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IMPLEMENTING NATURAL INFRASTRUCTURE IN THE UPPER MISSISSIPPI RIVER BASIN:

LESSONS FROM IOWA

A REPORT PREPARED FOR ENVIRONMENTAL DEFENSE FUND

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Implementing Natural Infrastructure in the Upper Mississippi River Basin: Lessons from Iowa

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EXECUTIVE SUMMARY

The Upper Mississippi River Basin (UMRB) suffers from poor water quality due to high nutrient runoff from the over-application of fertilizers in industrial agriculture and the increasing frequency of flooding (America's Watershed Initiative, 2020). A promising solution to address these issues is construction of natural infrastructure, such as restored wetlands, that reduce both flood risk and nutrient pollution. The state of Iowa in particular has struggled with increasing flooding and nitrogen pollution, and shows great potential for the benefits of natural infrastructure. However, implementing natural infrastructure in Iowa - and the region more broadly - has been slow due to knowledge gaps, policy conflicts, and institutional barriers. In order to fill knowledge gaps and explore barriers, the central questions of this project are: how can natural infrastructure implementation be improved and how can natural infrastructure benefit socially vulnerable communities? To answer these questions, the project has five specific objectives: (1) evaluate the potential for hydric soil proxies to help identify key locations for natural infrastructure interventions, (2) evaluate the flooding and nitrogen pollution exposure of socially vulnerable communities in Iowa, (3) understand the social and political conditions for successful natural infrastructure implementation in Iowa, (4) identify policy opportunities for expanding natural infrastructure in Iowa, and (5) propose priorities for future natural infrastructure research and advocacy.

Objective 1: Identify Key Locations for Natural Infrastructure Interventions

Wetland restoration is an approach to improve the ability of historic wetlands to regulate water quality and quantity. However, the location of historical wetlands does not necessarily indicate the location of restorable wetlands. We found **that the 90-100 hydric soil categories are suitable proxies at both the watershed and state levels, but do not perform well in urban areas.**

Currently, the identification of wetland requests the cost of $300 per acre and 60 days reporting time on the official price in Wisconsin DNR (Wetland Identification Program, 2021). **By using the HS proxy, the estimated region can be narrowed which saves the corresponding cost and process time. Therefore, this successful evaluations of hydric soil proxy can assist in identifying suitable regions, reducing data processing steps, and analysis costs.**

Objective 2: Evaluate the Flooding and Nitrogen Pollution Exposure of Socially Vulnerable Communities in Iowa

This objective examined two aspects: (1) correlation between social vulnerability, flood risk, and nitrogen pollution by applying a multiple linear regression, and (2) comparisons between current (2020) flood risk to projected (2050) flood risk in Iowa and social vulnerability. Positively correlated and statistically significant relationships were found between multiple social vulnerability factors, flood risk, and nitrogen pollution. **The seven statistically significant social vulnerability factors are: poverty rates per census tract, lack of high school diploma per census tract, persons over 65 per census tract, single parent households per census tract, household crowding per census tract, persons in a minority group (non-white population) per census tract, and number of households without a vehicle per census tract.** Forty-nine state-level maps were created to visualize these statistically significant relationships. These maps can be found in Chapter II and in Appendix A.

This analysis has changed the general understanding of risk distributions in Iowa by examining the impacts of agricultural practices on downstream communities and the differences in exposure across communities. The results of this analysis can better inform communities and decision-makers about exposure and social vulnerability in Iowa. Furthermore, the results can be used to rectify past injustices and prevent future injustices by implementing natural infrastructure in socially vulnerable communities.

Objective 3: Understand the Social and Political Conditions for Successful Natural Infrastructure Implementation in Iowa

This objective of the project worked to investigate (1) the similarity and difference of Des Moines Water Works lawsuit and Middle Cedar Partnership Project, and (2) the key conditions for successful collaborative conservation, especially the promotion of future natural infrastructure practice and implementation based on two case studies. We used semi-structured interviews with key stakeholders to identify (1) the water issues such as the mitigation of flooding and nutrient loading in Iowa; (2) the existing barriers and opportunities of natural infrastructure implementation in Iowa; (3) the collaborative conservation relationships among stakeholders.

