Indiana’s Forested Wetlands

An Overview of the Effects of the Changing Climate on Forested Wetland Ecosystems 2025

Introduction

Wetlands in Indiana are diverse ecosystems that can be found in every one of the state’s 92 counties. The state has various wetland vegetation, including forested, shrub-dominated, and herbaceous (Jr. Whitaker John O et al., 2012). This document will focus on forested wetlands, which are distinguishable by primarily woody vegetation that is often over 20 feet tall. Examples of forested wetlands include bald cypress (*Taxodium distichum*) swamps and wet floodplain forests that were historically dominated by elm, ash, and cottonwood. In the northern part of the state, there are a few examples of forested fens, which are groundwater-fed. Forested wetlands are critical ecosystems for the survival of flora, fish, amphibians, reptiles, and birds.

This overview summarizes the expected climate projections and how they will impact Indiana’s forested wetland ecosystems over the upcoming decade, outlines expected changes to forested wetlands and provides 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 wetland 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 by 3°F above the long-term average by early-century (2011-2040) and 5°F to 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, specifically:**

- The average coldest winter night temperatures are expected to rise by 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 come earlier, and summers will be much hotter in the future, specifically:

- The number of hot days (85°F to 95°F) and extremely hot days (above 95°F) will increase statewide, with the largest increases in the north where mid-century projections show 24 to 25 more hot days annually compared to the past. In southern Indiana, hot days are expected to increase by 10 to 15 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).

Precipitation 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 by 2-3% above the long-term average by early-century (2011-2040) and by 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, specifically:

- 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, specifically**:

- 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 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 to two-thirds by the late century (Phillips et al., 2018).

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Potential Implications of the Changing Climate on Indiana’s Forested Wetlands

The prevalence of current wetlands in the Midwest region depends primarily on climate conditions (Garris et al., 2015). Warming temperatures and variable rainfall patterns have been cited as significant climate stressors affecting Indiana’s forested wetlands. Often manifesting as changes in soil and hydrological regimes (long-term patterns and characteristics of soil moisture, temperature, and other conditions that influence its development and behavior), these stressors are likely to change species composition, promote the presence of non-native or invasive species, and reduce the resilience of the overall ecosystem. There is widespread agreement that the changing climate will significantly impact wetland biogeochemical processes (Salimi et al., 2021). In some instances, a few wetland species, such as the bald cypress (*Taxodium distichum)* or swamp white oak (*Quercus bicolor*), show potential for adapting to expected changes in climate (Brandt et al., 2014). Climate stressors, such as reduced isothermality, increased winter precipitation, and higher moisture index seasonality may create more favorable conditions for forested wetlands. These conditions can lead to increased forested wetland areas, particularly in regions prone to seasonal flooding and soil saturation (Garris et al., 2015). However, this is uncertain in the face of changing climate factors affecting the region. The overall impact of the changing climate on forested wetland function and services can vary over time and between different systems, depending on the simultaneous occurrence of multiple climate stressors.

Warming Temperatures

Temperature-sensitive biogeochemical processes are expected to increase due to warming soil temperatures. Higher temperatures can increase the rate of biogeochemical processes like organic matter decomposition, denitrification, and methane production (Trettin et al., 2019). This, in turn, may lead to **increased carbon and methane output**, potentially **threatening the role of wetlands as carbon sinks** (Salimi et al., 2021).

Productivity of wetlands and carbon input in soil could increase in response to warming temperatures. Warming temperatures could extend the growing seasons and increase productivity in temperate wetland regions. However, this effect may be limited in areas with lower soil moisture. As temperatures warm, the productivity of wetland plants is likely to increase, resulting in more litterfall and root productivity. Upon litter and root decomposition, carbon inputs into the soil will also increase (Trettin et al., 2019). Additionally, **prolonged growing seasons may accelerate succession and lead to shifts in community composition** (Salimi et al., 2021), generally toward shrublands or even open water areas.

Warming temperatures will likely worsen the impacts of invasive species. In Indiana's forested wetlands that contain black ash (*Fraxinus nigra*) and green ash (*Fraxinus pennsylvanica*), their density has been decreased by emerald ash borer (EAB) invasion, altering the vegetation composition of black ash wetlands. However, **the combined impact of EAB invasion and the changing climate is not always negative** (Brandt et al., 2014). EAB infestations could reduce the drying of wetlands by killing black ash trees, leading to reduced transpiration. Reduced transpiration would result in higher water tables, thus **offsetting the drying of wetlands** driven by the changing climate (Shannon et al., 2022). **As changes in climate progress, the range of suitable habitats for EAB may shift, leading to a potential divergence in its invasion range**. In Indiana, the northern part of the state is expected to maintain suitability for EAB, while the southern part may lose suitability due to increasing temperatures (Liang & Fei, 2014), suggesting that land management plans in the southern portion of Indiana may need to reflect this shift.

Rainfall Variability

Forested wetland soil is expected to be significantly impacted by rainfall variability. Wetlands will likely experience extended dry periods followed by rapid inundation during heavy rainfall (Shannon et al., 2022), causing those wetlands to be vulnerable to such changes (Trettin et al., 2019). Additionally, these **dry and wet cycles can alter the types of wetland vegetation and faunal communities**.

Increased Precipitation: Higher rainfall levels can raise the water table within wetlands, effectively reducing the volume of aerated soil. Reduced aerated soil volume can lead to decreased organic matter decomposition, increased methane emissions, and denitrification. Heavy and intense rainfall can overwhelm wetlands' storage capacity and lead to flash flooding. This can result in changes to flow and storage characteristics and impacts on various ecosystem services such as fiber, food, clean water, climate and flood regulation, coastal protection, and recreational opportunities (Trettin et al., 2019).

