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Evaluating the Ecological Functions of Plantation-Based Forest Restoration: Impacts on Biodiversity Recovery, Ecosystem Services, and Carbon Sequestration

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Abstract. Forests help maintain the diversity of life and regulate the environment in other ways. Due to continuous deforestation and habitat loss around the world, plantation-based forest restoration has gradually been employed to increase forest coverage and restore damaged environments. At present, it is unknown whether plantation forests can restore biodiversity and provide ecological services to the same extent. Assess the ecological functions of plantation-based forest restoration by evaluating their contributions to biodiversity recovery, ecosystem services and carbon sequestration in this paper. Other reasons for the failure of the restoration effort include single-crop forests, broken habitats, poor soil conditions and human activities. In addition, the above strategies for restoration include expanding the diversity of native species, building mixed-species forests, fostering natural regeneration, and conducting long-term biodiversity monitoring. Research has shown that while plantation forests can increase the proportion of vegetation and raise carbon sinks at an earlier stage, their low species diversity compared with natural forests is also a problem. Based on the results of the restoration work, native species can be used to increase structural diversity and carry out continuous management. In short, in the future, the plans for biodiversity protection and forest restoration should be combined to create resilient and stable forest ecosystems.

Keywords: Plantation forest restoration, biodiversity recovery, ecosystem services

1. Introduction

In recent years, deforestation and land-use change around the world have been intensifying steadily, resulting in widespread destruction of natural habitats and serving as a primary cause of biodiversity loss. Forests are rich in all sorts of plants and animals, help absorb carbon dioxide, regulate the water cycle and protect the soil. As a result, restoring degraded forest ecosystems and protecting biodiversity have become the main content of ecological research today.

Recently, many countries have begun large-scale forest restoration work to combat forest degradation. Among them, the first type of plantation-based forest restoration is the most common. This way, trees will be planted in the degraded Area to restore a forest, increase vegetation rapidly,

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reduce soil and water erosion, and enhance carbon sink capacity. Thus, plantations have been widely used in ecological restoration and climate change mitigation.

Recently, as research has been conducted, some scholars have begun to explore the actual ecological benefits of plantation restoration. Although plantations can expand the area of forests at a high speed, their ecological structure is generally relatively simple and significantly different from that of natural forests; as a result, the biodiversity and species richness in plantations are generally lower than those in natural forests [1]. Many plantations can only restore some parts of the plant and animal communities and are unable to fully reconstruct the original ecosystem [2].

In recent years, studies on the connection between biodiversity restoration and carbon sequestration have been accumulating. Some studies have found that the recovery rate of carbon sink in plantations is generally higher than the recovery rate of biodiversity [3]. It does not mean that more forests have been established in terms of improved ecological conditions. Therefore, a problem has arisen in recent years: how to simultaneously strengthen the carbon sequestration ability and biodiversity conservation of restored forests.

Given the above reasons, this paper studies the role of plantation restoration in biodiversity conservation, analyzes its performance in species recovery and ecosystem function restoration, and investigates the main factors influencing the results of restoration. Based on the above studies, some optimisations have been proposed for improving the quality of restoration, offering a reference for future forest restoration. People need to know the strengths and weaknesses of plantation-based restoration in order to introduce suitable protective policies and extended-term sustainable forest management plans in the future.

2. Plantation-based forest restoration

2.1. Definition of plantation-based forest restoration

Plantation-based forest restoration aims to create tree plantations in areas damaged by disasters, deforestation or former agricultural land to expand forest cover and boost ecosystem services. Plantation restoration is not natural regeneration; it is the result of people's active efforts to plant and cultivate trees, etc. Therefore, many countries have employed this method to increase the extent of forest cover rapidly and achieve visible restoration results in a relatively short amount of time [4]. A typical case of plantation-based forest restoration in China is the Grain for Green Program (GGP), which began in 1999 to turn steep farmland into forests and grasslands. The GGP is a very large ecological restoration project in the world that has restored many millions of hectares of damaged land, increased forest coverage significantly, and reduced soil erosion. Research has also found that the programme has increased carbon sequestration and improved some ecosystem services. Many of the first restoration sites were monoculture plantations and thus had a lower level of biodiversity than natural forests. Therefore, although plantation restoration can expand vegetation coverage and ecosystem services at a relatively high speed, the quality of restoration is also influenced by plantation design and species selection.

