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Factors affecting the structure and function of forest ecosystem: disturbance and climate change

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FACTORS AFFECTING THE STRUCTURE AND FUNCTION OF FOREST ECOSYSTEMS: DISTURBANCE AND CLIMATE CHANGE

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Abstract

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This paper discusses the effects of climate change and disturbance on forest ecosystems. At present, the increasing temperature caused by global warming and the occurrence of various fire events has posed a huge challenge to forest managers. In this paper, the effects of climate change on the structure and function of forest ecosystems and the effects of disturbance factors on ecosystem services were discussed through literature review and database comparative analysis. As we learn more about the effects of these factors on forest ecosystems, we can urge forest managers to better protect forest ecosystems and promote their sustainable development through human activities in the future.

Keywords: forest ecosystem, climate, disturbance, influence, forest landscapes, forest biodiversity.

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1.0 Introduction

Nowadays, climate change affects changes in the world, and people are generally worried that climate change will change the natural disturbance mechanism, which will have a negative impact on the forest ecosystem. Recent changes in disturbance mechanisms in certain regions, such as increased wildfire activity and large-scale insect outbreaks in North America, have been attributed to climate change (Pavel et al., 2017). Regarding climate change, although there is sufficient evidence that climate change will affect forests of all ages, we lack a comprehensive understanding of how climate change will interact with forest age to affect forest restoration (Kristina et al.,2013). Therefore, in order to assess the continuous changes and future changes of climate change and disturbance conditions, it is necessary to establish a summary to sort out their different effects on forest ecosystems.

By definition, disturbances are short events relative to the longer time frame of forest dynamics, but they may have long-term effects on forest structure and composition. For example, disturbance can change the age structure of forest landscapes, benefit early species, and change the development trajectory of forest ecosystems. This effect can last for centuries after the disturbance event (Pavel et al., 2017). Due to the long-term impact of disturbances on forest structure and composition, past disturbances may also greatly affect the current and future ability to provide ecosystem services to human society (Thom and Seidl, 2016). Therefore, in this article, we will also discuss and analyze the long-term disturbance activities in the past, hoping to reduce relative errors and contribute to future forest management.

For disturbance events, disturbance can be divided into two categories: man-made disturbance and natural disturbance. Both man-made disturbance and natural disturbance will affect the composition, structure and functional process of the forest system, thereby affecting it (Virginia et al., 2001). In fact, American forests are shaped by their land use and disturbance history. In the United States, the natural disturbances that have the greatest impact on forests include fires, droughts, alien species, insect and pathogen outbreaks, hurricanes, storms, ice storms and landslides. Each disturbance has a different impact on the forest. According to Virginia (2006), some disturbances will cause large-scale tree deaths, while others will affect community structure and organization without causing large-scale deaths (for example, ground fires)

1.1 Objective:

In this article, I have expanded the broad definition of disturbance and reviewed the research on the impact of climate and disturbance on forest ecosystems. Specifically, I will answer a few questions 1) The impact of climate on the diversity of forests and the distribution of age structure is beneficial or harmful. 2) How disturbing factors affect forest ecosystems? 3) In future forest management, should disturbance and climatic factors be regarded as natural components of forest ecosystem dynamics or disadvantages?

2.0 LITERATURE REVIEW

2.1 Forest ecosystem

2.1.1 Background

Forest ecosystems include forest organisms, which extend vertically upwards to the atmosphere surrounding the forest canopy, and then downwards to the lowest soil layer affected by roots and biological processes. In a sense, forest ecosystems are open systems that can exchange energy and materials with other systems, including neighboring forests, aquatic ecosystems and the atmosphere (Richard 2007).

2.1.2 Features

Ecosystem services have been defined as the benefits people get from the ecosystem and have been divided into four categories. These services include food, water, wood and fiber supply services; monitoring services that affect climate (such as carbon sequestration), pollination, biological pest control, flooding, disease, waste and water quality; providing cultural services for entertainment, aesthetics and spiritual benefits; And support services such as soil formation, photosynthesis and nutrient cycling (Aerts 2011). In Canada's northern forests, about 40% of the forest area is covered by permafrost, some of which have been irreversibly degraded, triggering a process of forest degradation and reconstruction that lasted for decades. At the same time, it also releases a large amount of greenhouse gases, which will intensify future global warming trends.

