

The Impacts of Climate Change on Biodiversity in the African Savanna

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Abstract.

For a long time, the African savannah has been famous for its extremely rich biodiversity. However, the changed global climate is threatening this special and precious ecosystem and is predicted to cause a huge blow to plants and animals in this region. Recent research shows that the rising temperature, the changing pattern of extreme rainfall events, and woody encroachment have impacted the completeness and continuity of the food web in the African savannah--the decreasing of some plants causes the food shortage of some herbivores. Decreasing herbivores would further lead to the difficulty of hunting many carnivores. Thus, the change in global warming would impact the biodiversity of species in the African savannah by affecting the food web in this region. Although existing research has achieved certain results in the field of the impacts of climate change on the African savannah, there are still huge gaps worthy of continued research. This paper discusses the impacts of climate change on the biodiversity and functions of the ecosystem in the African savannah region by analyzing the impacts of climate change on specific animals (Elephants, Small mammals, and Ants). This discussion emphasizes the importance of making strategies to reduce climate change's impacts and protect the African savannah's biodiversity. It provides the generality of current impacts of climate change in the African savannah for further research in this field.

Keywords: Climate change; biodiversity; woody encroachment; African savanna.

1. Introduction

The African Savannah is one of the most special ecosystems in the world because of its special climate and geographic characteristics. However, with the strengthening of global climate change, the stability of the ecosystem and biodiversity in the African Savannah is challenged. Many reasons can explain the effects of climate change on the African savannah. Among them, the main reason is that the extreme conditions brought by climate change will decrease the number of suitable habitats for plants and animals, thus resulting in extinctions. The biodiversity of the African savannah also plays an important role in the stability and work of the global ecosystem. This is because the complex ecosystem of the savannah is composed of enormous living and non-living things, and the interactions among them are a crucial part of the global system. Therefore, climate change and biodiversity research in the African savannah is crucial. Understanding the changes, loss of biodiversity, and degradation of ecological functions in these ecosystems will help discover ways to protect and restore them. At the same time, these studies can also help predict future changes and develop sustainable management plans to ensure that the African savannah ecosystem can continue to provide services to humans and the natural environment. Existing research shows that climate change is expected to lead to greater changes in rainfall and elevated temperature in African savanna ecosystems over the next few decades [1] and that changes in rainfall and temperature

will significantly promote shrub encroachment [2], both of which will significantly impact Ecosystem diversity, thereby threatening savanna habitat conditions and regional biodiversity. As the climate warms and carbon dioxide concentrations rise, the woody cover of southern African savannas will also increase. It is predicted that the savanna area in Africa and South America will be reduced by half in the coming decades, which is a worrying trend for conserving grassland biodiversity [3]. In this context, this article further explores the impact of climate change and changes in carbon dioxide concentration on the biodiversity of African savannas by specifically studying the effects of rainfall changes and lignification on elephants and wildebeest.

2. Impact of Climate Change on the African Savanna Region

The African savanna area is vast, including Kenya, Tanzania, South Africa, Namibia, Zambia, and other countries, and is located on the southern edge of the Sahara Desert. It is a very important grassland ecosystem. The grassland plants are mainly herbaceous, and the climate is usually dry and hot, with seasonal rainfall in summer. However, due to deforestation, agriculture, and increased carbon dioxide emissions caused by the fast-developing human industry, the climate and ecological environment of the African savannah have undergone significant changes. The original herbaceous plants were gradually replaced by shrubs, the dry and hot climate

became even hotter. The seasonal rainfall patterns that occurred in the summer also changed. These changes led to the decreasing number of suitable habitats for many animals and plants and negatively impacted savanna biodiversity.

2.1 The Occurrence of Extreme Rainfall

The climate of the African savannah region is mainly composed of the savannah climate with seasonal rainfall, mostly in summer and winter. However, because of global climate change, the African savannah faces a serious challenge of rainfall variability. Climate change has caused remarkable changes to rainfall patterns in the African savannah. Existing research shows that the average rainfall in the savannah region may decrease by 5-15% or increase by 30-40%. This transformation will impact the frequency and variability of extreme rainfall events, which may increase. The African savanna region is at risk of facing detrimental effects of climate change, and therefore, it is crucial to implement measures to mitigate the situation [4]. The impending environmental changes will undoubtedly have a profound and lasting impact on the delicate balance of the local ecosystem. A decrease in plant density due to low rainfall for several years can have a severe and long-lasting impact on the survival of wildlife and human food resources. More specifically, the reduction in rainfall can adversely affect the growth rate of various plants, such as weeds [5]. This can lead to a decline in the population of herbivores, which, in turn, can affect the eating habits, survival, and reproduction of carnivores. Ultimately, it can cause a ripple effect throughout the animal food chain. While increasing rainfall may seem positive, it could create new environmental threats. For instance, it could lead to the conversion of grasslands into woody jungles, further reducing the area's biodiversity and resulting in the loss of habitats for several vulnerable species [6]. Moreover, the uniformity of these jungles would limit the availability of resources for grazing animals, causing further damage to the local ecosystem.

