

Understanding Secondary Forests: From Definitions to Regional Case Studies in China

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Abstract: Forests are essential for maintaining environmental health and supporting human well-being. However, human activities and natural disturbances have greatly altered primary forests, forming secondary forests. This study examines the distribution and types of secondary forests in China, analyses the causes of their degradation, and discusses measures for their restoration. Secondary forests in China can be classified according to four criteria: age, location, natural characteristics and management measures. These classifications help to develop effective management strategies for secondary forests. The degradation of secondary forests in northeastern China is mainly caused by anthropogenic activities such as logging and natural disturbances. In addition, the total nitrogen and phosphorus contents of the surface soil of secondary forests were significantly reduced. Degraded secondary forests can be restored through natural succession and managed restoration practices. Natural succession, including secondary forest succession, refers to the gradual recovery and re-establishment of primary forests after disturbance. However, this process is slow and often requires human intervention to be effective. Managed restoration practices include dynamic management, conserving valuable tree seedlings, introducing ecologically critical species, and establishing mixed and multi-layered natural forests. Active human interventions, such as engineering and biological methods, are recommended for severely degraded forests to rapidly restore the natural landscape of secondary forests. Therefore, effective management and restoration practices that are tailored to the degree of degradation and successional processes are essential for the sustainability of these important ecosystems.


1 INTRODUCTION

Forests encompass one-third of the world's land mass. Humans depend on forests for food, shelter and energy. Forests are home to most terrestrial species and absorb carbon from the atmosphere, which helps regulate the global carbon cycle and mitigate climate change. Forest ecosystems can protect soil, stabilize river flow and water runoff, prevent land degradation and desertification, and reduce the risk of natural disasters such as droughts, floods and landslides. In addition, rivers near forests provide freshwater resources for human life, agriculture, industry and the environment. Forests are essential for climate regulation and biodiversity, but the world still faces the challenge of deforestation. Deforestation is mainly driven by agriculture, forestry and other land-use activities. This is one of the important factors leading to global greenhouse gas emissions. These

can reduce the forest's ability to adapt to threats such as climate change and habitat degradation, thus forming a negative feedback loop that ultimately leads to more biodiversity loss. Humans need to strengthen forest protection and conduct sustainable resource management to reduce damage to forests (UNEP, 2024).

Forest land refers to natural forests, secondary forests and artificial forests, including timber forests, economic forests, firewood forests, shelter forests and other types of forests, young forests and nurseries. Forest land resources are the land used to produce and reproduce forest resources and the most basic means of production for forestry production, including forested land, suitable forest land, sparse forest land, unforested afforestation land, shrub land and nursery land.

Secondary forests are naturally regenerating woodlands that arise after primary forests have

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undergone repeated unsustainable logging or extensive damage (Zhao et al., 2006; CATIE, 2016). These forests develop after the original environment has been significantly altered due to unsustainable logging, fuelwood collection, wildfires, agriculture, and excessive grazing. Secondary forests, although classified as natural forests alongside primary forests, replace the original forest communities and exhibit significant differences in structure composition, productivity, and ecological functions compared to primary forests. Additionally, forests that regenerate on sites where plantations have been harvested, including those with sprouting of planted species and mixed forests formed by invasive species, are also categorized as secondary forests (Zhao et al., 2006; CATIE, 2016). This paper introduces the distribution and types of secondary forests in China, the causes of secondary forest degradation and restoration measures.

2 IMPORTANCE OF SECONDARY FORESTS

With the continuous expansion of human activities and the intensification of environmental damage, the survival of secondary forests faces great threats. Human activities such as excessive logging, clearing and grazing have reduced the area of secondary forests and damaged the ecological environment (Yu et al., 2011). Secondary forests occupy a dominant position in China's forest resources, so their protection is vital. Secondary forests are crucial for soil and water conservation and play a key role in nourishing water, regulating climate, protecting the ecological environment and creating economic benefits. Their dense vegetation cover can effectively reduce soil erosion and protect soil quality while stabilizing regional water supply by storing water and regulating the hydrological cycle through forests. In addition, secondary forests can absorb carbon dioxide from the atmosphere and reduce greenhouse gas emissions, which helps regulate the climate and improve air quality. The conservation and restoration of ecosystem diversity also benefit from secondary forests, supporting the habitats of many rare and endangered species. From an economic perspective, secondary forests provide abundant timber resources and non-timber forest products, which provide employment opportunities and economic gains for local people and promote a virtuous cycle of sustainable development and ecological conservation. Therefore, effective management and conservation

measures can ensure that secondary forests continue to fulfill their ecological and economic functions, providing wide-ranging benefits and long-term sustainable development for all sectors of society (Liu, 2007).