To reduce deforestation and soil erosion, plantation restoration is often carried out, and at the same time, more carbon will be taken up to help mitigate climate change. Many large-scale restoration projects have employed plantation forests to some extent, given that they are relatively easy to manage and grow [4]. Therefore, plantation restoration has gradually been added to the list of world reforestation efforts.

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2.2. Types of plantation forests

The two types of plantation forests are monoculture plantations and mixed-species plantations. Plantations of a single type of trees, such as eucalyptus, pine or acacia. Most of these plantations are for commercial timber production because they are relatively easy to manage and often have a high growth rate. However, they generally have low ecological complexity. Mixed-species plantations have two or more types of trees. Add more kinds of plants to create a multi-species plantation that can offer different living spaces for many different organisms in nature. To improve the biodiversity protection and ecological resilience of the mixed-species forest, native species are frequently added [5].

The aims of the plantations' administration may also differ. Some are mainly for timber production, and others aim to achieve the purpose of ecological restoration. Ecological restoration plantations generally aim to protect biodiversity, ecosystem functions and long-term sustainability more.

2.3. Advantages and deficiencies of plantation restoration

Plantation restoration has the following merits. First, it will increase the vegetation coverage of the degraded area. Tree planting usually has a relatively short cycle for recovery and is more noticeable. Increased Vegetation cover can reduce soil erosion, improve water-holding capacity and stabilise degraded areas [4].

Second, plantation forests are good carbon sinks. Trees absorb CO2 from the atmosphere to grow and are thus carbon sinks. Thus, it will help mitigate climate change and has prompted some governments to include plantation restoration in their climate policies and carbon offset schemes [3].

Thirdly, plantation forests can be economically feasible for timber production and other forest products. The above economic reasons may motivate landowners and governments to carry out restoration work.

There are still some defects with the above advantages. Many plantations have been established for a small number of tree species and have simple ecological structures. Plantations generally have lower biodiversity and offer fewer habitats for animals and plants compared to natural forests [2].

In addition, plantation forests may not be able to restore all the ecosystem functions of natural forests. Although the quantity of tree cover will be higher, the ecological processes of nutrient cycling, species interactions and habitat complexity will not be fully restored. Therefore, some scholars have referred to certain monoculture plantations as "green deserts" because, although there are trees, there is relatively little biodiversity [2]. Therefore, although plantation restoration can help to restore forests, the actual ecological benefits will vary depending on the Design of the plantation and the selection and management of species.

3. Biodiversity recovery in plantation forests

3.1. Plant diversity recovery

The recovery of plant diversity is a representative index of the extent of restoration. Plantation forests can form a relatively favorable microclimate and reduce environmental stress on the plants. As the plantation trees grow older, they will offer shade and improve the quality of the soil to help other plants grow [4].

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Plant diversity recovery in plantations is also often incomplete. Monoculture plantations generally have a lower number of understory plant species compared to natural forests because of dense canopies and a restricted habitat for colonization. Mixed-species plantations generally support a higher level of plant diversity because they have a more complex structure and are environmentally heterogeneous [6].

A world-class meta-analysis on natural regeneration and active restoration found that restoration projects using native tree species generally supported higher plant species richness and more complete vegetation recovery than plantations dominated by exotic or single-species stands [6]. Native trees are more suitable for their own environments and provide various ecological services, such as seed dispersal, pollination and nutrient cycling. Therefore, the restoration effect of a native-species-only restoration project will be more enduring than that of a monoculture plantation.

3.2. Animal diversity recovery

The third is the increase in species of animals. Many kinds of animals live in the plantation forest, such as birds and mammals, reptiles and amphibians, insects, etc. An expansion of the vegetation area will provide food and shelter for some animals to return to the rehabilitated area. Bird communities generally recover more rapidly because many bird species are migratory and can disperse widely to use new habitats. Large animals and other special kinds of living beings need relatively large spaces, which are unavailable in plantations. Species that require the features of old-growth forests, such as large trees, dead wood and special food resources, are often missing in plantation forests [1]. The Diversity of Insects in different Plantations. Monoculture plantations generally support fewer insect species due to a lack of food and habitat diversity. Mixed-species plantations generally support a richer diversity of insects because they have higher plant diversity and more complex ecological environments [5].