We found the conditions for success were: (1) firm trust in collaborative networks, (2) political support, (3) stable and consistent funding, and (4) involvement of experienced coordinators. Future collaboration can take advantage of this study to precisely position the project efforts.

Objective 4: Identify Policy Opportunities for Expanding Natural Infrastructure in Iowa

This objective of the project sought to identify policy opportunities and barriers for natural infrastructure through interviews with Iowan stakeholders. The interviewees were asked about water issues in the state, natural infrastructure opportunities and barriers, and specific policy questions during semi-structured interviews. **Based on our interviews, key policy opportunities are: (1) reduce administrative barriers, (2) incentivize long-term planning and funding, (3) enable coalition building and trust building, (4) prioritize environmental justice, and (5) capitalize on Farm Bill opportunities coming with the change in administration and Democratic control of Congress.** In Chapter IV of this report, each policy recommendation's barriers, opportunities, and levers are explored in greater detail. Implementation of these recommendations would lead to an increase in natural infrastructure implementation with a focus on equity, justice, and accessibility.

Objective 5: Propose Priorities for Future Natural Infrastructure Research and Advocacy

This analysis links the identified issues with the policy levers and opportunities in order to improve the chances of success for natural infrastructure research and advocacy. **The utilization of hydric soil proxy can shorten the process for identifying locations for wetland restoration and reduce the associated cost.** Thus, it may lead to increased retention of stakeholders who are interested in adopting natural infrastructure practices by reducing the processing time if implemented. Then, **the social vulnerability study has provided a new version that corresponds to the environmental justice incentivization in policy recommendation.** This analysis uncovered the major points when considering nitrogen pollution in Iowa, and it also provided suggestions for how to incorporate various voices from POC and socially vulnerable groups. Finally, **the identified success conditions are mostly in line with long-term planning and funding, coalition and trust building, and the opportunities with the change in administration and congressional turnover.** With the Biden administration's concentration on the environment and congressional turnover that has resulted in a Democratic majority in the House and the tie-breaking vote in the Senate, it is good timing for obtaining stable and long-term support from the government. This cross-analysis among different chapters has connected the four chapters tightly, and has offered a novel interdisciplinary model for similar research in the future.

Acronyms

Best Management Practices (BMPs)
Communities of Color (COC)
Des Moines Water Works (DMWW)
Department of Natural Resources (DNR)
Environmental Defense Fund (EDF)
Government Accountability Office (GAO)
Middle Cedar Partnership Project (MCPP)
Natural infrastructure (NI)
Technical Service Provider (TSP)
United States Department of Agriculture (USDA)
Upper Mississippi River Basin (UMRB)

Introduction

The Upper Mississippi River Basin, or UMRB, extends almost 700 miles, from near the Canadian border to the mouth of the Ohio River. It reaches around 500 miles across the Midwest, from Indiana to South Dakota, resulting in a drainage area that spans approximately 189,000 square miles in Illinois, Iowa, Indiana, Minnesota, Missouri, and Wisconsin (America's Watershed Initiative, 2020). Its geographical location is illustrated in **Figure 1**. The UMRB is home to approximately 30 million people, several large urban areas, and with extensive agricultural and recreational land (America's Watershed Initiative, 2020).

Figure 1. Map of the Upper Mississippi River Basin ((2020). Upper Mississippi River Basin

In 2020, the America's Watershed Initiative assessed the health of the UMRB across six goal areas -- Water Quality and Ecosystems, Flood Control and Risk Management, Recreation, Transportation, Economy, and Water Supply. When graded against these areas, the UMRB was graded at a 'C' quality, due to the UMRB's high nutrient runoff from regional agriculture and its increasing flood frequency (America's Watershed Initiative, 2020). Agriculture and urban runoff nonpoint source pollution, exacerbated by the loss of wetlands, are causing water quality issues. This demonstrates that the communities that live in the UMRB are at risk of facing challenges surrounding water quality contamination, nutrient pollution, and flooding.

Natural infrastructure (NI) is a tool that can be used to address these issues. NI uses landscape management strategies (e.g., restoration, conservation, and sustainable management) to provide essential ecosystem services (i.e., clean water). For example, NI methods such as wetland restoration and cover crops were both ideal techniques in terms of reducing flood risk in agricultural fields (Antolini et al., 2019).

