any economical way to conserve soil and protect slopes without damaging the environment? This is a pressing consideration. Through the previous plantation of vetiver in the Lankao area, it was found that soil erosion at Caiji section was effectively relieved, which would offer a solution to the soil erosion along the Yellow River (Chen 2009).

The new measure of slope protection and soil conservation takes full advantage of vetiver's strong root system. Vetiver roots form a solidified composite with the slope soil of the river banks which immobilizes the loose soil, so that the substances and nutrients between the bank slopes and the river water can be fully exchanged (Ren 2015, Wen et al. 2008, Xia 1999, Zhang and Yang 2008).

Experiments combined with literature review were applied in the study. With abundant experiment data, the effect was compared and analysed by studying the characteristics of slopes ecologically restored by vetiver and slopes protected without vetiver.

FEASIBILITY STUDY ON SLOPE PROTECTION AND SOIL CONSERVATION SYSTEM OF VETIVER IN LANKAO AREA

Overview of Vetiver's Biological Characteristics

Scientific name: Vetiveria zizanioides

Generic name: Vetiveria of poaceae family

Vetiver is a perennial bunchgrass whose culm reaches 1 metre to 2 metres. Vetiver leaves are linear and

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Table 1. Plants' Tensile strength (Yan 2013)

Category	Willow	Poplar	Yellow Fir	Silver Cattail	Bilberry	Barley	Gramineae	Lichen	Vetiver
Tensile strength / MPa	9-36	5-38	19-61	15-30	16	15-31	2-20	0.002-0.007	40-120

hard with a width of 4 millimetres to10 millimetres. Vetiver panicles are 15 centimetres to 40 centimetres long and have whorled lifting or erect branches. Vetiver racemes are in multiple sections and can reach 5 centimetres long. The spikelets are opposite to each section and pedicelled spikelets are sterile. Vetiver's root system is finely structured and very strong which can grow vertically downward to about 3 metres. Vetiver has strong immobilizing power for deep soil (Guo 1995). On the earth's surface, vetiver is densely clustered, and if under close contour planting, vetiver can form a dense "biological dam" within a short time, which can effectively block surface water runoff and silt, so as to greatly prevent surface silt from flowing into rivers.

Engineering Characteristics of Vetiver

Vetiver grows fast and it has a strong adaptability. The stems are tall and erect and the height of a single plant can reach around 2 metres. Under close planting, vetiver can effectively prevent the surface water runoff from eroding the surface soil due to the unique divergent shape of its upper part, which can block 60% of surface water runoff and 90% of silt so as to prevent riverbed elevation caused by silt deposition.

Table 1 shows the numerical contrast of tensile strength between vetiver and other common plants. It can be found that vetiver's tensile strength is distinctly higher than others.

Climate and Soil Characteristics of Kaifeng Section in the Lower Reaches of the Yellow River

Kaifeng City has a temperate continental climate mainly controlled alternatively by Mongolian high pressure and Pacific subtropical high pressure. For the city, there is a clear distinction between four seasons with an annual average temperature between 14.24°C and 14.50°C. The highest annual average temperature is 19°C and the lowest is 9°C. The highest temperature in history is 43°C in 1972 and the lowest is -16°C in 1971. The frost-free period lasts 213 to 215 days long and the multi-year average annual precipitation is 675 millimetres with the highest of 1175.30 millimetres and the lowest of less than 400 millimetres. The rainfall intensity is affected by monsoon and the summer rainfall accounts for more than 1/2 of the annual (Kaifeng Yellow River Bureau under the Henan Yellow River Bureau 2017).

Kaifeng City is located in the Eastern Henan Plain. The city has a flat terrain sloping from the northwest to the southeast with a slope between 1/4000 to 1/2000 and an altitude above sea level between 69 and 78 metres. The surface coverings are mostly alluvium accumulated after the Yellow River's flooding for many times which is mostly silty. The soil parent material of Kaifeng City is the Yellow River alluvial deposits of different types in various times. The soil can be divided into four types, i.e. fluvo-aquic soil, saline soil, wind-sand soil and alluvial soil, 9 sub-categories, 13 soil families and 55 soil species.

Lankao County is located in Kaifeng City, Henan Province in the middle reaches of the Yellow River. Being in the eastern part of the middle and lower reaches of the Yellow River, the county is in the central and eastern part of Henan Province with a warm temperate monsoon climate of a cold and dry winter and a high-temperature and rainy summer. The annual average temperature is 14 degrees and the annual solar duration is 2529.7 hours with an average annual rainfall of 678.2 millimetres. Most of the precipitation happens in July and August and the average annual temperature in the county is 14.52°C.

Currents on the Yellow River floodplain of Caiji region of Lankao County intercept each other and the side slopes and river sand slopes cross each other over large areas. More domestic garbage is dumped there and the region suffers serious soil erosion. The fragile geo-ecological environment and unbalanced precipitation time and spatial distribution result in poor local geological conditions, which seriously restrict the local economy and social development. Therefore, it is imperative to conserve soil and water in Caiji region of Lankao County.

