

Review on the Impact of Climate Change on Great Lakes Region's Agriculture and Water Resources

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Abstract

This study investigates the multifaceted impacts of climate change on the Midwest region of the United States, particularly the rising temperatures and precipitation brought about by hot weather activities and technological advances since the 19th century. From 1900 to 2010, temperatures in the Midwest rose by an average of 1.5 degrees Fahrenheit, which would also lead to an increase in greenhouse gas emissions. Precipitation is also expected to increase due to increased storm activity and changes in regional weather patterns. This paper explores the impact of these changes on urban and agricultural areas. In urban areas such as the city of Chicago, runoff from the increasing impervious surface areas poses challenges to the drainage system, and agriculture areas are challenged by soil erosion, nutrient loss, and fewer planting days due to excessive rainfall. Sustainable solutions such as no-till agriculture and the creation of grassland zones are discussed. Using historical data, recent climate studies and projections, the paper outlines ways to enhance the Midwest's ecology and resilience to climate change.

Keywords

Climate Change, Midwest USA, Agricultural Impacts, Urban Runoff, Sustainable Practices, Precipitation Patterns, Temperature Increase, Greenhouse Gas Emissions, Soil Erosion, Water Management

1. Introduction

With the ongoing expansion of human activities and advancements in technology, there is a continuous upward trend in Earth's overall climate and precipitation patterns. Since 1850 there has been a notable increase in temperature, primarily attributed to the warming effects caused by the Industrial Revolution

(*What Is Climate Change?* n.d., NASA Science). Midwest region has also experienced raising temperatures, with an average increase of 1.5 degrees Fahrenheit from 1900 to 2010 (U.S. EPA, 2016). This temperature increase is expected to result in hotter weather, increased demand for air conditioning, and more greenhouse gas emissions (Davis & Gertler, 2015).

Additionally, precipitation in the Midwest region is anticipated to rise due to increased storms and regional precipitation patterns (Easterling et al., 2017). While temperature changes in the Midwest may not differ significantly from other regions, it is noteworthy that nearly a third of the U.S. population resides in the Great Lakes region (Ducey et al., 2018). This region, bordering much of the Midwest, provides a lens through which we can observe the impacts of climate change and human activities on water resources.

The effects are particularly evident through factors such as impervious surfaces increase, agriculture, groundwater, and flooding of the Chicago River (Rougé & Cai, 2014).

2. Agriculture

Agriculture is an important part of the regional economy and plays a key role in supporting national livelihoods and economic activity. The Midwest has a vast corn belt, which is broadly defined as a staple crop grown across state lines. It is worth noting that the United States is the world's largest corn producer, with 75 percent of the corn produced in the Midwest. In addition, soybeans as well as various vegetables and fruits are grown in the region, which accounts for 60% of the country's soybean production (Thaler et al., 2021). Another distinguishing feature of the Midwest region is its predominantly tall grass prairie or savanna terrain prior to cultivation (Ratajczak et al., 2016). This natural landscape avoids any additional measures needed to prevent slope erosion before planting crops, thus contributing to the prosperity of agriculture in the region (Thaler et al., 2022).

However, intensive agricultural practices have also led to land degradation, erosion and pollution, problems that have been going on for years and are now being exacerbated by the increasing frequency of extreme weather events. In the Midwest, Annual total wet-day precipitation (PRCPTOT) levels increased significantly, with some areas increasing by 40 to 100 mm over a decade (Wilson et al., 2022). Especially in areas to the west and south around Lake Michigan, heavy rainfall has become more common. These climate changes will inevitably bring challenges that will have a significant impact on agriculture. For example, increased precipitation in the spring can lead to nutrient leaching from the soil, which in turn leads to soil erosion caused by runoff. In addition, excessive rainfall will reduce the number of planting days (Begemann, 2020). Soil loss can lead to an increase in nutrients flowing into groundwater and rivers, causing irreversible damage to river ecosystems. However, the negative environmental impacts of intensive agricultural practices are not limited to land degradation, ero-

sion and pollution. These practices also result in the loss of biodiversity and the destruction of ecosystems. The heavy use of fertilizers and pesticides not only pollutes soil and water, but also harms beneficial insects, birds and other wildlife (Delgado et al., 2013).