2.2 Fire

The frequency, size, intensity, seasonality, and type of fires depend on weather and climate in addition to forest structure and composition. Fire initiation and spread depend on the amount and frequency of precipitation, the presence of ignition agents, and conditions (e.g., lightning, fuel availability and distribution, topography, temperature, relative humidity, and wind velocity) (Ayres 2000).

2.3 Climate

Climate change may change the dynamics of forest restoration, or even prevent restoration, trigger feedback to the climate system, change regional biodiversity, and affect the ecosystem services provided by forests (Anderson 2013). Climate controls the speed of weathering and biological processes (Wagai et al. 2011) and influences forest vegetation and structure. The ongoing changes in the global climate system have already altered disturbance regimes in some ecosystems. For example, insect outbreaks have spread to higher latitudes and altitudes as a result of reduced thermal constraints by warming temperatures (Weed, Ayres & Hicke 2013). The positive influence of warming on insect population dynamics – increasing reproductive rate and reducing winter mortality – has led to increasing damage in some forest ecosystems (Seidl et al. 2014). Concurrently, climatic extremes such as longer and more intensive droughts are increasing the susceptibility of trees to insect attacks via exhaustion of non-structural carbohydrate reserves, weakening secondary defence reactions to bark beetles (Bentz et al. 2010).

2.3.1 Storm

Storms can cause high mortality, damage tree canopy, reduce tree density and size and structure, and change local environmental conditions. These effects can change succession patterns, gap dynamics and other ecosystem-level processes. In different forests and species, the relationship between wind intensity and disturbance severity is not constant; although species with shallow roots and sparse forest stands may be particularly susceptible to wind, many factors affect the resistance of trees to strong winds reaction (Ayres 2000).

2.3.2 Drought

Droughts occur in nearly all forest ecosystems. Drought effects are influenced by soil texture and depth, exposure; species present; life stage; and the frequency, duration, and severity of drought. Droughts occur irregularly in forests of the humid regions east of the Mississippi River and in the superhumid Pacific Northwest (Hanson 2000). The consequences of drought depend on annual and seasonal climate changes and on whether the current drought adaptations are sufficient to confer resilience to new conditions (Hanson and Weltzin 2000).

2.4 Disturbance

In the past few decades, forest disturbance has been increasing in many parts of the world (Chapin et al. 2000). In many areas, changes in interference types (i.e. unique types, magnitudes, severity, and frequencies on extended time and space scales) are expected. Disturbance is one of the most serious impacts of climate change on forest ecosystems (Lindner et al. 2010). Therefore, constantly changing. The disturbance system may greatly change the forest ecosystem, and it may have a profound impact on its biodiversity and the ability to provide ecosystem services to society (Thom et al. 2016).

Disturbances, both human-induced and natural, shape forest systems by influencing their composition, structure, and functional processes. Indeed, the forests of the United States are molded by their land-use and disturbance history. Within the United States, natural disturbances having the greatest effects on forests include fire, drought, introduced species, insect and pathogen outbreaks, hurricanes, windstorms, ice storms, and landslides. Each disturbance affects forests differently. Some cause large-scale tree mortality, whereas others affect community structure and organization without causing massive mortality (e.g., ground fires) (Hanson 2000). Natural disturbances cause abrupt changes in forests with a lasting effect on forest dynamics and succession over decades to centuries (Carpenter & Turner 2001). Disturbance by, for example, wildfire, bark beetles or windstorms causes pulses of tree mortality, disrupts ecosystem structure, community or population, and changes resource availability in the biophysical environment (Turner 2010). Forest species are well adapted to and have co-evolved with disturbance regimes (Gutschick & BassiriRad 2003). Forest disturbances are discrete events that lead to the death of trees and the destruction of plant biomass (Pickett and White 1985, Seidl et al. 2011a). Disturbances from factors such as wildfires, bark beetles, or strong winds are common in forests around the world (Johnson and Miyanishi 2006). For example, in European forest ecosystems, the two most important abiotic and biological disruptors (wind and bark beetles) together account for an average annual loss of 0.13% of tree stock (Schelhaas et al. 2003).