OVERALL PLAN AND TECHNICAL ROUTE OF PROJECT RESEARCH

Previously, this was an industry-university-research project carried out in April 2016 cooperatively by organizations and companies including Henan Yellow River Bureau, Kaifeng Yellow River Bureau, Nanyang Institute of Technology, Henan Kun Yuan Ecological and Environmental Protection Technology Co. Ltd., Lankao Yellow River Bureau under Kaifeng Yellow River Bureau. In November 2017, the project passed the evaluation of the Henan River Bureau to be

appraised as a top level in China. In December 2017, the project won the second prize awarded by the Henan River Bureau for scientific and technological progress. Current fruits of the project have played an important demonstrative and leading role for conserving, governing and ecologically restoring the soil and water in the Yellow River floodplain and promoting regional economic development along the Yellow River. Once the fruits are applied in the soil conservation and slope protection project of the Yellow River levees, the Yellow River harnessing project will be bound to open up a new way of combining bioengineering with water conservancy projects, which is of great significance for consolidating embankments and reducing project costs (Xiao and Zhang 2017).

Research Methods and Technical Approaches

Experiments combined with literature review were applied in the study. With abundant experiment data, the effect was compared and analysed by studying the characteristics of slopes ecologically restored by vetiver and slopes protected without vetiver. With the reviewed and summarized related materials and literatures as well as the teachers' guidance, the effect was compared and analysed from the characteristics of slopes planted with vetiver and vetiver-free slopes to determine the role of vetiver in ecological restoration.

Periodically analysing the comparative changes of soil nutrient elements and observing the effect of vetiver on improving soil and the solidification or absorption of nutrients not only benefit the growth of vetiver, but also reduce the pollution index of the water discharged into the Yellow River, which helps improve the water quality of the River. By figuring out the specific effects of vetiver on the mechanics index experiments and environmental improvement of related soil, the experiment data were refined.

In the ecological protection project of slopes, data of the pilot site of Kaifeng City in the middle reaches of the Yellow River was collected, including data of hydrology, soil and meteorological conditions. Preliminary vetiver experiments of mechanics index and the test report of soil fertility were completed and the analysis was conducted with the relevant data.

Analysing the changes in soil mechanics index and the economic indicators of vetiver planting to study and confirm the feasibility of the project.

Implementing Plan

In the early stage of the project, relevant organizations and companies at the Yellow River sections of Kaifeng City and Lankao County gave their support, and relevant data of hydrology and meteorology were collected. The soil of different river sections was also collected for testing to see the impact of local soil quality on vetiver plantation.

In the initial stage of the project, data of particle gradation and soil fertility test report of the soil samples were measured through experiments for further research.

Analysis, Organization and Implementation of the Main Research Contents

Sampling in Caiji region of Lankao County

(1) Area selection: selected side slopes ecologically restored by vetiver and vetiver-free protected side slopes.

(2) Experiment 1: took 4 soil samples: soil sample of vetiver plots before spraying water, soil sample of vetiver plots after spraying water; soil sample of vetiver-free plots before spraying water and soil sample of vetiver-free plots after spraying water, numbered and sealed them for testing.

(3) Experiment 2: repeated step (2) to collect another 4 soil samples and numbered and sealed them for testing.

(4) Experiment 3: flushed the soil of vetiver plots and vetiver-free plots with floods and collected 2 jugs of the flushed sample silt, numbered and sealed them for testing.

Experiments on testing soil fertility and comparatively measuring the content of soil nutrients

Yu Haiyan, a teacher at the School of Biological and Chemical Engineering, Nanyang Institute of Technology, respectively tested the soil total nitrogen, rapidly available phosphorus, slowly available potassium, rapidly available potassium, organic matter, pH and salinity with the soil samples in Experiment 1. For the soil samples in Experiment 2, Yu did experiments on the content of moisture.

Yu measured the silt content of the 2 jugs of silt in Experiment 3, dried the silt and stored it for further experiment.

Measuring the particle gradation of the soil samples by experiment and further testing the mechanics index of the relevant soil

Chen Guochao, a teacher at the School of Civil Engineering, Nanyang Institute of Technology, guided me to conduct experiments of particle size analysis with