Decreased Precipitation: Precipitation-dependent wetlands are particularly vulnerable to decreased rainfall, which can lead to lowered water input, increased organic matter decomposition, and potentially increased carbon dioxide emissions to the atmosphere. However, decreased water input may also reduce water output from the wetland, which can enhance flood mitigation.

Altered Hydrological Regimes

Factors associated with changes in climate cause altered hydrological regimes in forested wetland ecosystems. Forested wetland ecosystems are often regionally unique and highly diverse, making them sensitive to changes in wetland hydrology caused by changing climate stressors, such as **hotter and drier summers and warmer and wetter winters** (Shannon et al., 2019). Since water plays a crucial role in regulating hydrologic processes in these ecosystems, **biogeochemical processes are, in turn, affected,** as mentioned in the *Warming Temperatures* section above (Trettin et al., 2019).

Changes in hydrology in forested wetland ecosystems driven by the changing climate are expected to affect species composition. Altered hydrology in these ecosystems may pose challenges to the reproduction of native species and create opportunities for competition from undesirable species, establishment of invasive species, and invasion by pests (Shannon et al., 2019). Increased flooding frequency and intensity can drive oak and hickory decline, promote ash dominance, and cause more significant shifts in community compositions in wet bottomland forests. Swamp systems, more tolerant of periodic and long-term flooding, suggest swamp white oak (*Quercus bicolor*) may thrive without competition from shade-intolerant species like sugar maple (*Acer saccharum*), blue ash (*Fraxinus quadrangulata*), and swamp tupelo (*Nyssa biflora*) (Brandt et al., 2014).

Altered hydrologic regimes can lead to changes in water chemistry. Changes in hydrological regimes in forest wetlands could result in altered water chemistry, such as increased mobilization of pollutants and sediments to surface waters, altered pollutant resident times, and increased water temperatures (Shannon et al., 2019).

Habitat suitability for individual tree species is expected to shift. Species like swamp chestnut oak, swamp white oak, and swamp tupelo, commonly found in forested wetlands in Indiana, are predicted to have decreased habitat suitability in the future. However, bald cypress shows no change (Brandt et al., 2014).

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

Higher temperatures and changing rainfall patterns will alter biogeochemical processes in forested wetland soils. As mentioned above, changes in hydrological regimes due to the changes in climate are expected to affect biogeochemical processes in forested wetland soils. Warming temperatures will likely **extend the growing season and enhance productivity** in temperate wetland regions, increasing the soil's biogeochemical activity and **temperatures**. Additionally, wetlands rely on precipitation to sustain their water balance and are particularly vulnerable to changes in precipitation, which will cause some wetland areas to become drier and others wetter (Trettin et al., 2019).

Existing threats affecting forested wetlands are expected to worsen. Forested wetlands in Indiana face diversity loss, composition shifts, changes in flood regime and water table, sedimentation from upland soil erosion, bald cypress damage from pests, fungi, and insects, and invasion by EAB. These threats are likely to be aggravated by the changes in climate. For instance, the combined effects of the changes in climate and disturbances like EAB will likely result in greater species homogenization across landscapes through the loss of ash species. Changes in climate are projected to lead to a shift in the dominance of tree species, with southern- and warm-adapted species increasing in biomass by the end of the century. This shift is also expected to result in a decline in overall biodiversity due to the loss of northern-adapted species (Olson et al., 2021).

Levels of Uncertainty

Extensive research has been conducted to understand the impact of the changes in climate on wetland ecosystems, as **forested wetlands are highly sensitive to changes in temperature and rainfall patterns**. However, there are uncertainties surrounding the impacts of changes in climate on these ecosystems that make it challenging to predict their responses to various climate variables. For instance, the net effect of increased temperature on forested wetland soil processes remains complex, as temperature and factors like plant production, soil aeration, and local conditions influence these processes. Additionally, uncertainty arises from climate projections and the potential for unforeseen vegetation responses to future climates, with current models potentially underestimating the magnitude of these changes. These **uncertainties underscore the importance of preparedness and the development of adaptable strategies to safeguard the resilience of wetland ecosystems in the face of an uncertain climate future**.

Management and Adaptation Strategies

Based on the literature reviewed, the following strategies have been proposed as potential actions to ensure the optimal health of forested wetland ecosystems in Indiana and can be adapted in the future.

- **Research**: There is a need for a deep understanding of how warming temperatures interact with other factors, such as vegetation composition, to inform effective management strategies for maintaining desired wetland conditions. This will help guide potential restoration efforts.
- **Invasive Species Management**: Invasive species, such as EAB, significantly threaten native ash species in forested wetlands. The interplay between EAB and the changing climate is complex, with potential winners and losers among tree species. Understanding these interactions is crucial for managing and conserving forested wetlands in Indiana. The potential to mitigate the impact of the changes in climate on native ash species relies on effectively restraining EAB dispersal and reducing its spread rate over time (Liang & Fei, 2014).
    - **Targeted planting of replacement species**: EAB can potentially increase the resilience of wetland hydrology to the changes in climate by removing ash species. Targeted planting of replacement forested wetland species is an important management tool to maintain wetland hydrology and function (Shannon et al., 2022).

Conclusion

In summary, the anticipated impacts of the changes in climate on Indiana's wetlands reveal a complex and multifaceted future for these ecosystems. Rising temperatures and shifting precipitation patterns are set to disrupt the delicate balance of wetland processes, affecting various facets from species composition to biogeochemical processes. While some species may display resilience, invasive species, altered hydrology, and intensified disturbances pose significant challenges. Thus, it is essential to consider these potential modifications and inherent resiliencies while planning future strategies focused on forested wetland ecosystems.

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