In addition to these environmental concerns, the increasing frequency of extreme weather events is exacerbating the challenges facing agriculture in the Midwest (Usgcrp, 2018). For example, heavy rainfall following a long drought can lead to reduced soil compaction and water permeability. This makes it difficult for crops to get nutrients and water from the soil, ultimately affecting their growth and yield (Qiu et al., 2021).

In addition, excessive rainfall can cause flooding in low-lying areas near rivers or lakes. This not only damages crops, but also causes significant economic losses to farmers who depend on agriculture for their livelihoods. Floodwaters can carry sediment containing pollutants into nearby bodies of water, further deteriorating water quality (Usgcrp, 2018).

In such an environment, the most important measure to improve the resilience of agriculture and water resources without damaging crop acreage is to adopt no-till tillage. This model not only improves soil quality, but also reduces soil erosion (Claassen et al., 2018). In addition, it can reduce the use of nitrogen fertilizer, thereby preventing nutrient enrichment in water bodies and subsequent oxygen depletion. In addition, a study in Iowa on grassland protection of farm ecology is also one of the effective methods (Schulte et al., 2017). Grassland restoration can transform a single farmland environment into a perennial community, not only enhancing water temperature regulation, but also improving soil water quality. When a grassland zone was created in the growing area, soil erosion and nutrient loss were reduced by 1.6 times. Of Iowa's 9.8 million hectares of arable land, another 390 hectares could benefit from such protection. The Midwest's commitment to sustainable agricultural practices should also not be overlooked. Many farmers employ conservation methods such as crop rotation techniques, which help maintain soil fertility while reducing reliance on fertilizers or pesticides (Schulte et al., 2017).

Overall, with its extensive corn belt and soybean growing strengths, coupled with wheat production capacity, and the horticultural contributions of livestock feeding activities, including cattle ranches and dairy farms, and orchards and vegetable farms—all supported by sustainable practices—agriculture remains an integral part of the Midwest's economic prosperity.

3. Urban Area

3.1. Impervious Surface

Pervious surfaces, also referred to as porous or permeable surfaces, facilitate the infiltration of water into the soil, effectively filtering out contaminants and replenishing the groundwater table. Conversely, impervious surfaces can exert detrimental effects on both surface and groundwater systems (Basics: Water

Flows). The presence of impervious surfaces contributes to surface water pollution due to the movement of rainwater. As precipitation flows off these impermeable areas, it accumulates pollutants along its path towards storm drains, ultimately leading to direct contamination of rivers, lakes, wetlands, and oceans. Moreover, impervious surfaces exacerbate rapid urban runoff and overwhelm the urban sewer system within cities such as Chicago (Figure 1) Given that Chicago's impervious surface area already encompasses the entire cityscape, proactive measures involving increased tree cover and enhanced soil management are imperative for mitigating excessive rainfall runoff promptly (Duan et al., 2016).