Table 2. Soil Nutrients Test Report page 1

Sample tester	**Du Hongwei, School of Civil Engineering**				**Sample submitting time**	**20 Dec. 2017**
Sampling spot	Number	Total nitrogen (%)	Moisture (%)	Silt content (%)	Rapidly available phosphorus (mg/kg)	Slowly available potassium (mg/kg)
Vetiver Plot	1 (before water spray)	0.1530	--	--	7.25	669.5
Vetiver Plot	1 (after water spray)	0.1715	--	--	5.56	677.3
Non-vetiver Plot	1 (before water spray)	0.1931	--	--	3.05	1126.9
Non-vetiver Plot	1 (after water spray)	0.2359	--	--	3.54	914.8
Vetiver Plot	2 (before water spray)		4.0	--		
Vetiver Plot	2 (after water spray)		18.2	--		
Non-vetiver Plot	2 (before water spray)		3.1	--		
Non-vetiver Plot	2 (before water spray)		20.9	--		
Vetiver Plot	Kettle 1		--	12.58		
Non-vetiver Plot	Kettle 2		--	49.53		
Table maker:	Chen Xuanyang, Zhou Zhaohui, Bai Jing				Reviewer:	Yu Haiyan

Table 3. Data of Silt Content in the Kettle

	Total weight (Kg)	**Kettle weight (Kg)**	**Beaker weight (Kg)**	**Total weight after drying (Kg)**	**Silt content (%)**
Vetiver plot	3.6925	0.1480	0.2840	0.7300	12.58
Vetiver-free plot	1.2760	0.1475	0.2650	0.8240	49.53

the sieving method on the dried soil samples collected in Experiment 3 at the Soil Mechanics Laboratory. With the data obtained, the soil particle grading curves of vetiver plots and vetiver-free plots were drawn.

Further integrating the research work on the relevant experiment data

Processing and analysing the data obtained from the experiments under the help of the teachers to draw a conclusion and complete the results analysis for a preliminary research conclusion of the soil conservation and slope protection effect of vetiver.

ANALYSIS OF TEST RESULTS

Meauring Method of Soil Fertility of Vetiver Plots in the Yellow River Floodplain

Vetiver affects the content of carbon, nitrogen and phosphorus in the soil, thus in the experiments, the soil was periodically monitored and the content of soil elements was regularly tested. Experiments on total nitrogen, rapidly available potassium, organic matter, rapidly available phosphorus, slowly available potassium, pH and salinity were done by the laboratory of the School of Biological and Chemical Engineering, Nanyang Institute of Technology.

Reagents used in the following content measurement of the organic matter and total nitrogen in soil were NaOH solution, H_3BO_3 solution, standard hydrochloric acid solution, methyl red-bromocresol green (Deng et al. 2016).

Test Report

Sample name: soil

Sample tester: Nanyang Institute of Technology

Test category: commission

School of Biological and Chemical Engineering, Nanyang Institute of Technology

Soil nutrients test report

ANALYSIS & CONCLUSION

Effect of Vetiver on the Content of Organic Matter in Soil

The experiment data showed that planting vetiver largely affected the content of organic matter in soil, which increased obviously after planting vetiver, indicating that vetiver had a prominent effect on soil improvement. Vetiver could also maintain the content of total nitrogen in the soil to some degree. Vetiver absorbed a small amount of nitrogen in the soil for its growth, which decreased the content of nitrogen in soil, but the decrease was not obvious.

Some other experiments on soil elements were conducted, which mainly showed how the elements in the soil had changed after planting vetiver. Experiments showed that there were more types of substances in the soil. Although the content of nitrogen in the soil decreased slightly, the content of other beneficial substances slowly increased, which illustrated that planting vetiver was good for the soil and played a big role in improving the soil.

By analysing the elements in the soil, it was noted that vetiver had good vitality and had to absorb some elements from the soil for its growth, but on the whole,

planting vetiver was beneficial to enrich soil elements, which would facilitate the growth of more species, so that the soil fertility would increase and the plant richness would be promoted. In doing so, a sound cycle of soil and water conservation can formed, which can also be a virtuous cycle for the slope protection and soil conservation project.

Role of Vetiver in Intercepting Rainfall and Surface Runoff

The loose structure of the soil in the Yellow River floodplain and the climate in the area make the soil highly vulnerable to rain and river water, which takes the surface soil into the Yellow River channel along with the caused surface runoff, bringing much silt to the Yellow River. By planting vetiver, the vegetation coverage on the bank slopes can be increased, and the rain will have to pass through the weaving stems and leaves of the vetiver before reaching the surface of the soil. Stems and leaves of vetiver can cover more than 90% of its planting area, which reduces the impact of precipitation on the soil of the riverside slopes and weakens the decomposition of the rainfall upon the surface soil of the river bank slopes. To some extent, planted vetiver forms a thick protective layer for the soil of the river bank slopes, which delays the surface rainfall and runoff production, reduces the surface rainfall and blocks the surface runoff, so as to mitigate the soil washing and erosion of the riverside slopes from the rainfall, which is conducive to conserving water and soil.

The ecologically composite restoration technology centring on vetiver has yielded fruitful results in the soil conservation and slope protection on floodplains. What's more, the technology plays a unique and practical functional role in many ways, including conserving water and soil, stabilizing steep slopes, restoring vegetation, optimizing ecological environment, improving soil polluted by heavy metals; conserving water, protecting water quality; integrated utilization as well as helping local farmers to make a fortune.

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