This project focused specifically on Iowa due to the potential that can be found in the state for improvements to flood risk and nitrogen pollution. Beyond its borders, Iowa contributes approximately 618 million pounds of nitrogen pollution from agricultural runoff to the Gulf of Mexico Hypoxic zone each year (Eller, 2018). Along with this, the state contains cases such as the Des Moines River Works Lawsuit and the Middle Cedar Partnership, which are events that this project analyses as case studies in order to determine aspects of successful collaborative conservation. The state of Iowa as a whole has a population of 3.18 million, 50% of which depend on the Des Moines River Watershed. 90% of these residents are White, 3.51% are Black, 2.4% are of Asian descent (Census, 2018). The total state GDP is approximately $194 billion, of which $72 billion is directly from the agricultural sector. Production agriculture and ag-related industries employ one out of every six Iowans, so it is a primary economic driver in the state (USDA, 2019). A result of this is that the agricultural sector has been allowed to continue degrading the water quality at the extent that it has. Nitrogen pollution flowing out of Iowa to the Gulf of Mexico has grown by close to 50% over the last 20 years (Eller, 2018). Floods are growing more frequent and extreme as well, as a result of erosion and runoff.

Iowa's has particular nitrogen pollution and flood risk issues that could be addressed with NI implementation (Eller, 2018), but uptake and implementation have been slow. This project has sought to analyze opportunities for more effectively and equitably using NI to reduce flood risk and nitrogen pollution. This is done through: utilizing a hydric soil proxy to determine locations for restored wetlands, identifying socially vulnerable communities that would benefit from NI implementation, analyzing two case study areas - the Des Moines Water Works lawsuit and the Middle Cedar Partnership Program - to determine what allows successful collaborative conservation efforts, and identifying ways in which policy changes would be effective in assisting the implementation of natural infrastructure solutions.

Background

The Challenges Facing the Upper Mississippi River Basin

Flood damage risk has been increasing steadily in the UMRB. In 1995, it was estimated that the mean annual flood damage in the region had increased by 140% throughout the 20th century (Hey, 1995). This was illustrated by The Great Flood of 1993, which caused $15 billion ($27 billion in 2020 cost year) in damages and was the largest flood ever recorded on the Mississippi (Larson, 1996). In addition to this, a study conducted by America's Watershed Initiative revealed that the condition and maintenance of the transportation infrastructure within the basin are poor, its water quality is low, and there is a high rate of wetlands loss (America's Watershed Initiative, 2020). Additionally, communities that live in the UMRB are at risk for facing adverse effects surrounding water quality contamination, nutrient pollution, and flooding. The poor water quality indicates that agriculture and urban runoff nonpoint source pollution is present and is likely exacerbated by crumbling infrastructure and the loss of wetlands. Flood risk has been increasing primarily through the increase of urban areas and industrial agriculture in the region. This is illustrated by the fact that the amount of excess water that passed St. Louis during the 1993 flood would have covered a little more than 13 million acres, or half of the wetland acreage drained since 1780 in the UMRB (Hey, 1995).

Starting from January 2020, the Mississippi River encountered heavy storms and river levels began to rise. Eventually, the City of New Orleans announced the start of the flooding stage on March 5th, 2020. As the constant precipitation entered the Mississippi River, the states of Arkansas, Mississippi, and Louisiana received a flood warning from the National Weather Service (NASA, 2020). It is reasonable to believe flooding would be less severe in the Lower Mississippi River Basin if effective flood control actions were taken in the UMRB. Additionally, nutrient pollution conditions are also not optimistic. Studies showed the concentrated precipitation increased the nitrogen load (Wolf et al., 2020) and accounted for nearly one third of the yearly nitrogen runoff in Mississippi River Basin (Lu et al., 2020).

Flooding and nitrogen pollution in the UMRB are also frequent challenges in two cities that were selected for this analysis: Cedar Rapids, IA and Des Moines, IA. In Cedar River Watershed, the active USGS stream monitoring station's data shows the average annual streamflow at the station is 3,759 cubic feet per second in 2009. However, streamflow in the Cedar River is highly seasonal, with higher flows in the spring and early summer (Iowa DNR, 2006). Agricultural land is the predominant land use in the Cedar River Watershed. In addition to row-crop agriculture, livestock operations are scattered throughout the watershed, such as beef, sheep, and poultry operations (Iowa DNR, 2006). Because of this seasonality, the nitrate concentration in the city of Cedar Rapids is highly seasonal, with intensive frequency in May and June.