National Land Cover Database 2019 Chicago Impervious Area

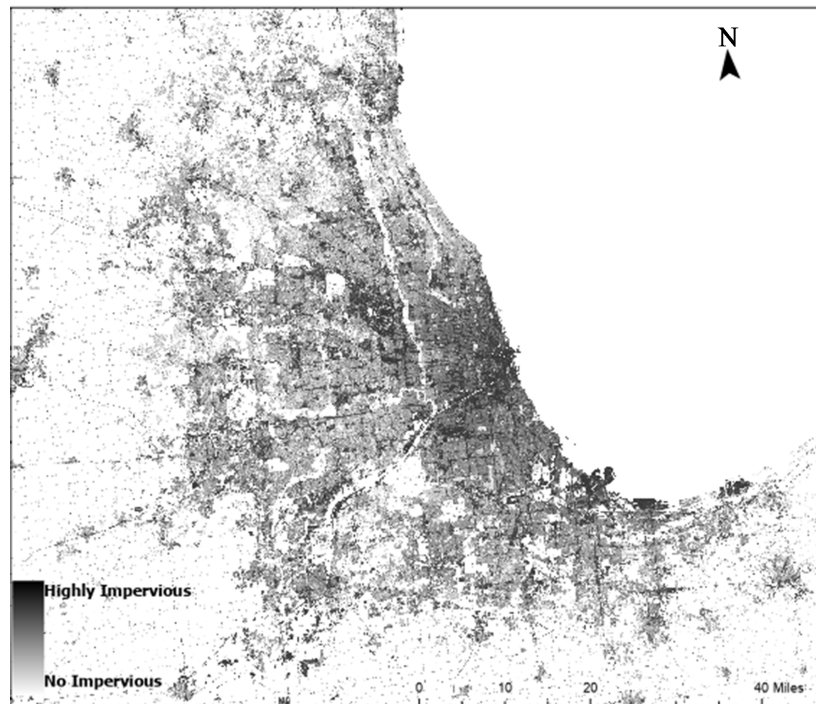


Figure 1. Impervious surface in Chicago (NLCD, 2021).

3.2. Domestic Water Supply and Sewage System

A combined sewage system means that domestic sewage, industrial sewage, and stormwater are transported in the same pipe. When heavy rains occur, one pipe can't handle all the water, and they deliberately let the pipes overflow into local rivers, lakes, or coastal waters (US EPA, 2023). This can allow raw sewage to enter drinking water sources and recreational water, which can cause illness if consumed (Burian et al., 2000). A classic example is the Chicago Sewer System and the Chicago River. Chicago's economic boom in the 19th century, however, came at a huge environmental cost. It also marks a critical moment in the city's history when rapid industrialization and urban growth brought unforeseen ecological challenges (Chicago Sewers Digital Collection, n.d.). More and more factories were built along the Chicago River, and as the industry boomed, they increasingly dumped waste into the Chicago River, which began as a clear and

free-flowing river and gradually became a conduit for sewage and industrial wastewater. By the second half of the 19th century, the Chicago River was notorious for its pollution, and the water was polluted by countless pollutants.

The Chicago River also inevitably flows into Lake Michigan. Lake Michigan, an important source of fresh water for Chicago and the surrounding area, has borne the brunt of this uncontrolled pollution. The lake's proximity to the city means that polluted water from the Chicago River directly affects its ecological health. The influx of sewage and industrial waste has led to severe water pollution, which not only deteriorates the water quality of the lake, but also poses a major threat to public health (**Figure 2**). There were even small animals that could come out of the tap.



Figure 2. At first, people could bathe in the Chicago River, but later it became a sewer (**Chicago River Pollution**).

The city's fight against pollution requires an engineer with innovation, engineering prowess and bold decisions. A key moment in this saga came in 1855, when Chicago approached Ellis Chesbrough, a renowned engineer who had designed Boston's water system.

Chesbrough has earned a strong reputation for innovative solutions to urban infrastructure, and his vision for Chicago's water problems is both ambitious and inspired by best practices in European cities. His plan was straightforward, but revolutionary for the time: to extend the city's water intake to Lake Michigan, thereby avoiding polluted waters on the shore (**Chicago Sewers Digital Collection**, n.d.).

Chase Boro's plan was to connect the Chicago River to the Des Plaines River. By making the canal deeper than the river to the east, gravity would pull the water from Lake Michigan to the west, directing it toward the Mississippi River

([How Chicago Reversed Its River: An Animated History, 2018](#)).