2.2 The Occurrence of Tree Encroachment

In recent years, climate change has led to a significant increase in savanna woody plant cover, which has profound consequences for the African savanna's unique, diverse, and ever-changing ecosystem. This phenomenon, also known as woody encroachment, is changing the face of the savannah, and posing a significant challenge to its biodiversity. The increase in woody plant cover can be caused by various reasons, including rising temperatures, increased rainfall variability, increased atmospheric carbon dioxide, and other factors [2]. Because of all these

factors, the original herbs on the savannah have become woodier, causing grasslands to gradually transform into jungles. This shift significantly impacted the composition of the community, resulting in negative impacts on small mammals, especially those that mainly rely on herbs and are highly associated with the savannas. Some studies also show that woody encroachment will reduce their diversity for mammals and reptiles [7].

Moreover, the negative impact of woody encroachment is not only limited to the wildlife of savannas but will also affect those grazing Livestock that rely on grasslands for nutrition. As a result, even though some species that rely on tree-covered habitats may benefit from such changes, the negative effects of woody encroachment on species diversity and specific species in the African savannah regions will still be remarkable and unignored. Overall, to protect Africa's unique grassland landscapes and the biodiversity there, it is crucial to address the problem of woody encroachment.

2.3 The Loss of Biodiversity

Every living and non-living thing plays an equal and vital role in maintaining the balance of the ecosystem, no matter how big or small. However, global climate change (increasing temperatures, changes in rainfall patterns, and woody encroachment) exacerbated by human activities has had a remarkable negative impact on the biodiversity of this region. Due to rising temperatures and changes in rainfall patterns, herbaceous and desert plants in grassland areas have been severely damaged and are transforming into woody plants. Moreover, due to the influence of climatic factors, the flowering time of some plants would be different from the original time, thus affecting their reproduction and population size. Then, the loss of original plants will significantly impact the area's animal habitats and food resources. Thus, many region animals face remarkable reductions in suitable habitats, food resources, and population numbers. Some herbivores that rely on specific plants and carnivores that rely on these herbivores are facing extreme threats of extinction. In fact, for large mammal populations in East Africa, the decline in animal numbers is no longer a prediction but a fact that has already happened. Long-term data indicates that animal populations in the region have declined by more than 50% over the past half-century [8]. The impacts of climate change on African savannas are complex. It not only hurts the species diversity and ecological stability of the area but also greatly impacts the people living there. In summary, the biodiversity of the African savannah is currently under negative threat from climate change, and if these changes persist, they may cause irreversible damage to the region's ecosystems. Since biodiversity

loss is a complex and multifaceted issue, more attention should be paid to it, and long-term research should be conducted.

3 Specific Causes of Climate Change's Impacts on Biodiversity

3.1 The Impacts of Extreme Rainfall Events

Elephants are a keystone species in the African savanna ecosystem; they are true mixed feeders and exhibit a seasonal dietary shift from summer rainy season grazing (consuming mainly grasses) to winter dry season foraging (relying mainly on woody foods) [1]. Research shows that Kruger's elephants exhibit a transition from a diet containing 50% grass during the wet months to a diet containing 10% grass during the dry months [9].

3.1.1 Impact of Changes in Rainfall on Elephant Ranges

Due to higher vegetation productivity in the rainy season, the quality and abundance of forage in the savanna are positively correlated with rainfall, and the quality of forage will gradually improve after mid-August. Changes in feed resources caused by rainfall will lead to changes in the range of elephants' activities. Compared with arid areas, relatively abundant water means more abundant feed, which makes elephants' activities range wider. Dry seasons with below-average rainfall may reduce elephant ranges as elephants search for remaining foraging opportunities, and the situation is likely to intensify as drought frequency increases [1].

3.1.2 Change in Rainfall Can Affect Elephants' Movement Patterns

The study showed that elephant movement patterns showed different trends at the upper and lower breakpoints. Lower breakpoint (dry to rainy season transition): 29% of elephants increased speed before the rain breakpoint and 71% at the lower breakpoint. Speed increased after the breakpoint; upstream breakpoint (wet to dry season transition): 63% of elephants increased speed before the upstream breakpoint of rainfall, and 37% increased speed after the upstream breakpoint of rainfall [9]. This is mainly because areas of palatable grass are more widely spread in the early and middle rainy season, and elephants move more to access these areas during this period. Later in the rainy season, some areas become less palatable, resulting in less grazing and slower elephant movement.

In summary, greater changes in rainfall and rising temperatures in African savanna ecosystems will lead to changes in wet and dry seasons, increasing elephant movement and foraging behavior at the population level.

Because elephants are a keystone species in the African savannah, changes in their movement and foraging behavior at the population level can have knock-on effects on other species. Therefore, elephant movement and foraging changes can affect biodiversity by affecting the ecological roles and positions of other herbivore species and predators in the ecosystem.

3.2 The Impacts of Woody Encroachment

In southern Africa, 13 million hectares of land are encroached upon by bushland [10]. The loss of soil functions caused by shrub encroachment is a precursor to desertification and is related to the general reduction of ecosystem functions and processes [10].