The application of fertilizer on agricultural land in the fall and the release of ammonia from decaying organic matter on streambed causes the steep increase of nitrate concentrations (Seelig & Nowatzki, 2001). As agriculture requires nitrogen and phosphorus fertilizers, the accumulation of those nutrients over time reduces soil health and water quality. Additionally, nitrate exposure from agricultural runoff in water systems is a major issue in Iowa. This exposure has been connected to an elevated risk of ovarian, thyroid, kidney, and bladder cancer, 'blue baby syndrome' (a condition in which an infant is deprived of oxygen, sometimes fatally), and other major health issues (Temkin et al., 2019). In Iowa specifically, nitrate-attributable cancer ranges from 2.3 to 10.43 cases per 100,000 people (Eller, 2019a). Conservation practices work to hold nitrates and phosphorus in place on the field, reducing unwanted contributions to the water supply and decreasing the need for additional nutrient application.

In 2019, Des Moines witnessed its second 100-year flood in 20 years, and at least 200 miles of levees were breached in the watershed (Norvell, 2019). The dominant nonpoint source pollution in the Des Moines River Watershed is sediment from agricultural practices, such as cropland tillage and livestock in pastures, woodlands, and feedlots (Environmental Protection, 2020). More than half of Iowa's assessed water bodies are impaired by pollution that limits recreation, kills fish, and impairs potable water sources (Jordan, 2017). This is only an estimate, as the Iowa Department of Natural Resources (DNR) was only able to assess 52% of rivers, 61% of lakes, and 83% of wetlands due to budget constraints, so this statistic could be higher (Jordan, 2017). Des Moines water is obligated to meet the Environmental Protection Agency's Standards under the Safe Drinking Water Act. However, the maximum contaminant level for nitrate, 10 mg/L, is high enough to cause health risks, such as blue baby syndrome and endocrine disruption (Des Moines Water Works, 2015).

Natural Infrastructure as the Solution

Natural infrastructure that uses landscape management strategies (e.g. restoration, conservation, and sustainable management) to provide essential ecosystem services (i.e. nutrient and flood management) can address these human and environmental issues. **Figure 2** illustrates which natural infrastructure solutions can be implemented to solve various water management issues as well as which grey infrastructure solutions are typically implemented instead (Ozment et al., 2015). **Natural infrastructure practices** on agricultural land can include cover crops, saturated buffers, wetland restoration, grass waterways, and riparian buffers (full list found in **Figure 1**). **Natural infrastructure implementation** refers to the process of putting policies into practice. This includes identifying the various policy levers, external factors, and political will that impact the ability for natural infrastructure practices to be put into place. Antolini et al. (2019) demonstrated that wetland restoration and cover crops were both ideal natural infrastructure techniques in terms of reducing flood risk in agricultural fields. Thus, natural infrastructure measures are considered to be Best Management Practices (BMPs) for agricultural land managers as these measures can greatly decrease both flood risk and agricultural pollution (Antolini et al., 2019).

Natural infrastructure practices could be used as a method to reduce water quality issues and flooding in the UMRB. Cunniff's 2019 report states that well-managed natural areas can absorb more precipitation and slow surface flow to reduce flood height and speed, reducing both runoff and flood risk (Cunniff, 2019). Moreover, agricultural and forest land have shown to significantly reduce nitrate pollution in their nearby area if they properly leverage plant assimilation or denitrification mechanisms (Schoonover & Williard, 2007). Habitat deterioration and loss mean the loss of ecosystem services, and this loss causes an increase in extreme weather events that can cause flooding and nutrient runoff. Through the implementation of natural infrastructure, one can reduce the effects of flood-intensifying conditions associated with climate change and restore crucial habitats (Cunniff, 2019).

However, the relatively difficult implementation demands of the terrain, longer restoration times, and higher installation costs restrict the wide adoption of natural infrastructure (Antolini et al., 2019). Additionally, the implementation of these natural infrastructure strategies across the basin can not be divided by state boundaries, as an affected watershed may not follow legal borders. This is due to the nature of downstream runoff, while a pollution source may start in one state, it may have adverse impacts in another downstream. As a result, individuals, non-government organizations, state agencies, and even federal agencies have initiated multiple projects and planning initiatives, such as natural infrastructure adoption plans that span across the UMRB in order to adequately mitigate the flood and nutrient pollution problems. Because a small action in one part of the UMRB may affect the entire basin as a whole, natural infrastructure adoption will need to be increased and facilitated through watershed partnerships in order to mitigate the flood and water quality issues.