This bold plan meant changing the natural course of the Chicago River—an engineering feat unprecedented in scale and ambition. Workers had to dig out millions of cubic yards of dirt to create a trench deep and wide enough for the river to flow upstream. They also had to build a series of locks and dams to control water levels and flows to ensure that reversals did not cause flooding or other unintended consequences ([Changnon & Changnon, 1996](#)).

However, this approach had exposed Chicago to many legal challenges, and it had suffered from accusations of too much pollution of the lower Mississippi River city and too much water from Lake Michigan. Surrounding states, worried about falling water levels in the Great Lakes, took the case to the Supreme Court. The court's decision led to Chicago being required to build a dam to control water withdrawals, a move designed to maintain the delicate balance of water levels in the Great Lakes. Despite the installation of locks and DAMS, the return of the Chicago River still had a significant impact on the environment. Every second, about 23,000 gallons of fresh water flowed from Lake Michigan into the Mississippi River and eventually into the ocean ([Reversal of the Chicago River, 2023](#)). This ongoing change is not only affecting water levels in the Great Lakes but is also contributing to a complex interplay of ecological, legal, and political issues surrounding water management in the region.

Today, more than a hundred years later, in addition to having a certain impact, this approach seems to be a good one. But now the river has a new challenge. Rainfall has become more important to the Chicago River due to extreme weather, rising impervious water levels, a warming climate, and reduced flood plains ([Dodge, 2023](#)). The most important factors affecting surface water resources are evaporation and rainfall, especially in lakes ([Egan, 2021](#)). They need to be balanced so that the water level doesn't change too much. But starting in 2014, the Great Lakes region experienced several harsh winters, in part due to a vortex of cold air around the North Pole. This can blow Arctic air into the Great Lakes region for weeks. Many scientists think it's also linked to global warming ([LeComte, 2015](#)). But in the 20th century, geographers worried about the effects of falling river levels on the city ([Changnon, 1989](#)), but in just a few decades, the Chicago River has become a much bigger problem due to extreme rainfall. In either case, these conditions have led to an increase in extreme storms that turn city streets into rivers and start causing flooding. So, we need to use data from the U.S. Geological Survey and the U.S. Environmental Protection Agency to look at Lake Michigan's water level over the last decade, and we can see that Lake Michigan's water level continues to rise under the influence of rain and wind. Nearly 40 billion gallons of runoff and waste have been discharged into the lake since 2008, three times as much as in the previous 20 years.

Although it will decline later, at its peak it will erode Chicago's lakeshore.

4. Solutions

Engineers currently have two solutions to this problem. The first is to build



Figure 3. McCook Reservoir, one of the reservoirs that store excess river water (Hawthorne & Pérez, 2023).

reservoirs so that when the river rises due to heavy rains, it has an extra place to store water. Then when the water level drops, the stored water is slowly discharged (**Figure 3**) This method is mainstream at present and the effect is obvious (Hawthorne & Pérez, 2023). In this study, we analyzed and summarized data collected by the National Weather Service and the Metropolitan Water Reclamation District of Greater Chicago on the Chicago River's return to Lake Michigan from 2013 to 2023, as well as monthly precipitation. **Figure 4** included two bar graphs, one showing the highest monthly flow of the Chicago River to Lake Michigan each year during the past 10-year period, and the other showing the amount of precipitation in the months with the highest flow from Chicago River to Lake Michigan was observed. From the figure, we can see that there is little change in the maximum annual precipitation or the precipitation that causes the maximum return, but the sewage discharged into Lake Michigan has decreased drastically since it was impounded through the reservoir. Although this has approved to be a very effective solution, it takes a long time to design and build, and requires significant capital investment (*The History of the Chicago River, 2023*).

