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Research on the effects of global warming on forest litter decomposition

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Abstract: Global warming is currently one of the foremost environmental challenges, exerting a profound and extensive influence on natural ecosystems. The alteration of forest litter, as a crucial source of organic matter within these ecosystems, plays a pivotal role in the context of global warming. Litter decomposition represents the process through which carbon and nutrients contained therein are transferred, serving as a crucial nexus for vegetation-litter-soil nutrient cycling and biogeochemistry, playing a significant role in soil nutrient composition. This paper aims to investigate the impact of global warming-induced changes in certain factors on the rate of forest litter decomposition, while evaluating their potential implications for ecosystem function, the carbon cycle and climate change. This study delves into the complex interplay between various environmental factors and their impact on forest litter decomposition. The five factors examined in this research—temperature, precipitation, snow cover and associated freeze-thaw phenomena, soil composition, and disasters—all play a crucial role in shaping the rate of decomposition. Based on the findings presented in this paper, it can be inferred that global warming will exert direct or indirect influences on forest litter decomposition from multiple perspectives.

Keyword: Global Warming, Forest Litter, Decomposition Rate, Ecosystem Function, Carbon Cycle.

1. Introduction

The phenomenon of global warming, caused primarily by the excessive emission of greenhouse gases into the atmosphere, has far-reaching consequences for our planet [1-3]. One of the most significant impacts is the redistribution of global precipitation and glaciers. As temperatures rise, more water evaporates from oceans and land surfaces, leading to an increase in atmospheric moisture content. This excess moisture then falls as rainfall or snowfall in different regions around the world. As the primary mechanism for nutrient cycling in forest ecosystems, litter decomposition is predominantly influenced by temperature, making it susceptible to the impacts of global warming. Although forest litter is a hot research topic in recent years, it also faces some problems. There is not enough systematic research on forest litter, which leads to scattered research results and the omission of some influencing factors. For example, the traditional perspective that only focuses on nitrogen and phosphorus does not pay attention to the effects of sodium and potassium. In this paper, the literature reference method is used to summarize the previous studies to further reflect the comprehensive impact of global change.

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2. Influence factor

2.1. Temperature Impact

The increase in global temperature is a fundamental characteristic of climate warming, as it has a significant impact on the composition of decomposed nutrients found in litter. Based on studies conducted on various plant species across different latitudes, it has been observed that changes in leaf nitrogen (N) and phosphorus (P) content are highly sensitive to temperature variations. Consequently, alterations in temperature may directly influence both the quantity and rate of forest litter decomposition. According to the experimental records published in the European Journal of Forest Research, the data indicate a positive correlation between temperature and the content of nitrogen (N) and phosphorus (P). However, it should be noted that different decomposition sites exhibit varying control factors for litter decomposition, resulting in differential effects of temperature. Current research findings highlight that climate and other factors exert significant influences on fine root litter [4]. The increase in temperature simultaneously enhances the enzymatic activity involved in litter decomposition, thereby accelerating the rate of litter decomposition [5]. Research findings indicate that under identical conditions with temperature as the sole variable, an elevation in temperature expedites the decomposition process for individual litters of Mongolian oak and red pine [6].

2.2. Rainfall Impact

The most immediate effect of warming on the climate is the unprecedented water vapor content, as rising temperatures allow more water vapor to be held in the air. According to the China Meteorological Administration, a one-degree Celsius rise in temperature can hold 7 percent more water vapor in the air. A large number of observational data show that the middle and high latitudes and tropical areas generally show an increasing trend of precipitation, while the subtropical areas generally show a decreasing trend of precipitation, so that dry places become drier and wet places become wetter [7]. Rainfall affects soil biological activity including the decomposition of forest litter, due to soil moisture and temperature. Leaching by rainfall increases the mass loss of litter at the beginning of the decay process [8]. Based on previous work by some researchers, we can speculate that the mass loss observed in fully exposed and partially exposed litter is due to leaching [9]. Despite the presence of mulch, the litter-soil interface remained moist and remained within the threshold range for microorganisms. As a result, even when litter is covered, the litter-soil interface still becomes moist, allowing litter-breaking organisms to survive and remain active in soil bio-chemical processes [10].

2.3. Snow cover and freeze-thaw effects

Forest litter decomposition is also influenced by freeze-thaw patterns under varying snow depths. The depth of the snow impacts the internal soil temperature, with excessive thickness resulting in decreased soil temperature and increased frequency of freeze-thaw cycles. As global warming progresses, there will be a reduction in the extent of snow cover. The freeze-thaw process encompasses freezing, deep freezing, and thawing stages. The decomposition of litter during the freeze-thaw period is a crucial ecological process in permafrost regions [11]. Two approaches were employed to investigate the impact of snow cover changes on litter decomposition: forest window - examining natural snow gradients within forests and controlling artificial snow thickness. It is concluded that the decrease in snow cover will lead to an increase in freeze-thaw cycles, which will slow down the decomposition rate of litter due to a decrease in microbial numbers and enzyme activity. The existing literature suggests that freeze-thaw cycles can induce both physical and chemical damage to litter, facilitating enhanced contact between litter and decomposers, thereby promoting decomposition. However, frequent alternations of freeze-thaw events may have an opposing effect on this process. Furthermore, the presence of snow can further influence litter decomposition by affecting its quality and the release of essential elements.

