Indiana's Grasslands

An Overview of the Effects of the Changing Climate on Grassland Ecosystems 2025

Introduction

Comprising over 3.7 million acres, grassland ecosystems cover more than 15% of the land in Indiana. Grasslands, prairies, and reclaimed mine lands are primarily present in the state's southern, central, and extreme northern regions. Grassland habitats are defined as open areas dominated by grass species and include early successional areas, farm bill program lands, fescue, hay lands, pasture, prairies, reclaimed mine lands, savanna, vegetated dunes and swales, and shrub/scrub (Indiana State Wildlife Action Plan 2015).

This overview summarizes the expected climate projections and their impacts on Indiana's grassland ecosystems throughout the upcoming decade(s). This document outlines expected changes to grasslands and potential adaptation strategies to manage these ecosystems effectively. While this document is not a detailed report, it aims to provide stakeholders with a comprehensive understanding necessary for informed decision-making and effective grassland management in the face of the changing climate.

Key Climate Projections for Indiana

Warming Temperatures

Indiana's annual average temperature warmed 1.43°F from 1895 to 2022 based on a linear trend (MRCC, 2023). This warming trend is expected to continue and intensify into the foreseeable future (Widhalm et al., 2018). Average temperatures are expected to warm 3°F over the long-term average by early-century (2011-2040) and 5-6°F by mid-century (2041-2070).

Warming is expected in all seasons, with notable changes in the length and timing of seasons.
Indiana's winters will be shorter and warmer:

- The average coldest winter night temperatures are expected to increase about 6°F by mid-century, and the number of cold days (days when the daily minimum temperature is below 5°F) and frost days (days when the daily minimum temperature is below 32°F) will decline, particularly in northern Indiana.
- Rising temperatures will reduce the amount of winter precipitation falling as snow, and instances of snowfall of 2 inches or more will become less frequent.

Springs will arrive earlier, and summers will be much hotter in the future:

- The number of hot days (85-95°F) and extremely hot days (above 95°F) will increase statewide, with the largest increases in northern areas where mid-century projections show 24-25 more hot days annually as compared to the past. In southern Indiana, hot days are expected to increase by 10-15 days per year.
- The average length of heat stress events (consecutive days with high temperatures above 86°F) is expected to double by mid-century (Day et al., 2018).

Ongoing temperature increases will accelerate evapotranspiration rates (the amount of moisture lost to plant use and evaporation from surface soils and water) by 5-6% across Indiana by mid-century (Cherkauer et al., 2023).

Rainfall Variability

Indiana's annual precipitation has increased by 6.38 inches from 1895 to 2022 based on a linear trend (MRCC, 2023). Annual precipitation is projected to increase 2-3% above the long-term average by early-century (2011-2040) and 6-8% by mid-century (2041-2070) (Widhalm et al., 2018). Historical observations show that extreme precipitation events are becoming more frequent and intense in Indiana (Marvel et al., 2023).

However, those changes will not be evenly distributed throughout the year.
Precipitation will increase in winter and spring with slight declines or no change in summer and fall:

- Winter and spring precipitation is expected to increase 4-10% by the early century and 13-20% by the mid-century (Hamlet et al., 2020). Conversely, summer and fall precipitation changes are less certain, with early-century projections showing modest 1-4% declines in summer and fall precipitation and 2-3% declines by mid-century.

Seasonal temperatures and precipitation changes are expected to impact snowfall, snow cover, frozen soils, and evaporation rates. **Indiana winters are projected to be generally less snowy, and summers will have increased evaporation rates**:

- Rain is projected to replace much snow during the cold season (November to March). The percentage of cold-season precipitation falling as snow is expected to decrease significantly throughout the state. In southern Indiana, there will be little snowfall by the late century under both emission scenarios. Instances of more than 2 inches of snow will be quite rare in southern Indiana by the 2080s under the high emission scenario. In northern Indiana, snowfall will be greatly reduced as compared to the past. Throughout the state, snow events greater than 2 inches are expected to happen about half as often by the end of the century (Widhalm et al., 2018).

- The number of days with frozen soil per year is projected to drop by half or up to two-thirds by the late century (Phillips et al., 2018).

Potential Implications of the Changing Climate on Indiana's Grasslands

Grasslands have thus far demonstrated substantial resilience to observed changes in climate (Ratajczak et al., 2019). This does not preclude eventual compositional changes in faunal and floral communities, particularly if abiotic thresholds needed for their survival have not yet been met. The main aspects of grassland ecosystems expected to change due to climate stressors (such as increased average temperatures, rainfall variability, and enrichment of carbon dioxide and nitrogen) are community composition, diversity, and switches in the dominance of species or functional types (Figure 2). Additionally, grassland habitats will be indirectly impacted by shifting land-use patterns due to the changes in climate.