3 DISTRIBUTION AND TYPES OF SECONDARY FORESTS IN CHINA

Secondary forests in China are widespread, constituting most of the country's forest resources. Excluding natural reserves, forest parks, undeveloped regions in Tibet, protected tropical rainforests, and scattered primary forests, all other forest areas are secondary forests (Figure 1). These secondary forests form the backbone of China's forest resources and are crucial for forest resource management.

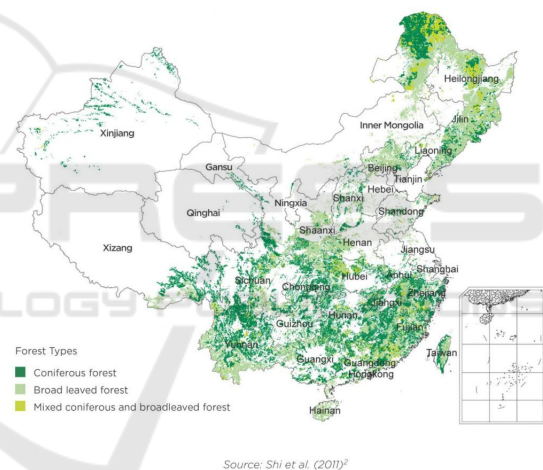


Figure 1: Distribution and types of secondary forests in China (Lei, 2011).

3.1 Types of Secondary Forests

Secondary forests in China can be classified based on different criteria for effective management (Liu et al., 2022):

Secondary forests in China can be classified based on various criteria to ensure proper management. These criteria include age, location, natural characteristics, and management practices. Firstly, secondary forests can be categorized by age into early-stage, mid-stage, and late-stage forests. Early-stage secondary forests are typically characterized by young, fast-growing pioneer species that quickly colonize disturbed areas. Mid-stage secondary forests represent an intermediate phase where a mix of

pioneer and climax species coexist with increasing structural complexity. Late-stage secondary forests are more mature, with a higher proportion of climax species and greater biodiversity, resembling primary forests more closely in structure and function.

Secondly, secondary forests can be classified by location, distinguishing between remote and near-urban secondary forests. Remote secondary forests are situated far from human settlements and are often less disturbed by human activities, allowing for more natural ecological processes. In contrast, near-urban secondary forests are located close to urban areas and often face higher levels of human impact, such as pollution, recreational use, and land-use changes, which can affect their structure and ecological function.

Thirdly, natural characteristics also serve as a basis for classification. This includes dominant species and species composition, ecological factors, and topographical and site conditions. Dominant species and species composition refer to the main tree species that define the forest type, which can vary widely depending on local climate and soil conditions. Ecological factors influence the forest's growth and development, including climate, soil type, and hydrology. Topographical conditions encompass the forest's location on slopes, valleys, or flat areas, affecting water drainage and sunlight exposure. Site conditions and dominant species highlight the interaction between the physical environment and the species that thrive there, providing a detailed understanding of the forest's ecological dynamics.

Lastly, management practices are crucial for the classification of secondary forests. These practices include thinning and tending, regeneration and rehabilitation, and utilization and protection. Thinning and tending involve selectively removing trees to reduce competition and promote the growth of remaining trees. Regeneration and rehabilitation efforts aim to restore degraded forests through natural or assisted regeneration, enhancing biodiversity and ecosystem services. Utilization and protection encompass sustainable harvesting practices and conservation measures to balance economic benefits with ecological integrity. By using these classification criteria, effective management strategies can be developed to enhance the sustainability and ecological function of secondary forests in China.

3.2 Distribution

Figure 1 shows China's forests are mainly located in the Northeast, a region with unique characteristics

and great research potential. Therefore, this section will focus on the distribution and types of forests, and specific tree species in the Northeast.

3.2.1 Northeast Region

The Northeast region includes the provinces of Heilongjiang, Jilin, and Liaoning, as well as the eastern parts of Inner Mongolia. The primary forest resources are concentrated in the Da Xing'anling, Xiao Xing'anling, and the Changbai Mountains (Figure 1).

The Da Xing'anling Mountain is located in the northwestern part of Heilongjiang Province and the northeastern part of the Inner Mongolia Autonomous Region. It is dominated by cold temperate coniferous forest and deciduous broad-leaved forests, with the main tree species being Dahurian larch and White birch (*Betula platyphylla* Suk.).