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2.4. Influence of soil composition

Studies have shown that global warming increases soil temperature and accelerates the rate of microbial decomposition of organic matter [12]. This phenomenon of global warming is more obvious through positive feedback, which also affects microbial growth, enzyme activity, mineralization rate and microbial community composition [13]. Under the action of biological and abiotic factors, litter can release nutrients back to the soil for reuse by green plants, thus realizing the circulation of matter and energy. Litter decomposition may also be an important factor in soil organic carbon accumulation. In order to study the effect of soil microorganisms on the decomposition of forest litter, a large number of studies have been carried out internationally, including but not limited to the litter net bag method, the chemical reagent removal method, and the microcosmic method [14]. As an important biological factor that can affect litter decomposition, soil animals can directly or indirectly affect its decomposition rate through burrowing, feeding and stimulating microbial activities [15]. The increase of temperature will make soil animals and microorganisms more active, which will accelerate the decomposition rate of litter. In studies on tropical rainforests, researchers found through litter bag experiments that there was a strong interaction between litter and soil animals, and soil animals might increase the content of nitrogen in litters by enhancing the stimulation of microorganisms, making the mineralization of N by microorganisms more intense and affecting the release of nitrogen [16]. The change in litter C/N value enables microorganisms to successfully promote litter decomposition. The effects of climate change include temperature and humidity, so the soil characteristics may be closer to the soil characteristics of tropical rain forests, so the data from tropical rain forests can be used as a reference for our research.

2.5. Disaster impact

Greenhouse gases are a crucial contributing factor to global warming, while the emission of sulfur dioxide and nitrogen oxides results in acid rain formation. The phenomenon of global warming leads to temperature increases and climate alterations, with research indicating that natural disasters like acid rain significantly impact forest litter decomposition. Cheng Yu et al. conducted a simulation experiment to investigate the impact of acid rain on litter decomposition. By conducting decomposition tests on leaves of Schima Superba and Masson pine under varying pH values and precipitation levels, they observed that both species exhibited increased litter decomposition with higher water content and longer decomposition time, indicating a positive correlation [16]. Global warming not only intensifies the phenomenon of acid rain, but also increases land temperature and evaporation in summer. In the interior of continents such as the Taklimakan Desert in China, water vapor is harder to reach, resulting in less precipitation and increased evaporation, which makes desertification more pronounced and leads to a loss of soil nutrients and decreased productivity. Li Yuqiang et al. studied the impact of desertification on litters and found that with the aggravation of desertification, the decomposition rate of litters would also decrease, and the release rate of C and N would slow down. Studies have shown that the rise in temperature caused by global warming, the extension of dry periods, and the decrease in air humidity will lead to the advance and extension of the fire risk period, and the frequency and area of forest fires will increase, and the intensity of each forest fire will be more powerful than before. Forest fire, as the most common natural disaster in forest ecosystem, will also affect the decomposition of litter. Because of the speed and size of the ground fire, it not only enhances the rate of decomposition of forest litter but also breaks down more rapidly than conventional methods such as small soil animals.

3. Conclusion

Global warming and forest litter have been hot topics in recent years because they are related to the future fate of mankind and the future direction of forest ecosystems. Because forest litter determines soil nutrients and the overall material and energy cycle of forest ecosystems. Therefore, people need to pay close attention to all the factors that affect the decomposition of forest litter, so as to avoid its great changes and affect the forest ecosystem. As one of the important pillars to maintaining global biodiversity, forest resources insulate and store carbon in the atmosphere, help regulate the global carbon cycle, and slow down the trend of global warming. As temperatures change more and more, the status

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of forest resources increases. As temperatures change more and more, the status of forest resources increases. To explore the effects of global warming on the decomposition of forest litter, the purpose is to explore the changes of various factors and their effects on the decomposition rate. Many researchers around the world have conducted in-depth and specific discussions on the impact of forest types on litter decomposition. Based on the above analysis of various factors affecting forest litter due to global warming, the study makes the following recommendations. First, because different responses of microorganisms to nutrients affect carbon release patterns, microorganisms can be regulated to optimize carbon sinks and protect forest resources. Second, studies have shown that phosphorus and sodium can promote the release of CO2 from leaf litter when warming occurs. Therefore, carbon sinks can be protected by controlling excessive input of phosphorus and sodium. Third, no clear conclusion has been drawn on the specific mechanism by which nitrogen deposition affects litter decomposition. Therefore, even though a large number of research data points are still uncertain, further research on nitrogen deposition is still needed to make a breakthrough. Finally, due to the significance of forest litter decomposition and the long time required by many factors, there are still many factors that have not been deeply investigated, and no specific conclusions have been drawn. Therefore, it is necessary to establish a set of special research methods for forest litter decomposition and to detect and estimate its decomposition rate for a long time.

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