Another solution is to allow water in Chicago River pour back into Lake Michigan. This approach would introduce pollution to the drinking water sources, and requires river level to rise higher than the lake level. Nearly 40 billion gallons of runoff and waste have been discharged into the lake since 2008, three times as much as in the previous 20 years (Hawthorne & Pérez, 2023). Although water level lines in the Chicago River as well as Lake Michigan have not risen significantly in recent years, climate change has led to an increase in the chance of extreme weather. The water level line of the Chicago River can be seen to have been in some sort of balance when compared to Lake Michigan, but extreme weather and water waves can cause the balance to be broken, which makes it harder to release water from Chicago River to Lake Michigan.

5. Discussion

Iowa, the national leader in wind energy, has the highest percentage of wind power at more than 57 percent (2022). Iowa also ranks second in the nation in installed wind power capacity with 12,219 MW (2021) (Iowa Environmental Council, 2022). provides more jobs. In 2020, Iowa’s wind industry supported more than 3953

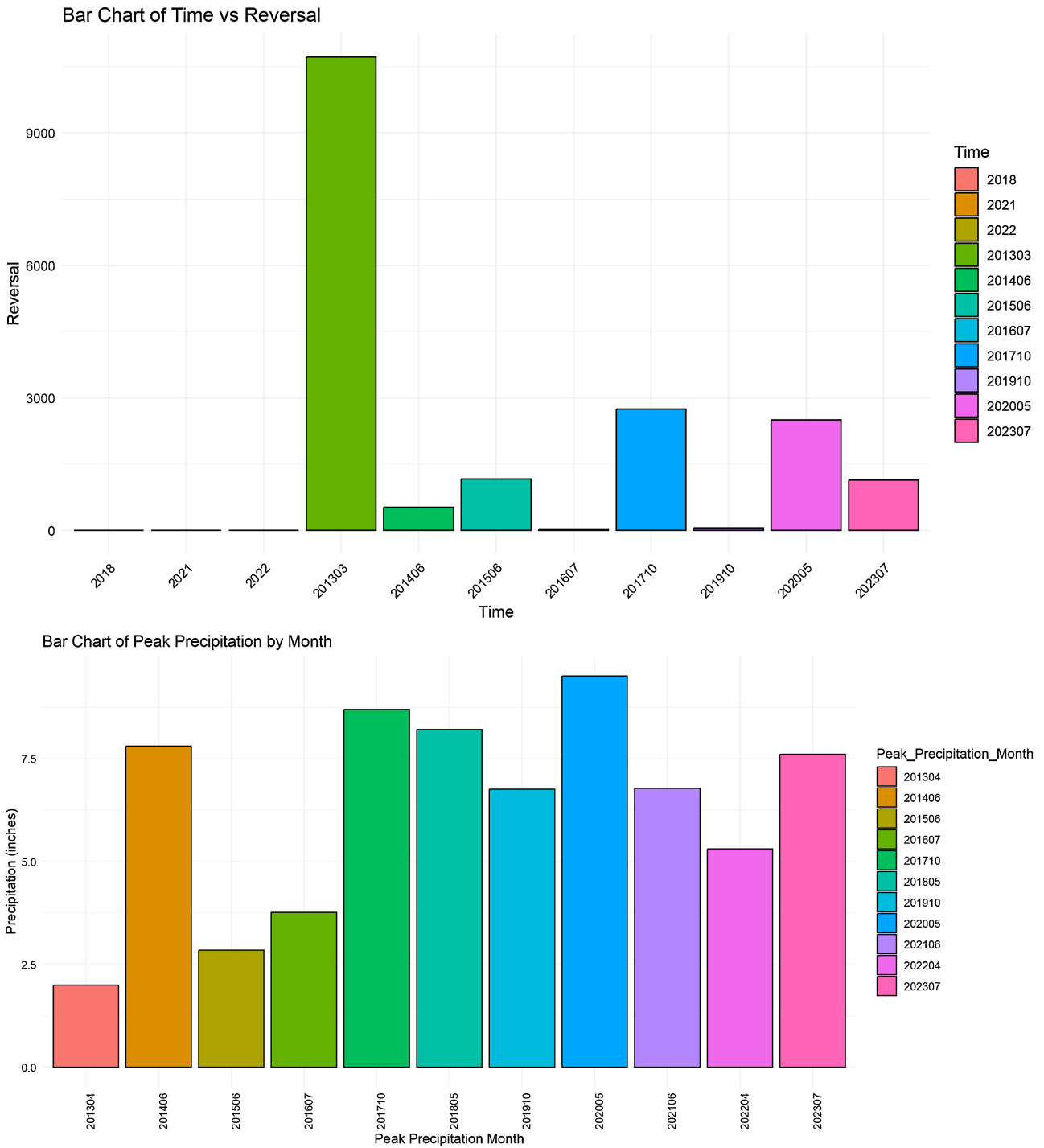


Figure 4. The rainiest months of the year in the Chicago area and how much water the Chicago River flows into Lake Michigan during those months (National weather service; Metropolitan Water Reclamation District of Greater Chicago, 2023).

Wind energy is not only the cheapest source of new power generation, but it also jobs while providing millions of dollars in property tax revenue to landowners and counties that own turbines. Companies in Iowa's wind energy supply chain are located throughout the state.

From the above Lake Michigan water protection measures, each approach is to solve the problem while creating new problems, of which downstream pollution, water damage and flooding are the biggest problems in my opinion. The return of the river can avoid the pollution of the lake, but it creates more problems. The scientists concluded that rainfall of more than 2.5 inches per day is expected to increase by 50 percent by 2039, which could lead to more sewage discharge into Lake Michigan (Hawthorne & Pérez, 2023).

Therefore, this method of building reservoirs cannot be used for a long time. Not to mention the continued dumping of wastewater into Lake Michigan, which not only causes the sewage to enter people's water, but also contaminates the entire Great Lakes freshwater system through the water flow.