Plantations can offer some support for wildlife recovery, but Newbold and others have also found that land-use change caused by plantation forests significantly reduces local terrestrial biodiversity compared with natural forests [7]. Chazdon and Guariguata have also determined that the restored plantation forests generally have a lower level of animal diversity due to simpler habitat structures compared with those in natural forests [5]. Therefore, plantations should not be viewed as full-fledged replacements for natural forest ecosystems.

3.3. Comparison with natural forests

Natural forests generally have a high level of biodiversity compared with plantation forests [1]. Over a long time, natural forests have developed complex vegetation structures and many microhabitats with various ecological interactions that are difficult to replicate in plantation restoration. Primary forests have many different kinds of plants and animals, many of which are rare and specialised. These ecosystems provide the environment for a rich food web and other ecological processes [1]. Monoculture plantation forests are relatively simple in structure.

Research has repeatedly shown that plantations and natural forests have different numbers of species and communities. Although plantations have increased biodiversity compared to degraded land, it is far from the level of diversity in natural forests [5]. Therefore, plantation restoration should be regarded as an expansion of the protection area for existing natural forests, not a replacement. The other way to help protect nature is to preserve the remaining forests in the world [1].

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4. Ecosystem functions and carbon sequestration

4.1. Recovery of ecosystem functions

All kinds of ecological functions of forests include nutrient cycling, water regulation, soil stabilisation and habitat provision. Restoration aims to increase the quantity of trees and restore some of the ecological functions in those Areas.

Plantation Forests can help to restore some of the ecological functions. Roots of trees can stabilise the ground and curb erosion; the forest roof will also lower the temperature and increase humidity. Plantations can increase the soil's fertility gradually by adding litter and other organic matter [4].

Recovery of ecosystem functions is often not fully realised. Many ecological processes are the result of different biological communities and complex species interactions. Plantation forests generally have fewer species and simpler structures, so some ecosystem functions may take longer to recover than forest cover itself [2].

4.2. Carbon sink capacity of plantation forests

The second reason for building the plantation restoration site is to increase carbon sinks. Through photosynthesis, trees absorb atmospheric carbon dioxide and store carbon in biomass and soils. Plantation forests have accumulated more carbon over time [3]. As fast-growing tree species have a large quantity of biomass, they are often selected for afforestation. Therefore, plantation forests can help mitigate climate change to some extent. Therefore, many countries and organisations have increased investment in plantation-based carbon offset projects and afforestation efforts.

However, the Carbon Sink Ability of Plantations Differs. Generally speaking, multi-species plantations are relatively stable long-term carbon sinks because they are more resistant to pests, diseases and other environmental changes than monocultures. Natural forests generally accumulate a large amount of carbon over a long period due to a large biomass and complex structure [3].

4.3. Trade-offs between biodiversity and carbon sequestration

At the same time, forest restoration aims to protect biodiversity and increase the carbon sink function. Some of the restoration works focus on increasing carbon sinks quickly by planting fast-growing trees. Although this way can maximise the short-term carbon sink, it is not suitable for biodiversity protection goals.

Monoculture plantations are a typical case. Although they can sequester carbon effectively, they generally support relatively low levels of biodiversity [2]. At the same time, the diversity of native species in restoration may be higher; however, these approaches can also sequester carbon at a slower rate initially.

Recently, some research has shown that the goals of the restoration plan do not have to be in conflict with each other. Mixed-species plantations and natural regeneration can both increase biodiversity and carbon sequestration at the same time [8, 9]. Increase habitat complexity and support diverse biological communities to promote the long-term stability of the ecosystem and retain significant carbon sinks simultaneously.

Thus, the well-firthed forest restoration should have both biodiversity and carbon goals. Restoration projects that have only planted trees for carbon sequestration may have ignored other

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ecological benefits. Integrate biodiversity conservation in the planning for forest restoration to build an ecological forest system.

5. Factors limiting biodiversity recovery

5.1. Monoculture plantations

The other is that most of the Area is monoculture plantations. As there is only one type of tree, the vegetation structure is relatively simple and provides fewer ecological spaces for animals [10]. Therefore, many species of plants and animals have been unable to form stable populations. Monoculture plantations are also generally more susceptible to pests, diseases and other environmental factors and are thus less stable in the long run.