3.0 Materials and methods

3.1 Literature synthesis

A literature review was done using the keywords: forest ecosystem, disturbances, climate change. I searched the literature about the related effects of fire and climate change on forest ecosystems and research on forest species diversity. Since the ecological processes and human impacts of subtropical and tropical forests are very different, my literature review was limited to the frigid and temperate forest ecosystems. At the same time, the diversity of temperate forests is generally not as good as that of tropical forests, and they share common genus and driving factors of forest dynamics (such as temperature) (Thomas & MacLellan 2002). Furthermore, land-use history and recent management differ strongly between tropical and extratropical regions, with a long history of intensive human use and several decades of sustainable management in the temperate and boreal zone (Siry, Cubbage & Ahmed, 2005; Canadell & Raupach, 2008). Because ecological processes and anthropogenic influences in subtropical and tropical forests are generally very different, our literature review is limited to boreal and temperate forest ecosystems.

I collected articles on forest disturbance and boreal forests in the Scopus database from 1958 to 2013, made statistics, and evaluated the impact of disturbance on ecosystem services and biodiversity indicators. In this step, I descriptively categorized the impact of interference based on the findings reported in the literature (i.e., the negative, neutral, mixed, or positive impact of interference on various indicators). This classification allows us to uniformly and comprehensively use different methodological methods to obtain sufficiently accurate results. I summarized articles on related topics, summarized and compared them and finally concluded that within the margin of error, the impact of some interference factors on the forest ecosystem. At the same time, through the statistics of current and future climate data by many researchers, we inferred whether the impact of climate change on forest diversity and ecosystems is beneficial or harmful.

According to Thom's article in order to determine the magnitude of the interference impact, it is necessary to determine the quantitative information about the interference impact. He found that a meta-analysis can be conducted for two special research criteria: biodiversity and carbon storage.

3.2 Data analysis

3.2.1 Canadian Northern Climate Data:

In the past, most studies have used the General Cycle Model (GCM) to simulate the global climate's response to potential changes in atmospheric composition in the past and in the future. Price et al. (2011) et al. calculated the weighted average changes in the area of all Canadian terrestrial ecoregions and found that the level of agreement between GCMs on annual and seasonal averages is generally high, especially for long-term temperature increases. Trenberth et al. (2010) analyzed experimental data and obtained the “committed warming” caused by greenhouse gas emissions that have occurred in two to thirty years: only about 20 years later. By 2040, when early mitigation efforts clearly begin to have an impact, the trajectory of warming will change. In the future, the range of possible warming will expand, mainly because of differences between different greenhouse gas emission trajectories (Figure 1). , The variability of precipitations that precipitates in the future is expected to be greater than the variability observed recently (Figure 2).

