Research article

Forest restoration and Sustainable of Soil Water Resources and High-quality sustainable management

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Abstract

Along with economic development and an increase in population, there is an increasing demand for goods such as timber, food, medicine, and so on, and ecological services such as fresh water and the environment. Because goods and service produced by the original forest cannot meet the increasing need of people, so most of the original forest has become farmland, plantation, and grass, and a lot of exotic plants was introduced to produce special products and service. As introduced plants grow, vegetation decline and crop failure happen in dry years or resource waste in wet years. In order to solve these problems, Years of theoretical research and investigation in fixed positions have shown that there is a soil water resources use limit by plants and the soil water vegetation carrying capacity in the process of vegetation restoration. When the soil water resources in the range of the maximum infiltration depth are equal to soil water resources use limit by plants, the plant water relation enters the key period of plant water relation regulation. If existing plant density is more than the soil water vegetation carrying capacity in the key period of plant water relation regulation, the plant water relation has to be regulated on the soil water vegetation carrying capacity to get maximal yield and service and realize high-quality sustainable management of forest vegetation in a water shortage area.

Introduction

With economic development and an increase in population, there is an increasing demand for the quantity and variety of plant production and service. But the plant production and service produced by the original forest ecosystem cannot meet the need of demand for the quantity and variety of timber, food, medicine, and so on, and ecological service, 80% of the original forest in the loess plateau [1] and the world has become farmland, man-made forest and grass [2,3] and a lot of exotic plant species was introduced to produce more production and service. Because exotic plant changes the plant resources relation and the ability of self-regulation to adapt to climate change is very low, vegetation decline, crop failure, serious soil erosion, greenhouse gas emissions, and other ecological and environmental problems happen [4]. In order to solve the problem of soil degradation, vegetation decay or crop failure, or waste of resources and achieve high-quality sustainable development and meet the increasing need of people for plant goods and services. Years of research has shown that there is a limit to plant utilization of soil water resources and the carrying capacity of soil water to vegetation the method of high quality and sustainable management of forest vegetation in a water shortage area in the process of vegetation restoration [2,3,6]. The main contents are as follows:

Methodology

The study

Study site: The study was conducted at the Shanghuang Eco-experimental Station (latitude 35°59′-36°03′N, longitude 106°26′-106°30′E) in the semi-arid region of the Loess Plateau, in Guyuan County, in the Ningxia Hui Autonomous Region of western China. The area is in a hilly loess region with an elevation range of 1,534 to 1,824 m with slope gradients of 10° to 25°. The main soil type is Huangmian soil [7] which

is developed from loess parent material and is susceptible to soil and water losses, which are serious in this region. The rainfall is unevenly distributed in the year with a mean annual precipitation of 416 mm, and rainfall from June to September accounts for 64.7% of the total annual precipitation. The coefficient of variation of precipitation among the years from 1983 to 2001 was 23.8% and rainfall amounts ranged from 260 to 635 mm. The mean level of solar radiation is 5,342 MJ m²; the annual average temperature is 7.0 °C. The plant growing period is 152 days.

The research object includes young caragana shrubland with different sowing plant densities (*Caragana korshinskii* Kom) and adult caragana shrubland with different preserving plant densities through thinning in the same loess slope of about 8 degrees, 3m×4m young and adult Red plum apricot (*Apricot*) and fine pasture, Alfafa (*Medicago sativa* L.) grass and 1m×2m high calcium tree species, Saskatoon berries (*Amelanchier alnifolia* Nutt.) in loess terrace land and so on. The measure item includes plant height with a tape measure, basical diameter growth with calipers, canopy, and root in the growing season from April to October. The survey method involves measuring the height, length, and width of the canopy with a tape measure and then estimating the coverage, with a caliper measure, and then estimating the biomass with a standard rain or 20cm high mini gauges to measure precipitation inside and outside of canopy and then estimating soil water resources, with a neutron probe (CNC503A(DR) (Beijing Nuclear Instrument Company, Beijing) measures soil water content at different soil depth so on [1–3,6] and then estimating the soil water resources, maximum infiltration depth, utilization limit of soil water resources, the critical period of plant water relationship regulation and Soil water vegetation carrying capacity.

