New Bionic Tree Water and Soil Protection Device

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Abstract. In view of the existing soil erosion problems in China, a new bionic tree device is designed to solve the shortcomings of the existing tree planting control methods through the research and investigation of soil and water loss control by trees. In a short period of time, it can improve the soil loss and vegetation survival in the area prone to soil erosion by a new treatment method. Compared with the traditional way of afforestation, it has shorter treatment cycle and more convenient treatment method. Combined with natural trees, it can achieve better water and soil protection.

Keywords: Bionic tree, soil erosion, combined design.

1. Introduction
This device uses bionics principle and based on environmental investigation, designs a bionic tree device which can deal with two types of soil and water loss, i.e., rainy and dry. Mechanical devices are used to simulate the protection effect of natural trees on Soil and water, so as to solve the shortcomings of traditional trees in water and soil erosion control, while retaining traditional trees, reducing rain erosion, conserving water and soil and reducing soil erosion the ecological effect of wind speed near the ground. It can coordinate with traditional soil erosion control methods to achieve better effect of soil and water control.

2. Research background
China is one of the countries with the most serious soil erosion in the world. In the past 50 years, China has lost more than 50 million mu of cultivated land due to soil erosion, with an average of about 1 million mu per year. The national water and soil conservation plan (2015-2030) proposes to actively promote the comprehensive management of soil and water loss in key areas, strive to improve the ecological environment, and transform new ideas into new measures and new actions. The goal is to increase the area of soil erosion control by 940000 square kilometers by 2030.

According to the existing research on soil erosion and soil consolidation by vegetation, it is found that rainstorm and wind erosion are two important causes of soil erosion. Vegetation protection is the most useful method to control soil erosion, and trees are the most important population in vegetation. The branches, roots and leaves of trees can slow down the falling speed of rain water and connect the soil to maintain soil strength. However, the survival rate of traditional tree planting in soil erosion area is low due to the lack of soil and less precipitation.
3. Overall scenario

3.1. Bionic tree design in rainy area
As shown in Figure 1, bionic trees in rainy areas are composed of water blocking plates, tree trunks, three-dimensional vegetation networks on the ground, water conveying roots and fixed roots.

![Figure 1. Design of bionic tree in rainy area](image)

3.1.1. Design of upper water stop plate. In the rainy soil erosion area, the micro structure of soil and the root network of the ground surface are destroyed by the impact of a large amount of rainwater. Therefore, the use of the bionic device to intercept rainwater can reduce the damage and splash erosion of soil caused by rainwater, and reduce the soil loss caused by mechanical washing of rainwater.

The upper part of the device is composed of hard plastic layers, which are divided into three layers. The metal reinforcing rod is used to connect the upper part of each layer, and the gap of more than 200 mm is maintained. The overall design of the three layers is a paraboloid shape, which makes the structure more stable while maintaining a larger rainwater collection area. The overall parabolic shape can block and collect rainwater, prevent it from directly scouring the soil, and protect the integrity of the soil. There is a sequential replacement between the three layers, so that the rainwater can enter into the ponding device below. Because it is designed as a three-layer structure, it cannot only collect rainwater, but also prevent the center of gravity from being too high due to excessive storage of rainwater. Moreover, it can make the wind pass through smoothly and prevent the structural strength damage caused by rainstorm and gale, so as to improve its service life.

3.1.2. Design of middle branch. As shown in figure group 2 (half sectional view on the left and enlarged view of mechanical part on the right), the middle and lower branches are mainly composed of water collector, upper water storage tank, float, support plate, middle water storage tank, shell of mechanical control part, discharge pipe, drain pipe, lower water storage tank, drip irrigation head, water delivery root, regulating water tank, gear fixed rod, rotary water valve, rack, big gear and pinion Wheel, rack, gear, etc.

![Figure 2. Semi sectional view of bionic trunk and enlarged view of internal mechanical part](image)
In the design of the device, the middle bionic branch is made of PVC plastic pipe, which can ensure
the structural strength, reduce the structure weight and ensure the stability of the structure. It is mainly
composed of three parts, the upper part is the connecting frame of rain pan, the middle part is the water
storage tank, and the lower part is the support frame. There are six ribs on the outside of the connecting
frame of the rain pan to increase the contact area with the rain pan and increase the stability of the upper
structure.