3.2.1 The Negative Impact on Herbaceous Species Richness

As the degree of encroachment increases, the negative impact becomes more severe, and species highly associated with open vegetation structures may face local extinction. The increase in tree density will bring about changes in the habitat structure. Due to the intensified competition of original herbaceous species for resources such as soil moisture, nutrients, and light and their intolerance to high tree canopy shade, the herbaceous layer coverage area is expected to be reduced, and hybrids will be added. Litter, shrubs, or woody vines replace grasses. Herbaceous richness decreased significantly at moderate and high erosion levels [11]. According to existing research, this erosion alters soil nutrient and nitrogen fixation patterns, lowers pH, and continues reducing light availability at ground level. Encroachers effectively remove nutrients, and encroachment can also cause nutrient deficiencies, which can lead to reduced overall abundance, functional renewal, and diversity of herbaceous plants and local extinctions. Additionally, increased encroachment reduces the physical space available above and below ground through increased root density, reducing grass biomass. Encroachment results in reduced flammability and feed availability, altering the disturbance regime and limiting the entry of herbivores. Moderate and high levels of erosion reflect substantial changes in the abiotic and biotic environment of the ecosystem, ultimately leading to substantial losses of herbaceous species [11].

3.2.2 Significant Impacts on Biodiversity

Woody encroachment can also have significant impacts on biodiversity, often through changes in habitat structure, e.g., through changes in macro- and micro-habitat variables (amount of sunlight reaching the soil, microclimate, availability of water, food and shelter and vegetation structure), and influence the functional

responses of the community. The study showed that with erosion, the global weighted average lnRR of species richness in grassland ecosystems decreased from -0.245 when woody cover increased <33% to -0.562 when woody cover increased by 33%–66% and to -0.562 when woody cover increased by >66%. 0.962 [11]. Continued erosion results in a significant loss of biodiversity, and the loss of richness cannot be replenished.

Woody encroachment changes the structure of ecosystems. Research shows that the 2003 survey recorded ten species of small mammals, of which 70% were rodents and 30% were marsupials. The species with the highest abundance in the survey was *Necomys lasiurus*, accounting for 71% of the total population, which is a relatively large number. The rarest species are the rodent *Akodon cf. montensis* and *Calomys tener*, which account for 1.6% of the total abundance. In the 2017-2018 survey, 65% were rodents and 35% were marsupials. *Oligoryzomys* is the most abundant species, while the rarest species is the rodent *Nectomys cf.* Overall, changes in vegetation have led to a significant decline in the abundance of some species that are extremely dependent on grassland ecosystems, such as *Necomys Lasiurus*, which was the most abundant species in open grasslands in 2003 but was one of the rarest species in 2018 [2]. It also leads to changes in the structure of the ecosystem.

Woody encroachment affects not only ecosystems' structure but also these communities' functional responses. In the case of ant communities in savanna areas, studies have shown that the number of predatory species and the abundance of these species are significantly higher in closed habitats compared with savannas (Wilcoxon matched-pairs test, $z = 2.37$, $P = 0.018$ for both species and abundance; mean number of predatory species/site = 0.3 and 5.8, mean abundance predatory ants/site = 1.3 and 59.3 for savanna and closed habitat) [12]. It can be seen from the data that the total abundance of predatory species in closed habitats is more than an order of magnitude higher than that in savannas, which indicates that higher numbers of predatory ants are found in scrub habitats compared to savannas.

In summary, woody encroachment in African grassland areas has had a significant negative impact on biodiversity. Therefore, Slowing the rate of wood erosion is crucial. To achieve this goal, related agencies must set rules to limit human activities, promote sustainable land use and forest management, and undertake conservation and restoration activities. Thus protecting the ecosystem's stability and biodiversity in the African savannah regions.

4 Summary

Due to global climate change, the African savanna regions are experiencing rising temperatures, changing rainfall patterns, and woody encroachment. Based on relevant research on climate change and species diversity in the African savanna region, this paper mainly aims to dedicate the impacts of climate change on the African savanna region and specifically studies the impacts of these changes on the groups of elephants, small mammals, and ants in this region. The research shows that rising temperatures, changing rainfall patterns, and increased woody encroachment will decrease species diversity in the region. Since this paper analyzes the impacts of climate change on the whole ecosystem in the African savannah just by exploring the impacts of climate change on three species, this analysis method that extends from individuals to the whole has certain limitations and cannot fully summarize all impacts on species diversity and ecosystems in the savanna. Therefore, future research should study more species to accurately summarize the general impacts of climate change on single species and species diversity. In addition, as the reduction of species diversity in African savannahs due to climate change is a major threat to global ecology, future research should be an international collaborative effort and jointly develop effective conservation strategies through in-depth research on the impact of climate change on grassland ecosystems to address the challenges posed by climate change to the biodiversity conservation of grassland ecosystems and lay a solid foundation for protecting the unique and diverse ecosystems of the African savannah.

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