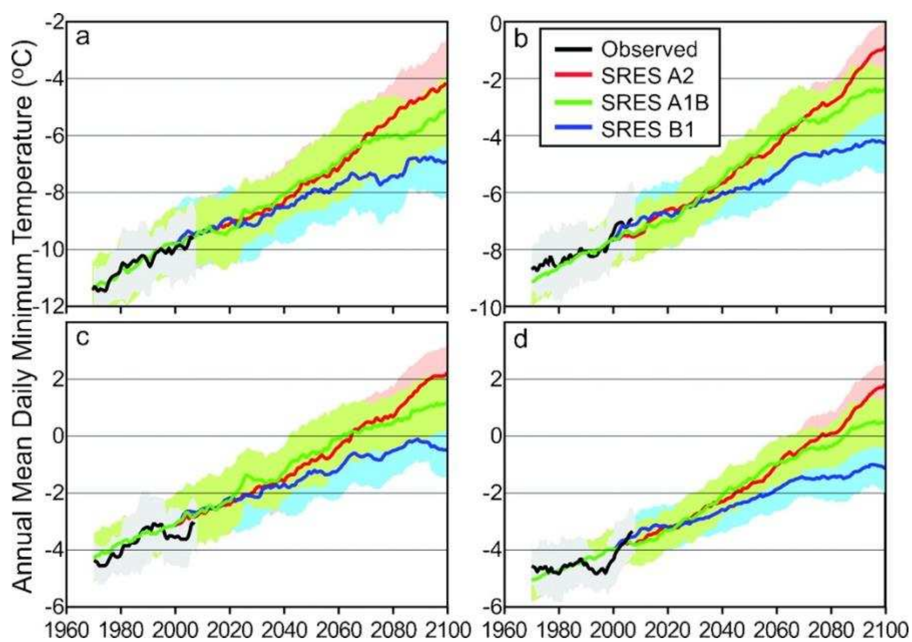
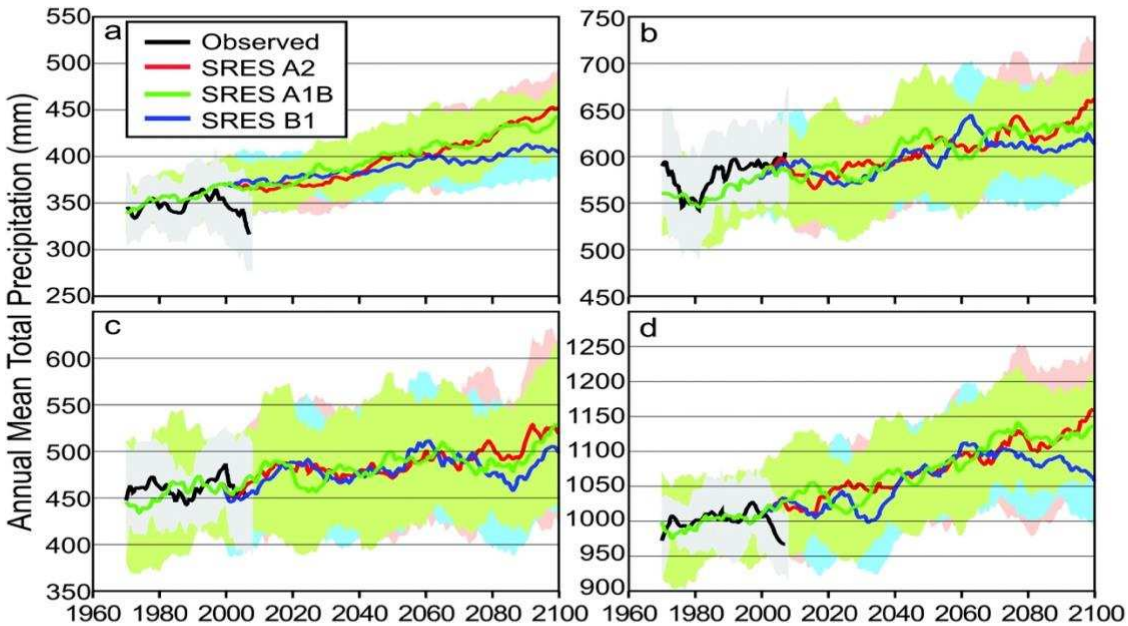


Figure1: Projected trends in annual mean daily minimum temperature (°C) in four representative boreal ecozones for the period 1960–2100, obtained from climate projections in the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report (e.g., Meehl et al. 2007). Also shown are observed data for the period 1960–2008. (a) Taiga Plains; (b) Hudson Plains; (c) Aspen Parkland; (d) Boreal Shield East. Lines are 10-year moving averages of projections from four different general circulation models (GCMs), forced by the same IPCC Special Report on Emissions Scenarios (SRESs) greenhouse gas forcing scenario (David 2013).



(Figure 2: Projected trends in annual precipitation (mm) in four representative boreal ecozones for the period 1960–2100, obtained from climate projections in the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report (e.g., Meehl et al. 2007). Also shown are observed data for the period 1960–2008. (a) Taiga Plains; (b) Hudson Plains; (c) Aspen Parkland; (d) Boreal Shield East. Lines are 10-year moving averages of projections from four different general circulation models (GCMs), forced by the same IPCC Special Report on Emissions Scenarios (SRESs) greenhouse gas forcing scenario (David 2013).

3.3.2 Disturbance data:

I researched the literature on the impact of fire, wind and other disturbances on forest ecosystem services and their impact on biodiversity. Seidl et al. (2014) focused on the total carbon storage of ecosystems (TEC), including living and dead vegetation components and the carbon in the soil (maximum soil depth does not exceed 100 cm). At the same time, they created an individual-based forest landscape model iLand to analyze the HJ Andrews Experimental Forest in the U.S. Small Falls (44.2°N, 122.2°W) in Western Oregon, USA. The fire frequency is doubled, reaching an average fire return interval of 131 years, which can reduce TEC by 10.5% and the presence of LSS (late species) in the landscape by 18.1% on average. Thom& Seidl (2016) mentioned that with regard to disturbance agents, the effects of forest fires are the most common in most of the literature, while only a few studies have investigated the effects of wind and the effects of bark beetles.