Results

The theory of utilization limits resources by plants

The utilization limit of resources by plants includes spatial utilization limit of resources by plants, soil water resources utilization limit by plants in water-limited regions, and soil nutrient resources utilization limit by plants in soil nutrient-limited regions. For example, As time goes on and plant growth, plant height diameter, forest canopy volume, and root volume increase, and roots develop deep, soil water and nutrient resources in the root zone are reduced but available soil water resources are declined soil water resources in the root zone reduced but available soil water and nutrient resources are declined. In order to obtain maximum yield and beneficial results and achieve high quality and sustainable development, even if the root distribution depth is more than the maximum infiltration depth, Figure 1, plant roots do not absorb water indefinitely due to lack of water such as in semiarid loess hilly region (Guyuan. China) the precipitation changes with year and month, Figure 2 [1,8]. There should be a control limit for the utilization of soil water resources by plants in water-scarce areas, that is, the soil water resources use limit by plants [9,10]. It is the soil water storage when the soil water content is equal to the wilting coefficient in the range of the maximum infiltration depth. The wilting coefficient at

Figure 1: The *Robinia pseudoacacia* L. root distribution depth and maximum infiltration depth (290 cm) relationship in semiarid loess hilly region (Guyuan, Ningxia China).
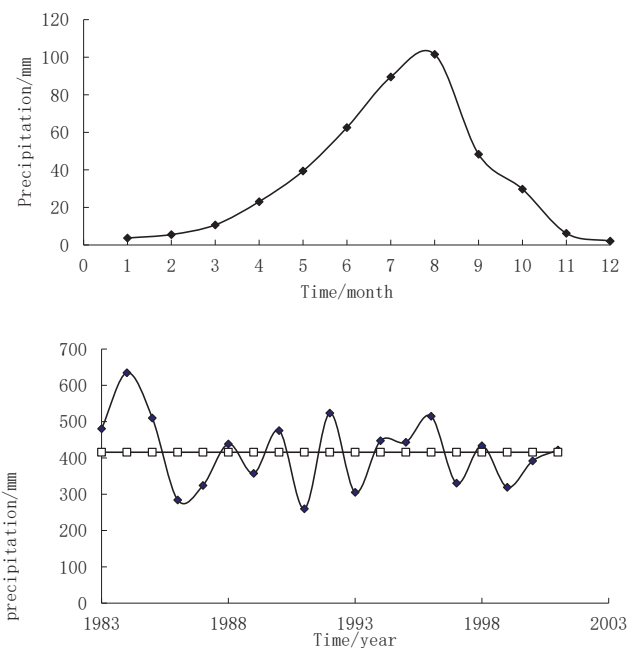

Figure 2: Change of precipitation with the month (photo above) and year (photo below) in semiarid loess hilly region (Guyuan. China).

different soil depths in the maximum infiltration depth can be determined by a centrifugal machine or press film. The undisturbed soil at different soil depths in a soil profile was taken by a cutting ring with a 5 cm high and 5cm diameter. The maximum infiltration depth can be estimated by the two curves method [6,11]. The wilting coefficient is expressed by the wilting coefficient of indicating plants in a plant community. The indicator plants of natural vegetation are the constructive species, and the artificial vegetation is the target species. When the soil water resources decrease to the utilization limit of soil water resources, the plant-water relationship enters the starting time of the critical period of plant-water relationship regulation [12,13]. At this time, the regulation of plant-water

relationship should be considered to be regulated. The initial planting density influences the soil water resource use limit by plants [14].

Theory of vegetation carrying capacity

The ability of land resources to support vegetation is limited. The limit is vegetation carrying capacity. The term vegetation carrying capacity includes spatial vegetation carrying capacity in soil water and soil nutrient-rich regions, soil water vegetation carrying capacity, and soil nutrient vegetation carrying capacity [8]. The ability of soil water resources to support vegetation is called soil water carrying capacity for vegetation. The concept of soil water-carrying capacity for vegetation was first raised by Guo in 2000 [15]. It is the best term for express forest restoration. It refers to the maximum quantity per unit area of soil water resources that can maintain healthy growth of indicator plants at a given period and site condition [11,16] and can be estimated by soil water-lant density model [11], expressed by the number (absolute index) or density (relative index) of indicator plant population in the plant community. Soil water vegetation carrying capacity (SWVCC), changing with plant species (vegetation type), time or position, time climate change, especially the critical period of plant water relationship regulation, which is the theoretical basis for determining indicators and criteria for forest resources use degree and high quality and sustainable management of forest vegetation [11].