The Xiao Xing'anling Mountain is located in the northeastern part of Heilongjiang Province and is mainly a temperate mixed coniferous and broad-broad forest, with the main tree species including Korean pine and Yeddo spruce.

The Changbai Mountains are located in the eastern part of Heilongjiang, Jilin and Liaoning provinces. It covers from mixed coniferous forests in the north to broad-leaved mixed forests in the south (Yu et al., 2011). White birch is a deciduous broad-leaved tree that grows in high-altitude areas. It likes sunlight and can grow in cold places. It has low soil requirements and can survive in weak acid and weak alkaline soils (Chen et al., 2021). White birch is one of the dominant tree species in secondary forests of temperate regions.

The study shows that natural secondary forests of birch in the Da Xing'anling Mountain have significant roles in water conservation, soil conservation, carbon sequestration and oxygen release, accumulation of nutrients, purification of the atmospheric environment, and biodiversity conservation, especially in soil conservation functions. Near-mature forests in the southern part of the Da Xing'anling occupy an important position in the total value of ecosystem services. Near-mature forests are incompletely mature forests that usually have high productivity and ecological functions, but need to be developed in terms of wood quality, canopy structure and ecological functions. Although the value of ecological services per unit area was similar for trees in all age groups, the overall value of near-mature forests was significantly higher than that

of other age groups, highlighting the key role of near-mature forests in ecosystem services (Zhou et al., 2014). Since 1998, the Government of China has transformed the focus of forest management from timber production to ecological sustainability. Natural forest protection projects and a categorised management system have been introduced. These measures have included reducing the amount of timber harvested and increasing the area and stock of forests. They conducted a series of policies and regulations, scientific management methods, social participation and economic incentives. The management of secondary forests has made some progress in ecological conservation and sustainable development.

3.2.2 Southwest Region

Southwest China includes Sichuan, Chongqing, Yunnan and Tibet. The region has a varied topography, including lowlands, plateaus and mountains. Differences in altitude and climate create a wide range of forest types. In Sichuan and Chongqing, subtropical areas usually have secondary forests. In Yunnan, the forests contain both subtropical and temperate species. Tibet is characterised by high-altitude coniferous forests adapted to cold and dry conditions. These forests are important for watershed protection, biodiversity conservation and carbon sequestration. However, they also face pressures from agricultural expansion, logging and infrastructure development.

3.2.3 Southern Region

The southern region includes Zhejiang, Anhui, Jiangxi, Fujian, Hubei, Hunan, Guangdong, Guangxi, Hainan and Guizhou. The region has a subtropical climate with dense forest cover. Most of the secondary forests here consist of fast-growing, hardy tree species. Many areas have been replanted with economically valuable tree species. However, human activities such as logging, urbanisation and agricultural encroachment often threaten them. These activities have led to habitat fragmentation and loss of biodiversity.

4 SECONDARY FOREST DEGRADATION AND RESTORATION MEASURES

4.1 Impacts of Secondary Forest Degradation

Degradation of secondary forests is common, resulting in significant ecological issues. For instance, in the Northeast region of China, there are significant differences between secondary forests and the original Korean pine forests. The productivity of forest stands, species composition, and community biodiversity have changed obviously. The stock of large-diameter trees has decreased significantly, and the proportion of precious tree species has decreased significantly. The biodiversity and uniformity of the tree layer in secondary forests were also significantly lower than those in primary forests, with differences increasing significantly after moderate and severe disturbances. The total nitrogen and phosphorus content of the surface soil in secondary forests was reduced considerably.

4.2 Causes of Secondary Forest Degradation

The degradation of secondary forests is the decomposition of primary forests caused by human or natural disturbances.

Human disturbances include felling, grazing, and burning. These activities reduce competing plants and increase light and space to promote the growth of target tree species. However, they may destroy the ecological balance and lead to reverse succession if they are unreasonable. In history, the Northeast region has experienced a number of large-scale over-harvests, particularly during the Russian and Japanese occupations from 1896 to 1945 and large-scale timber production from 1950 to 1977. These activities seriously damaged the forest structure and ecological functions. Large-scale population movements and agricultural exploitation resulted in clearing large tracts of forest for cultivation (Yu et al., 2011).

Natural disturbances include storms and fires. These natural events change the vegetation structure, affect the competitive relationship of plant populations, and promote the formation of new plant communities. In general, disturbances cause significant changes in the species composition, spatial structure, and function of secondary forests, manifested in reduced biological productivity, deterioration of soil microenvironment, decreased

forest vitality, and disordered ecological processes. Some secondary forests have undergone serious reverse succession.