Water management issue (Primary service to be provided)		Green Infrastructure solution	Location				Corresponding Grey Infrastructure solution (at the primary service level)
			Watershed	Floodplain	Urban	Coastal	
Water supply regulation (incl. drought mitigation)		Re/afforestation and forest conservation	X				Dams and groundwater pumping Water distribution systems
		Reconnecting rivers to floodplains		X			
		Wetlands restoration/conservation	X	X	X		
		Constructing wetlands	X	X	X		
		Water harvesting*	X	X	X		
		Green spaces (bioretention and infiltration)			X		
		Permeable pavements*			X		
Water quality regulation	Water purification	Re/afforestation and forest conservation	X				Water treatment plant
		Riparian buffers		X			
		Reconnecting rivers to floodplains		X			
		Wetlands restoration/conservation	X	X	X		
		Constructing wetlands	X	X	X		
		Green spaces (bioretention and infiltration)			X		
		Permeable pavements*			X		
	Erosion control	Re/afforestation and forest conservation	X				Reinforcement of slopes
		Riparian buffers		X			
		Reconnecting rivers to floodplains		X			
	Biological control	Re/afforestation and forest conservation	X				Water treatment plant
		Riparian buffers		X			
		Reconnecting rivers to floodplains		X			
		Wetlands restoration/conservation	X	X	X		
		Constructing wetlands	X	X	X		
	Water temperature control	Re/afforestation and forest conservation	X				Dams
		Riparian buffers		X			
		Reconnecting rivers to floodplains		X			
		Wetlands restoration/conservation	X	X	X		
		Constructing wetlands	X	X	X		
		Green spaces (shading of water ways)			X		
Moderation of extreme events (floods)	Riverine flood control	Re/afforestation and forest conservation	X				Dams and levees
		Riparian buffers		X			
		Reconnecting rivers to floodplains		X			
		Wetlands restoration/conservation	X	X	X		
		Constructing wetlands	X	X	X		
		Establishing flood bypasses		X			
	Urban stormwater runoff	Green roofs			X		Urban stormwater infrastructure
		Green spaces (bioretention and infiltration)			X		
		Water harvesting*	X	X	X		
		Permeable pavements*			X		
	Coastal flood (storm) control	Protecting/restoring mangroves, coastal marshes and dunes				X	Sea walls
		Protecting/restoring reefs (coral/oyster)				X	

Figure 2. Natural infrastructure solutions for water resources management (Ozment et al., 2015)

Incorporating Environmental Justice and Racial Equity

Institutional barriers and justice issues must be addressed in order for everyone to benefit from natural infrastructure. Acts of conservation do not necessarily have a positive impact on all communities. It is essential to acknowledge who is most negatively affected by pollution and natural disasters, in order to ensure that scenarios of inequity are not reinforced by the implementation of conservation solutions. In order to identify those most negatively impacted, this project utilizes a social vulnerability framework.

Social vulnerability consists of three aspects: exposure, sensitivity, and adaptive capacity. Exposure assesses physical conditions for environmental hazards while sensitivity measures the degree of hazard impact on communities. The adaptive capacity element examines the response of communities to environmental changes. Socially vulnerable communities are more vulnerable before, during, and after a disaster (also referenced in literature as “Frontline Communities’’ (Wilensky, 2019)), because they experience some combination of high exposure, high sensitivity, and/or low adaptive capacity. This project defines socially vulnerable communities as communities that are exposed and exhibit one or more factors selected from the CDC’s Social Vulnerability Index, which primarily describes the sensitivity aspect (see Chapter II for more detail). Generally, this project does not examine the adaptive capacity component of social vulnerability.