Critical period of plant-resources relationship regulation

Generally, along with plant growth, the amount of the available resources to a given canopy (cube) such as leaf amount in a given canopy or soil water resources in the maximum infiltration depth will also decrease, even though the soil water resources will increase after the rain. The plant-water relationship enters the critical period of plant-water relationship regulation. If the present plant density is more than soil water vegetation carrying capacity in the critical period of plant water relationship regulation, plant water relationship regulation has to be regulated. Plant-water relationship can be regulated Plant-water relationship can be regulated by different methods such as cultivating and selecting better plant species and varieties [5], soil preparation such as thin film cover and ridge tillage in the semiarid loess hilly region (Guyuan. China), see photo 3 and pruning some leave and trig and so on, but the most important method is to regulate the plant-water relationship by reducing plant density in the critical period of plant-water relationship regulation Figure 3.

Plant- resources relationship in the growing season can be divided into different stages according to the resource use limit by plants such as soil water resources use limit by plants in the water-limited regions. If the available resources in the canopy are more resources use limited by plants or soil water resources in the range of the maximum infiltration depth is more than soil water resources use limited by plants, showing resources such as soil water resources enough and plants grow healthily. If not, more attention should be paid to the plant-water relationship regulation.

Figure 3: Photo of Corn thin film cover and ridge tillage in semiarid loess hilly region on 21 May 2021.

The critical period of plant-resources relationship regulation refers to the time that the resources can maintain the plant growth healthy when the resources descend to the utilization limit of resources by plants such as soil water resources within the range of the maximum infiltration depth, it not only affects plant growth condition but also determines the maximum yield and benefit in the growing season in the water-limited regions. The critical period of plant-water relationship regulation is the period from the starting time soil water resources are reduced to the limit of soil water resources utilization by plants to the end time plant water relationship regulation is a failure. The ending time of the critical period of plant-water relationship regulation can be estimated by the thinning plant method. Sowing seeds in a plot with a maximum plant density and ensuring the maximum experimental plant density equals to or more than soil water carrying capacity for vegetation.

High Quality and sustainable management of forest

Firstly, the better plant species and varieties have to be selected according to site conditions and cultivation goals [5], and then suitable initially planting density has to be taken. The initially planting density is more than the soil water carrying capacity for vegetation such as the soil water carrying capacity for vegetation in water-limited regions. If the existing plant density is more than the soil water carrying capacity for vegetation in the critical period of plant-water relationship regulation, showing plant overuse of soil water and plant density exceeds soil water carrying capacity, which will cause soil degradation, vegetation decline, fruit, and crop failure if the plant-water relationship should not be regulated. In this movement, we should regulate the plant-water relationship by reducing the plant density. The reduced amount of plant density is equal to the difference between the existing plant density and soil water-carrying capacity for vegetation. When the soil water resources decrease to the utilization limit of soil water resources by plants in the range of maximum infiltration depth, the plant-water relationship enters the critical period of plant-water relationship regulation. if the existing plant density is more than the soil water carrying capacity for vegetation in the critical period of plant-water relationship regulation, the plant-water relationship should be regulated by estimating the soil water carrying capacity for vegetation in the critical period of plant-water relationship regulation, and

the maximum yield and benefit of non-commercial forest and grass can be obtained by determining and controlling the plant-water relationship according to the soil water carrying capacity for vegetation in the critical period of plant-water relationship regulation. High-quality and sustainable development can be achieved in water-limited regions.

Conclusion

Forest restoration efforts have increased over decades [17-23]. The most important work of forest restoration is the plant-resources relationship regulation in the process of vegetation, especially plant-resources relationship regulation in the critical period of plant-resources relationship regulation such as plant-water relationship regulation in the water-limited regions because it decides the maximum yield and benefit of a population or plant community. The foundation of plant-resources relationship regulation is resources use limit by plants and vegetation carrying capacity. When resources amount reduced to the utilization limit of resources by plants, such as the soil water resources within the range of the maximum infiltration depth descend to the utilization limit of soil water resources, plant- the relationship of the resource enters the critical period of plant- resources relationship regulation in which the resources severe influence the plant growth and decides the maximum yield and ecological, economic and social benefits. At this time, the plant-resources relationship should be regulated to obtain the maximum yield and benefit of non-commercial forest and grass and carry out high-quality and sustainable development.

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