4.3 Restoration of Secondary Forest Degradation

4.3.1 Natural Restoration

Natural restoration includes secondary forest succession, which refers to the process by which primary forests gradually recover and rebuild after being disturbed by human or natural factors. This process involves the reorganization of ecosystems and the successional changes of plant communities. This usually starts with pioneer species and eventually reaches a top community state similar to that of primary forests. Secondary forests require more than two hundred years of succession to regain their primary forest function (Wu et al., 2023). Secondary forest succession is generally divided into three stages.

1) Initial stage: Pioneer species invade and occupy open space.

2) Mid-term stage: Environmental conditions gradually improve, and more adaptable species gradually replace pioneer species.

3) Late stage: The community tends to be stable and gradually forms a top community close to the original forest.

4.3.2 Managed Restoration Practices

In recent years, China has implemented various policies and management strategies to address these challenges. Natural forest protection projects and a shift in forest management towards ecologically sustainable development have played a key role. Ecological restoration, scientific management, community participation and economic incentives have facilitated the gradual recovery of secondary forests. These efforts include disturbance control, human intervention and near-natural management to enhance forest resilience and biodiversity. Human intervention in secondary forests varies according to their degradation level and the concept of positive succession, suggesting standards and measures for restoration. Typically, interventions are classified into two categories: addressing the degree of degradation and promoting active succession.

According to the degree of degradation of the secondary forest, there are three measures:

1) Slightly degraded secondary broadleaved mixed forest: It is suggested for natural recovery,

providing a good external environment, and promoting positive succession.

2) Moderately degraded secondary miscellaneous wood forest: It is suggested to adopt dynamic management, strengthen the protection of precious tree seedlings, appropriately carry out human intervention, introduce ecological key species, establish mixed and multi-layer natural forests, and promote positive succession.

3) Severely degraded closed-off tussah forest: According to the characteristics of the forest stand, it is suggested that active human intervention measures be taken. For example, engineering and biology can cultivate coniferous and broadleaved mixed forests dominated by oaks and restore the natural landscape of natural secondary forests as soon as possible.

According to positive succession of secondary forests, there are four ways to promote:

1) Controlled disturbance: Through reasonable felling and burning, it is suggested to reduce the shrub layer, increase light and space, and promote the growth of target tree species.

2) Artificial intervention: In the case of insufficient natural regeneration, it is suggested that artificial replanting be carried out to increase the density and regeneration rate of target tree species.

3) Protection and management: It is suggested that grazing and picking activities be reduced, seedlings and seed banks protected, and retrograde succession prevented.

4) Near-natural management: It is suggested that scientific management models be adopted, such as planting needles, protecting broadleaf trees, and improving forests' ecological stability and diversity through selective felling and replanting.

Despite these advances, significant challenges remain. Large areas of low-quality forests, high demand for timber and inconsistent management practices across regions pose a continuing threat to sustainable forest management.

5 CONCLUSION

This study emphasises the importance of secondary forests in Northeast China, focusing on the distribution of secondary forests, causes of degradation, and measures for revegetation.

The analyses showed that secondary forests in China are widely distributed in the Da Xing'anling, Xiao Xing'anling and Changbai Mountains, and play a significant role in China's forest ecosystems. However, historical overexploitation, agricultural expansion and natural disturbances have led to severe

degradation, as evidenced by declining productivity, biodiversity loss, and ecological imbalance.

Both natural and artificial restoration methods are needed to address secondary forest degradation. Natural restoration occurs through secondary forest succession and relies on pioneer species to gradually restore ecosystem functions, although this takes a long time. Managed restoration practices requires targeted human intervention. Mildly degraded forests can recover naturally, while moderately degraded areas benefit from dynamic management practices that protect seedlings and introduce key species to promote positive succession. Severe degradation requires active measures, including engineering and biological interventions, to restore mixed forests and re-establish natural landscapes. Promoting positive succession in secondary forests requires disturbance control, artificial interventions to increase tree density, conservation measures and near-natural management practices. These efforts are aimed at improving forest resilience and biodiversity.

Despite progress in restoration, challenges remain. Large areas of low-quality forests, high demand for timber resources and inconsistent management practices pose a continuing threat to sustainable forest management. Sustained ecological restoration, supported by scientific management and government involvement, remains critical to ensure the restoration and long-term viability of China's secondary forests.

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