5.2. Habitat fragmentation

Habitat fragmentation reduces biodiversity restoration in the plantation forest. Many of the restoration projects are stand-alone patches in agricultural areas or urban areas. The broken-up areas are not connected, and thus it is difficult for animals to move around, reproduce and form large populations [2]. Limited gene flow among the isolated populations will reduce the species' adaptability and increase the risk of local extinction.

5.3. Poor soil conditions

Many plantation forests have been set up on severely degraded land with significantly reduced soil quality. Nutrient deficiencies, soil compaction and a reduction in beneficial microorganisms are all adverse factors for the growth of plants and the speed of ecological recovery. Although plantation trees gradually improve the soil conditions by decomposing leaves and increasing organic matter, the recovery of a healthy soil ecosystem usually takes many years [7].

5.4. Human disturbance

Human activities continue to impact the biodiversity restoration in the restoration area. Logging, grazing, tourism and the construction of facilities will damage the restored habitat and change the ecological succession. Good Management and extended protection are needed to help the plantation forest reach the goal of conservation. Reduce human disturbance to help improve the results of the restoration.

6. Strategies for enhancing restoration outcomes

6.1. Increasing native species diversity

A relatively large number of native trees will help to increase the variety of life in that Area. Native species are well-adapted to their local environments and have been supported for a long time by ecological interactions, such as pollination and seed dispersal [4]. They also offer a good home and food for native animals and help to stabilize the ecosystem.

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6.2. Mixed-species plantations

Multispecies tree and shrub forests have a complex structure and a large number of living spaces compared with single-species forests. A large number of different plants offer varied food sources for various animals, so these animals will better control pests and protect the environment [10]. Therefore, mixed-species plantations are gradually being used in ecological restoration.

6.3. Natural regeneration

Naturally regenerate where the environment is suitable to reduce planting costs. Natural regeneration needs relatively little money for tree planting and can help restore biodiversity and ecosystem functions more thoroughly [5]. Therefore, a combined approach of natural regeneration and active restoration may be more suitable for forest recovery.

6.4. Long-term biodiversity monitoring

Sustainably monitor the results of the restoration efforts. Most of the restoration projects aim to increase the forest area in the short run, but biodiversity restoration and ecosystem development take a long time. Monitor changes in species diversity, habitat quality, etc., of the ecosystem to adjust the management plan and improve the efficiency of restoration work. Adjust the long-term Ecological data to promote more sustainable forest restoration in the future through adaptive management.

7. Conclusion

Plantation-based forest restoration has been employed to address the problem of forest degradation and expand the area of forests to some extent, thereby reducing climate change. Assess how effectively plantation-type forest restoration can protect biodiversity and enhance ecosystem functions and carbon sinks at the same time in this paper. Plantations can provide a reference for the ecological restoration of degraded Areas through research, but their ecological benefits are subject to conditions such as plantation planning, selection of species and ongoing management.

Plantation forests are also good for the environment, as shown above. Increase the amount of forest cover rapidly, reduce soil erosion, enhance carbon sequestration, and provide habitats for the recovery of some plants and animals. Generally speaking, plantation forests are not suitable replacements for natural forests because they have a relatively simple vegetation structure, low species diversity and few ecological connections. Monoculture plantations generally have lower biodiversity than mixed-species plantations and natural forests. Therefore, the success of the restoration should not only be judged by an increase in forest area and carbon sinks, but also by the recovery of biodiversity, ecosystem services and long-term ecological resilience.

Although there are now many studies on plantation-based restoration, some deficiencies persist. Most of the existing research studies tropical forest ecosystems, and long-term monitoring data for other forest types are still lacking. Different Areas have different climates, soils, plant communities and management practices, so the results of restoration vary accordingly. Therefore, the restored areas in different ecosystems cannot be directly compared.

In the future, extended-term ecological observation will be conducted to determine how well the restoration efforts have increased biodiversity and improved ecosystem services. The restoration project will also use native trees and shrubs, mixed-species forest stands, etc., for natural regrowth. Incorporate the conservation of biodiversity with carbon sequestration and other ecosystem services

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to provide substantial support for sustainable forest management and the protection of global biodiversity through plantation-based forest restoration.

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