4.0 Result

4.1 The impact of climate change on forest ecosystem

4.1.1 The impact of climate change on the functions of forest ecosystems

Overall, there is strong evidence that climate has a clear effect on forest ecosystems. These reasons may be due to the increase in temperature caused by climate change, or the increase in the concentration of carbon dioxide in the atmosphere, which has many effects on the function of the ecosystem. In the article by David et al. (2013), it is mentioned that the impact of climate on forest ecosystems can be roughly divided into direct impact and indirect impact. Direct effects include the effects on the key processes of photosynthesis, respiration and transpiration common to all vascular plants, as well as the effects on the activity of all heterotrophic organisms from bacteria to vertebrates. From a comprehensive perspective of several articles: climate change may have a variety of effects, including the extension of the plant growing season. Climate change may cause more intense convective storms, leading to more lightning fires; wind disasters and/or floods; and other uncommon phenomena such as ice storms in early spring and frosts in spring after destruction (e g, Hoffer and Tardif 2009; Payette et al. 2010; Tardif et al. 2011). These effects will be accompanied by the negative effects of large-scale vegetation in the north.

As the temperature rise in climate change will cause the forest area in the northern permafrost region to gradually decrease, Chen (2000) used GIS to study five forest landscapes on the forest distribution map of Heilongjiang Province in northern China from 1896 to 1986. The results showed that during these 90 years, spruce-fir (Picea abies), fir and dogwood.) fell by 87%, 40% and 84%, respectively. The area of broad-leaved forest north of 51°N has increased by 500%, and the northern boundary extends approximately 290 km northwest. From this, we can see that if the climate continues to warm, the proportion of coniferous forests in northern China will decline, and the proportion of broad-leaved forests will increase. The stronger the warming, the more obvious the trend. In the article of Wu (2003), it was mentioned that under dry and warm climate conditions, the distribution range of broad-leaved Korean pine forests in Northeast China had decreased significantly, and its ability to adapt to the new ecological environment has also decreased. At the same time, according to the climate change data mentioned above, because the climate data has changed greatly in a few years, during the climate transition period, forests will not be able to provide many of the ecosystem services provided in the past: there will be fewer trees. As a result, the economic value is reduced, and at the same time, the carbon storage will be reduced. All in all, there is strong evidence that climate change will have a negative impact on the functioning of forest ecosystems.

4.1.2 The impact of climate on the diversity of forest ecosystems

In our literature sample, we found that complete ecosystems are very unlikely to move completely as climate zones change (Hansen et al. 2001 and David et al. 2013). In northern Canada, climate warming may severely affect reindeer in woodlands (Thompson et al., 1998; Racey, 2005; Vors and Boyce, 2009). Climate warming affects the distribution of habitats, and further affects the predation of animals and the availability of food. As we mentioned above, climate change may lead to widespread permafrost degradation, which will cause the habitat of woodland reindeer populations to suffer severe loss, further affected the number of species populations.

By contrast, we find that climate change mostly refers to temperature increases, which trigger changes in tree species distribution and in the age, number and type of debris and may lead to long-term changes in fungal communities. Therefore, due to the direct or indirect impact of climate change, the loss of tree species in a certain area will affect the survival of fungal symbionts.

4.2 The impact of disturbance on the forest ecosystem

4.2.1 The impact of disturbance on the functions of forest ecosystems

We observed that of the disturbance factors we examined in the literature, the effect of forest fires was the most common, while there were fewer studies on the effects of disturbance factors such as wind on forest ecosystems. In contrast, we found that almost all categories of ecosystem services (such as support, delivery, regulation, and cultural services) were negatively affected by the disruption. Some of these examples show that the reduction of biomass in an ecosystem affects carbon stocks, but there are also examples where individual perturbations have a positive effect on carbon stocks. For example, Chen (2010) mentions that in the boreal forest ecosystem of Ontario, ALC peaked 92 years after disturbance and then dropped to a significantly lower level after 140 years of disturbance in the following decades. Stable within the year. We found that compared with the northern ecosystem, the negative effects of disturbance on ecosystem services were more obvious in temperate communities. Meanwhile, the disturbance has a stronger positive effect on the biodiversity of temperate communities than that of frigid communities.

