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# Research progress of extreme climate and its vegetation response

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# Research progress of extreme climate and its vegetation response

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**Abstract**. The IPCC's fifth assessment report indicates that climate warming is unquestionable, the frequency and intensity of extreme weather events may increase, and extreme weather events can destroy the growth conditions of vegetation that is otherwise in a stable condition. Therefore, it is essential to research the formation of extreme weather events and its ecological response, both in terms scientific development and the needs of societal development. This paper mainly examines these issues from the following aspects: (1) the definition of extreme climate events and the methods of studying the associated response of vegetation; (2) the research progress on extreme climate events and their vegetation response; and (3) the future direction of research on extreme climate and its vegetation response.

## 1. Introduction

Climate change is one of the most important environmental events that human beings are facing in the 21st century, and global climate change has drawn much attention in the past century. The Intergovernmental Panel On Climate Change's fifth assessment report indicated that climate warming is unquestionable, and the earth's surface has continuously warmed in the past three decades, more so than in any other period since 1850 [1]. Both the current and future trends in extreme climate change show that there is consistency in temperature and climate variability. Climate change aggravates the instability of the climate system, and extreme climate events have even more influence on climate change, global water cycling and ecosystems. The number of litigation cases related to the current global climate has also increased dramatically [2].

The response between climate and vegetation is an important component of global change research, and it is a complex system. The impact of extreme events on ecosystem functions may be greater than that of average climate, and it will also undermine the growth of vegetation. It is essential to investigate the formation of extreme weather events and its ecological response in terms of the needs of both scientific and societal development. Furthermore, the relevance of extreme weather events, such as heat waves, colds, droughts and floods, has become an important issue in eco-research and global change agendas.

## 2. Definition of extreme climate events and research methods for vegetation response

### 2.1. Definitions

Extreme climate events, which can be described by probability distributions, are rare issues within a particular time and space. Scholars have conducted many studies of the definition of extreme climate events [3], and they usually use some percentage value as the threshold of extreme values, beyond which a value is considered to be extreme. Thus, the corresponding event is also referred to as an extreme event [4]. To meet the theme perfectly, climate events that are beyond the normal adaptation capacity of biological individuals in a certain region are defined as extreme climate events.

### *2.2. Research methods*

The process of vegetation response to extreme climate events is complex (Figure 1). The current research methods for extreme climates and their vegetation responses can be placed in two categories: the experimental method and the empirical method.

(1) Experimental Method. To observe the changes of plant community structure, organization and biomass in different contexts, we can select different plant communities and change their growth environments by irrigation or warming, through which it can reflect the response of vegetation to different extreme weather events. This method can control the nature of extreme weather well (such as time, space, strength, etc.), and it also allows us to observe the progress of species response to extreme weather and understand the ecological and physiological limit thresholds of vegetation. Due to the lack of reproducibility, this method is limited to the effects of single extreme weather events with small scale. The responses of vegetation to extreme events are sensitive. Thus, this method lacks universal applicability.

(2) Empirical Method. To understand the response of the vegetation to extreme climate in the area, we can calculate the extreme climate indices in some region and then analyze its relevance with NDVI in one year or one season. This method can capture the temporal and spatial changes of extreme weather events and their relevance with NDVI well. However, because of its hysteresis quality (which means that you can only research the matter after the extreme climate occurs) and because the nature of extreme climatic factors or other related factors (such as pests and diseases etc.) cannot be controlled, this method is also limited in its ability to assess the interaction between different extreme climatic types, such as severe droughts and heat waves, or other factors such as interference.

A and B-indicate that both temperature and precipitation are greater than extreme response thresholds; C and D-indicate that extreme temperatures or precipitation are greater than the extreme response threshold; LAI-Leaf area index; NDVI-normalized difference vegetation index; NPP-net primary production.

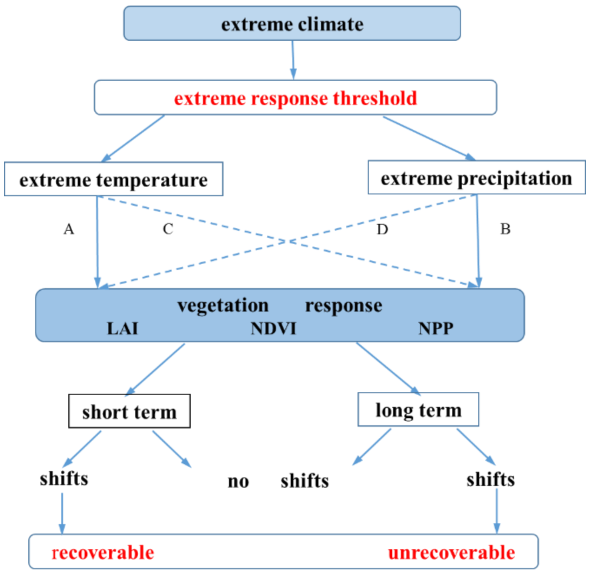


**Figure 1.** Framework of vegetation response to extreme climate

## 3. Progress of research on extreme climate events and vegetation response

Extreme climate, such as drought, may rapidly change the characteristics of vegetation structures and ecosystems. At the same time, heat waves and frost events can also have a negative impact on biomass [5]. At present, ecological research has realized that, as a driving factor, extreme weather plays a very important role in the growth, death, and ecological processes of plants. Therefore, the number of ecological studies of extreme weather and vegetation response is increasing at home and abroad.