Increased Average Temperatures

Species and community composition will likely change in response to earlier spring warming. In response to earlier spring warming, invasive species are more capable of advancing the timing of key life cycle events (phenology) than native species (Zettlemoyer et al., 2019). As a result, **earlier springs may preferentially benefit invasive species,** threatening community composition, health, and function in Indiana grasslands.

Plant carbon and productivity might increase in response to warming. Higher temperatures paired with CO2 enrichment will likely increase the productivity of grassland systems in Indiana and their capacity to act as carbon sinks (Reich et al., 2020). Although periods of drought will likely reduce prairie productivity and carbon storage, evidence shows that the positive effects of increased temperature and CO2 can outweigh the harmful effects of drought. Thus, Indiana's grasslands may become increasingly important from a carbon sequestration perspective. However, predicting the outcome of multiple interacting climate stressors is still challenging.

Fire management may become more challenging in response to warming temperatures. The early onset of spring makes it challenging to manage natural grasslands effectively. It is likely to decrease the effectiveness of mitigation activities such as prescribed burning in preventing the dominance of invasive grasses (Ratcliffe et al., 2022).

Rainfall Variability

Species and community composition are likely to change in response to variable rainfall. Increasing variability in rainfall is likely to decrease moisture stress in grassland ecosystems, thus decreasing the variability of resource availability. This allows certain particularly aggressive, fast-growing species to become more dominant (Smith et al., 2016). Thus, **rainfall variability is a prominent factor in the increased establishment of faster-growing invasive species**, decreasing the diversity of grasslands. Invasive species are more capable of shifting their phenologies in response to warmer climatic conditions than native species, further leading to the potential decline of the latter (Zettlemoyer et al., 2019).

Woody encroachment will likely increase in prairie systems in response to heavier rainfall events. In Indiana, woody encroachment constantly threatens grassland ecosystems, primarily where adequate precipitation exists for woody establishment. Increasing occurrences of heavier precipitation events have been shown to create favorable conditions for increased height and size of invasive woody plants, such as Amur honeysuckle (*Lonicera maackii*) (Ratajczak et al., 2019 & Schuster et al., 2017). Additionally, **rainfall variability is a crucial driver of soil moisture content**. In response to heavier rainfall, average soil moisture is expected to increase. This increase in soil moisture and rainfall amount has favored woody species with autumn phenologies concerning resource utilization and establishment (Schuster et al., 2017).

Health of grassland ecosystems may deteriorate in response to reduced rainfall. Studies conducted in the Midwestern region have shown that reduced rainfall events will likely decrease prairie plant productivity and total plant carbon. Additionally, lower precipitation in warmer months increases the risk and occurrence of droughts, directly impacting grassland ecosystems' health (Reich et al., 2020).