The structure of the drain is similar to that of the rainwater channel. The first layer is an inverted
cone shape, which is used to collect rainwater accurately. Make it flow in the specified direction. After
the water reaches the second layer, the second layer and the first layer are in close contact. Because of
the close interface, it can make water pass through and reduce the evaporation loss of water in sunny
weather. There are six ribs around the second floor, which are used to fix the trunk. There are four holes
in the lower part of the second layer, which can flow out of the four holes when there is less water. In
rainstorm and other weather, the water flow speed is fast, and the discharge rate of the four holes is
difficult to meet the requirements. Therefore, the water level rises and overflows from all around.

The central water storage tank is the main water storage device, which is used to store rainwater in
rainstorm weather, slow down the speed of water flow to the ground, and then reduce its erosion and
scouring effect on soil. There is a water free part in the middle and lower part of the water tank, and
there is a mechanical control part in the water free part, which can control the water discharge rate
of the water tank. The more water in the water tank, the slower the water discharge rate, the less water in
the water tank, and the faster the water discharge rate.

There is a floating tank on the side of the water tank, and the floating tank is connected with the water
tank through a fence like grid, so that the internal water level can follow the change of the water level
of the water tank at any time. There is a pontoon inside the pontoon, which can drive the rack to move
with it, so that the rack can change with the water level.

There are two racks and two sets of gears in the mechanical control part. The rack on the right can
move up and down with the pontoon, and the rack on the left moves up and down in the slot. The lower
pinion is connected with a rotary water valve to control the discharge rate of the water tank. The upper
coaxial gear is connected with two racks. The left side is the power input, and the right side is the output
rack. The gear changes the direction of rack movement and reduces the output speed of the left rack and
increases the output force. The lower part of the left rack is connected with a pinion, which is connected
with the drain valve to control the water discharge rate of the water tank. In case of heavy rain, the water
flows into the water tank quickly from the top, which makes the water level in the water tank rise. At
this time, the pontoon also rises, which makes the right rack rise, driving the big gear to rotate. Because
the big and small gears are coaxial, the big gear drives the small gear to rotate. However, due to the
different number of teeth, the rotation reduces the stroke and increases the force, and then drives the left
rack to rise and drive the lower side the small gear rotates anticlockwise and then closes the valve, which
slows down or even stops the water discharge speed of the water flow through the rotary water valve,
so as to slow down the erosion effect of rapid precipitation on the ground. When the rotary water valve
is closed, a drop of water filling valve will slowly discharge water to the lower water tank 18 to ensure
that water will not be accumulated in the middle water tank. When the rainfall is extremely heavy, the
water will flow to the lower part of the water tank automatically through the drain pipe, so as to avoid
the impact erosion of the surface soil caused by water overflow from the top.

When there is no rainfall, there is less water in the water tank. Contrary to the process of precipitation,
the drain valve is fully opened, so that the water flow will not be hindered and can flow down smoothly
to ensure the proper supply of soil water.

In addition, there is a bin wall door which can be opened at the middle branch, so that it can be
repaired and maintained.

3.1.3. design of lower branch. In the lower branch, there is a small water tank, which is responsible for
receiving the water from the middle section, and there are 6 holes in the lower part, which are connected
with 6 drip leaks. Through the combination of small water tank and drip leakage, the water flow is
evenly and slowly dropped, which avoids the change of water velocity caused by the change of water level, so as to ensure the uniformity of water supply to the soil. In the middle of the small water tank, there is also a drain pipe which is the same as that of the middle water tank. When the water volume exceeds the storage capacity of the middle water storage tank, the water will automatically flow to the emergency water outlet at the lowest level through the drain pipe to avoid water upwelling.

There are six runway shaped holes in the bottom branch to connect six bionic tree roots, and the water dripping from the lower water tank enters into the bionic tree roots. The lowest branch is also connected with six supporting platforms. The supporting platform is responsible for supporting the whole trunk and connecting the supporting root, which is connected with the supporting root through the hole, so as to further fix the trunk.

3.1.4. design of bionic tree roots. Bionic tree roots can be divided into two types, one is responsible for providing water for the soil, the other is responsible for fixing the fixed root.

The water delivery root is connected by several sections of PVC pipes. It is first inserted into the ground at a small angle, then through a turning angle, and then inserted into the ground at a larger angle. There are many small holes in the pipeline after the turning point, and there are sponges inside and outside the holes, so that the water from the drip irrigation of the lower branches can be evenly distributed to the soil around the bionic tree in a slow-release manner. Because of its very slow dispersion rate, it can complete the supplement of soil water while protecting the soil.

The fixed heel is made of ordinary steel bar, which is connected with the supporting platform through the hole on the support platform, and is connected with the trunk as a whole. One of them is distributed every 60 ° and is fastened to the soil by its structural strength and irregular patterns on its surface, so as to ensure the stability of the trunk itself.