The first was to build a better sewer system. Chicago's sewers were built as early as the 19th century and have been perfected over the past 100 years. However, the big problem with such sewer pipes is that the aging sewer pipes do not work perfectly with the newly built sewer pipes. The aging sewer pipes lead to congestion and sedimentation, which requires frequent maintenance by the city government, and still do not allow rainwater to flow smoothly into the sewer system. In addition, when replacing the new sewer system, it can be more convenient to replace the lead-free water supply lines for residents. It wasn't until 1986 that Chicago banned the use of lead in its water supply. So even if residents avoid drinking contaminated drinking water, they will still be affected by lead.

By the same principle, due to the excessive urbanization around the Chicago River, there is no chance of flood plain. Flood plain acts as a natural open space with trees, soil and so on in the periphery of the river. In this way, water can not only penetrate the underground aquifer during floods, but also increase the n index in Manning's formula, so that the speed and flow of the river can be reduced, and the speed of the river rise can be slowed down.

Today's industrial development needs to follow the concept of sustainable development, and such historical mistakes or costs are necessary and inevitable. But the development of modern industry needs to consider more impacts to reduce the occurrence of problem solving. Therefore, the concept of sustainable development needs to be instilled in the minds of more people, that is, "a development model that can meet the needs of our present, without harming future generations, and can meet their needs." And this is the best way. It also is one of THE 17 GOALS of the United Nations to make cities and human settlements inclusive, safe, resilient, and sustainable. If such a concept had been put in place more than a hundred years ago, it might not have been such a serious problem (United Nations, 2015).

6. Conclusion

After studying the effects of climate on agriculture and water on Great Lakes Region, we discussed the effects of soil erosion on agriculture, impervious surfaces of cities and the effects of extreme weather on cities, including flooding, river-bank erosion, etc., we also discussed the history of the Chicago's water resources and concerns about the loss of fresh water and the pollution of the river downstream. Finally, we talk about the actions people in the Midwest are taking on sustainable development strategies and existing issues. We hope that human beings can do better to protect the climate, soil and water resources.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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