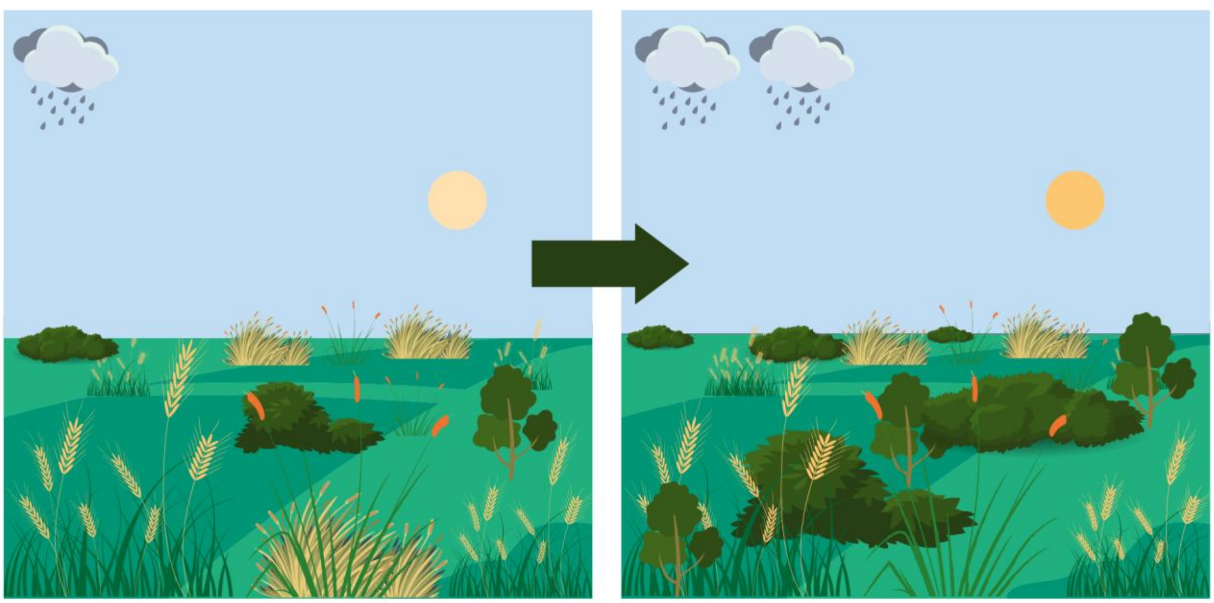

Figure 2. As grasslands experience increased precipitation and annual temperature, we can anticipate increased pressure from invasive species and woody encroachment. The timing of invasive species treatments and prescribed fires may have to shift as a result.

<u>Simultaneous Occurrence of Climate Stressors</u>

Habitat suitability for grasslands in Indiana may decline/shift due to a combination of climate stressors. Shifting climatic conditions, such as isothermality, precipitation patterns, and temperature seasonality may result in conditions that are no longer suitable for many native grassland species, such as big bluestem (*Andropogon gerardii)* (Kane et al., 2017). As habitat suitability for native species declines, **grasslands in Indiana may experience state transitions in animal and plant communities**.

Land Use Change

Grassland habitats will be indirectly impacted by shifting land use patterns due to the changes in climate. The growth conditions for Indiana's key agricultural products will likely be affected by warming temperatures and rainfall variability (Cunningham et al., 2022). Changing habitat availability due to shifting land use patterns will likely stress current grassland habitats further (Cunningham et al., 2022). However, potential shifts in land use for agriculture could benefit Indiana's natural grasslands and create restoration opportunities.

Levels of Uncertainty

Grasslands' response to the changes in climate has been understudied globally as well as in Indiana. This dictates considerable uncertainty in accurately predicting how these unique ecosystems will be affected by climate variables. **However, uncertainty does not mean that the effects of climate stressors on grassland ecosystems are unknown**. Rather, the influence of certain conditions is less understood than others. For example, changes to soil moisture conditions are well understood in the face of variable rainfall when the temperature is constant; however, it is hard to predict the extent of changes to soil moisture and its subsequent impact on plant community structure under varying temperature conditions in tandem with rainfall variability. Water availability outcomes due to altered precipitation patterns are also unforeseen, and there are limited studies correlating the changes in climate and composition changes in tallgrass prairies in Indiana. Lastly, the combined effects of numerous climate stressors that interact with each other to varying extents cannot be predicted with certifiable accuracy. Hence, noting uncertainties is crucial to understanding grasslands' response to changes in climate in order to **be prepared for a wide range of possible outcomes**. While developing an exact solution for dealing with climate stressors affecting grassland ecosystems is challenging, our goal is to develop resilient and adaptable strategies for a range of possible future outcomes.

Management and Adaptation Strategies

Based on the literature reviewed, the following strategies have been previously implemented to ensure the optimal health of grassland ecosystems in Indiana and can be adapted in the future.

- **Restoration**: Several opportunities exist to restore land used for the state's agricultural cultivation. For example, natural grasslands may have the opportunity to expand and grow into regions that have historically been utilized for row crop agriculture (Cunningham et al., 2022).
- **Invasive Species Management**: Invasive species management practices may shift due to species' changed flowering and seed maturation times in response to warming temperatures (Zettlemoyer et al., 2019). **It is likely that the window for effective treatment will need to shift to earlier in the year**. Careful observation of the timing of

flowering and seed maturation for key invasive species in areas that require grassland management will be important in the next ten years (Ratcliffe et al., 2022).

Conclusion

This brief overview presents the primary climate-related threats to grassland ecosystems in Indiana. Extensive research dictates that grasslands are resilient to specific stressors related to changes in climate. However, the multifaceted interactions and manifestations of these stressors and their effects are slated to decrease the suitability of grassland habitats and cause an increased occurrence of invasive species. Thus, it is essential to consider these potential modifications and inherent resiliencies while planning future strategies focused on grassland ecosystems.

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