Studies have shown that extreme climates can affect vegetation in many ways, such as the mortality of vegetation, the total primary productivity of organisms, and the biomass of forests [6-8]. Foreign scholars have found that different types of vegetation and biomass have different climate responses, which depends on the characteristic species, vegetation growth stage, and the timing and intensity of extreme weather occurrence. For example, the impact of heat waves on vegetation may be related to the timing, and vegetation response is different between early and late summer and [9]. The overall productivity of grassland and heather wood remains stable in drought or heavy rains, whereas grasslands may have little influence on extreme weather events [10].

Different communities of the same species may have different responses to extreme weather events, depending on the altitude. Different regions of the extreme climate may have different responses to the same vegetation. For example, semi-arid and sub-humid areas of vegetation are more vulnerable to drought [11-12]. The mortality rate of species is higher in hot and severely arid areas. At the same time, the biological community and ecosystem function are easily destroyed; even worse, this can change the ecological boundaries [13-14]. In addition, vegetation responses are different when extreme weather events occur in a different order [15]. For example, heavy rainfall that occurs after drought will increase the possibility of flooding, and runoff within the leaves, roots and stems of vegetation makes it more susceptible to fungal infection [16]. Precipitation has a significant relationship with the vegetation extremes of all biomes, which is different from extreme temperature. Moreover, precipitation is the main factor that affects vegetation extremes worldwide.

At present, there are few studies on extreme climate and its vegetation response in China that focus on the analysis and simulation of the temporal and spatial evolution of extreme climate in the whole country or in regions, as well as on the analysis of the response of the vegetation cover status to climatic factors in each ecosystem. The extreme climatic factors, which affect the changes in vegetation cover and the mechanisms of change, are still in the exploratory stage. For example, the wetland ecosystem and its NDVI value will be lower in extreme drought and flood years than in normal years [17]. The study of grassland ecosystems shows that NDVI is slowly rising in the case of increasing extreme high temperature and decreasing during low temperature events, and thus the degree of the response of different vegetation types to extreme climate factors is also different. In general, NDVI has good correlation with extreme precipitation events [18]. The study of lake ecosystems shows that the NDVI had a positive correlation with temperature in spring and autumn, and there is a positive correlation between NDVI and precipitation in summer and winter. Thus, NDVI had different correlations with different climate factors in different seasons [19].

It is clear that extreme climate, which is at a certain period of time, can lead to major changes in the ecosystem along with events caused by many interacting factors. Although we have a certain understanding of this theme, the research results in terms of key thresholds and influencing factors are fragmented and lacking in integrity. Both the empirical and experimental methods can capture the correlation between extreme climate events and NDVI in the study area. However, the former is lagging behind, and the latter lacks comprehensiveness. This means that the lag in the vegetation response to extreme climatic factors is not taken into account and neither is the possibility of ecological response to the other factors. In addition, few people think about the interaction between different climate extremes and other factors or the timing of the period of extreme weather occurrence and the occurrence of different effects. As a result, the response of vegetation to extreme climate events may be one of the most important challenges facing plant ecologists and climatologists in the future.

## 4. Conclusion

(1) The results of current research remain at the theoretical level because the research of extreme weather events is a new project. The research on extreme temperature is more adequate than the research on precipitation, and it does not include the specific definition of extreme climate and its impact on the ecosystem. Thus, it is urgent to establish the standard definition or indices system of extreme weather events from the ecosystem level.

(2) The study of extreme weather events and their vegetation response is important, and global climate change from the background of global warming and regional micro-climate is a new research direction. In view of the research ideas in this paper, there is a need to strengthen the research on the influence of extreme weather events on vegetation cover and the response of different vegetation types to extreme weather, as well as the simulation of extreme climate events in ecologically fragile areas. At the same time, we consider a number of climatic factors, such as El Niño, La Nina, and the monsoon anomaly.

(3) The response of vegetation to extreme climate is lagging behind. It is mainly focused on the normalized vegetation index, as well as other potential indicators of vegetation, such as leaf area index, net primary production, and vegetation mortality. Therefore, further studies should take into account the changes in vegetation and extreme vegetation, as well as the vegetation response model under the influence of extreme climate and multiple other factors.

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