3.1.5. design of ground three-dimensional vegetation network. The three-dimensional vegetation network is a new technology to build a protective system with its own growth ability on the surface of soil and water loss, and to reinforce the soil and water through the growth of plants.

The three-dimensional vegetation network in this design is divided into six parts, which are fixed between the trunk and six water conveying roots, and the six fan-shaped vegetation networks are connected to form a nearly circular three-dimensional vegetation network.

Through the effect of bionic tree on Soil and water conservation and water flow release, herbaceous plants with strong survival ability can be planted around the bionic tree, thus forming primary community under the protection and fixation of vegetation network. Plant root system and soil support each other on the framework of vegetation net, strengthen the anti-erosion ability and shear strength of soil, so as to achieve better soil and water protection.

3.2. bionic tree design in arid area

3.2.1. design of upper catchment pan. The main differences between the bionic tree design in arid areas and those in rainy areas are the upper catchment pan, sand blocking net and sand separator, while the other designs are basically the same as those in rainy areas.

As shown in Figure 3, it is mainly composed of water collecting branches, water collecting plates, tree trunks, vertical three-dimensional vegetation network, ground three-dimensional vegetation network, water conveying root, sand separator and fixed root.
In the design of bionic trees in arid areas, the branches and trunks are the same as those in rainy areas, which are designed to collect and slow down water discharge. The difference lies in the design of the upper diversion plate and the sand blocking net and sand separator around the bionic tree.

The main body of the upper water diversion plate is composed of paraboloid metal mesh, which is paved with waterproof and anti-seepage high-density woven fabric, so that it can bear the rain water in rainy season and achieve better ventilation function, and can better reduce the weight. In addition, there are hundreds of metal branches in the upper part, which can collect dew in the morning and obtain additional water supply.

Around the bionic tree, there are six evenly arranged sand blocking nets by using the space between the water diversion plate and the water conveying root and the traction support with the trunk. The sand blocking net is composed of 6-pin polyethylene mesh, which can significantly reduce the wind speed around the bionic tree, and make the medium and large sand particles settle, so as to slow down the wind erosion on the soil, and form soil aggregation around the bionic tree, so as to form a better water and soil protection function.

3.2.2. design of sand separator. The sand separators are distributed outside the trunk and arranged in an encircling manner. Its main body is a circular ring. There is an outlet and an entrance on the outside, and two herringbone channels placed side by side inside. A fine filter screen is arranged on the upper part of the herringbone channel to block the light soil particles and guide the wind to the high place, so as to make it easy to blow down the soil particles on the sand blocking net. When the wind sand passes through the sand separator, soil particles will flow out from the other side of the herringbone channel and accumulate near the tree trunk to form soil accumulation, thus reducing the erosion effect of wind sand on Soil and water and protecting soil and water.

As shown in Fig. 4, the sand separator is mainly composed of inner wall, outer wall, air inlet, air inlet, outlet channel and sand outlet channel.
4. Ecological benefits analysis

Soil erosion is accompanied by a large number of soil loss. The most important measure to control the soil erosion area by planting trees is to realize soil consolidation. According to the data, in the soil erosion area, the annual soil loss amount is as follows:

\[ SL = \sum A_i \times S_i \]

Among them, \( A_i \) is the unit average soil erosion intensity, \( S_i \) is the area of the unit.

According to the soil erosion intensity grading standard table (SL190-96), we set the unit average soil erosion modulus as 8000 \( t/km^2 \). According to the results of the second remote sensing survey in China, the area of soil erosion in China is 3.56 million \( km^2 \). The annual soil loss is as follows:

\[ SL = 8000 t/km^2 \times 356 \times 10^4 km^2 = 2.85 \times 10^{10} t \]

Assuming that 80% of the soil and water loss areas can be controlled by using the device, the amount of soil loss can be reduced in one cycle according to the calculation that one cycle is five years:

\[ SL_{decrease} = 2.85 \times 10^{10} t \times 80% \times 5 = 1.14 \times 10^{11} t \]

5. Conclusion

The new bionic tree water and soil protection device solves the problem of survival difficulties of existing trees in the control of water and soil loss by bionic way. The bionic tree trunk and tree root are used to reduce the soil erosion caused by rainstorm and the wind erosion on the soil by wind, which effectively protects the soil in the environment vulnerable areas and increases the survival rate of natural plants. The device provides a new solution to the problem of soil and water loss, improves the efficiency of improving soil and water loss, and has better economic and ecological efficiency.

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