In the data analysis section, we mentioned that in the literature on disturbance factors we investigated, the impact of forest fires is the most common, while only a few studies have investigated the impact of wind and other disturbance factors on forest ecosystems. Almost all ecosystem service categories (such as support, provision, regulation, and cultural services) are negatively affected by disturbance. Some of these examples show that the reduction of living biomass in the ecosystem affects carbon storage, but there are also instances where individual disturbances have a positive impact on carbon storage. For example, Chen (2010) mentioned that in the boreal forest ecosystem of Ontario, ALC peaked in 92 years after the disturbance, and then fell to a significantly lower level in the following decades, after 140 years of disturbance. In the literature search, I compared the different performances of disturbance effects in northern ecosystems and temperate ecosystems and found that compared with northern ecosystems, disturbances in temperate biological communities have more obvious negative impacts on ecosystem services. At the same time, compared with the frigid zone biological community, the disturbance has a stronger positive impact on the biological diversity of the temperate zone biological community.

4.2.2 The impact of disturbance on the diversity of forest ecosystems

Most of the documentation I collected shows that interference has a positive impact on biodiversity. At the same time, disturbances had positive effects on species richness, habitat quality and diversity index. However, this may be due to regional differences. There are also some studies showing that disturbance has a negative impact on the biodiversity of forest ecosystems. So far, there have been more and more studies on the effects of disturbance factors on the forest ecosystem, but there are often significant differences due to different regions. Even so, as the number of such articles increases, we can gain a better understanding of what distractors are.

4.3 Prospects for future forest management

In the research papers we have observed, the disturbance has a negative impact on ecosystem services as a whole and has a positive impact on biodiversity as a whole. If forest managers are to improve forest biodiversity, they can be incorporated into the way they manage forests. If the forest manager is to better maintain the service and stability of the forest ecosystem, interference will have an adverse effect on it, and we should try to avoid the occurrence of interference events.

Regarding climate, according to statistics, climate change will definitely affect most northern ecosystem processes and have a significant impact on the structure and function of forest ecosystems and ecological services. At present, the negative impacts are all substantive. However, it does not rule out that the consequences of future climate change are all negative. It is very likely that in the future, as a result of climate change, global temperatures will rise, leading to increased precipitation and global carbon dioxide concentrations, which may greatly increase forest productivity in the cold zone. It is worth noting that due to global warming, most of the permafrost vegetation in the boreal forest is reduced, and it may take a long time for us to maintain the forest vegetation of the forest. Therefore, on the whole, the impact of climate change on the forest ecosystem is negative. For forest managers, they should call on everyone to protect the Earth's environment and avoid global warming events to protect the stability of the forest ecosystem.

5.0 Conclusion

Climate change category(e.g.)	Impact on ecosystem services	Impact on biodiversity
Excessive temperature	Decrease in carbon storage. Ecosystem services cannot be properly provided	Affects the size of the species population by affecting the distribution of the habitat. Affects the survival of the fungal symbiont. Reduces biodiversity.
Cyclone		
Flood		
Storm		

(Table1: Impacts of climate change on ecosystem services and biodiversity.)

Disturbance category(e.g.)	Impact on ecosystem services	Impact on biodiversity
Fire	Reduce the total carbon storage of the ecosystem. Timber and primary production decreased.	Species richness increased. Increased habitat quality. The diversity index was positively affected.
Invasion of alien species		
Insect Pathogen Outbreak		

	Protection against gravity natural disasters is negatively affected.	

(Table2: Impacts of disturbance on ecosystem services and biodiversity.)

In the discussion of this article, we summarized the impact of climate change and disturbance on forest ecosystems from the literature database. Among them, most studies have shown that climate change will have many negative impacts on forest ecosystems, such as reduced vegetation and reduced biodiversity. At the same time, according to data from the Bureau of Climate Change, the global temperature will continue to rise in the next few decades, which will pose a huge challenge to the forest ecosystem in the frigid zone. Our review shows that the impact of disturbance on forest ecosystems is very complex. On the one hand, there are data showing that disturbance factors have a good impact on forest biodiversity, which will increase the abundance of species. However, at the same time, interference factors can also destroy the service function of the ecosystem (for example, reduce the total carbon storage of the ecosystem). In this case, if we want to develop a good forest ecosystem in the future, we need to weigh the pros and cons between the two to achieve a balance between negative and positive effects. This article only summarizes part of the literature on forest ecosystems and cannot cover all the impacts of climate change and disturbance on forest ecosystems, so there may be data inaccuracies. In the current situation, we need to protect the environment to reduce the impact of the temperature rise caused by climate change on the forest ecosystem. On the other hand, we must adapt to changing interference mechanisms so that we can continue to provide forest ecosystem services in the future.

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