Communities of Color (COC) are often described as socially vulnerable due to the systemic racism, oppression, and the cycle of poverty that persists in the United States. When this project uses the term ‘People of Color’ or ‘POC’, it is referring to all people who are not white. It is generally an umbrella term that dates back centuries, but became popular in social justice circles in the late 1970s to counter the condenscension implied by terms such as ‘non-white’ and ‘minority’ (Clark & Arborleda, 1999). This was also seen as necessary by anti-racist activists and academics who sought to move the understanding of race in the United States beyond the ‘black-white’ dichotomy that was prevelant at the time (Martinez, 1994). The term ‘BIPOC’, or ‘Black, Indigenous, (and) People of Color’, first appeared in social justice circles online in 2013 (Garcia, 2020). This project utilizes the term POC rather than BIPOC, as the term BIPOC can blur the differences between the two groups that it is meant to represent. According to Dr. Jonathan Rosa of Stanford, the term BIPOC is valuable as a way of thinking about how violence against Black and Indigenous people is foundational to the United States, as a country founded on the enslavement of Black people and the genocide of Indigenous people (Grady, 2020). However, when a term like BIPOC is adopted indiscriminately, differences between these groups can be erased, which is the very nature of the colonialist mindset (Garcia, 2020). Thus, this project utilized POC rather than BIPOC due to the erasure and terminology issues associated with the term BIPOC and the historical basis behind the term POC. Additionally, this project works to only use acronyms that describe People of Color as an amalgamation of groups when absolutely necessary for overarching analysis. In the same way, the term 'Communities of Color' is only used when an amalgamation of communities is necessary in order to describe the ways in which environmental degradation differently affects Communities of Color compared to 'White' communities.

Communities of Color and low-income communities are more vulnerable to detrimental environmental events for several reasons. These socially vulnerable communities often live in flood plains, are more likely to live below the poverty line, are more likely to speak English as a second language, and often lack vehicle access (Wilensky, 2019). Dwelling units in these areas are often of lower build quality, making them more susceptible to damage (Wilensky, 2019). Recovery processes are also unequally distributed in flooding disasters. For example, after catastrophic floods in Iowa in 2008, payments were not distributed until months after the flooding occurred (Ambrose, 2019). Low income communities cannot wait this long for relief and struggled disproportionally compared to residents who were able to utilize savings until relief funding was distributed (Ambrose, 2019).

This compounded with the fact that FEMA-provided temporary housing is only available for six months, the sudden disaster of a flood coupled with the lack of rebuilt homes leaves socially vulnerable communities in worse situations than before (Wilensky, 2019). Additionally, Iowa was only able to spend 3% of $798 million in federal block grants due to federal distribution rules. Further, this funding was distributed primarily to higher-income communities because the cost of the protection envisioned "must not exceed the value of the property being protected" (Wilensky, 2019). This rule allows for the justification of mitigation projects to protect higher-valued homes or land compared to the homes of socially vulnerable communities, even if these wealthier locations are better positioned to recover due to inherent community wealth (Wilensky, 2019).

Low-income communities and COC often face disproportionately high pollutant exposures as a result of agricultural runoff and nutrient pollution. Epidemiological evidence for health effects associated with drinking water about 5 mg/L NO_3-N raises concerns about the increased risk for the 5.6 million Americans served by public water supplies with average nitrate concentrations above this level (Schaider et al., 2019). Water systems that serve communities with lower median incomes, lower rates of home ownership, and higher proportions of non-white residents have been associated with higher levels of nitrate and arsenic (Schaider et al., 2019). A study conducted by the University of North Carolina found that there is a lack of policies and regulations put in place that address chronic water issues faced by low income communities and COC (Vanderwarker, 2012). Because of these facts, it is important to incorporate environmental justice into all considerations regarding natural infrastructure implementation. Who is going to benefit from this implementation? Will it be positively affecting those who are more at-risk of environmental disaster?

Natural infrastructure benefits socially vulnerable communities by helping to solve issues they face before they occur. Through implementing natural infrastructure in agricultural areas, both flood and nutrient pollution risks can be reduced. Natural infrastructure lowers the amount of financial investment needed to defend against damaging floods, as many natural infrastructure methods are cheaper investments than flood dams and barriers (Adriaenssens, 2019). Along with that, natural infrastructure in agricultural fields can mitigate water quality degradation. For example, buffers in agricultural fields improve the infiltration of water through propagation matter, and can retain or remove nitrate by 60-90% (Canning & Stillwell, 2018). By reducing the amount of pollution created by agricultural lands, the risk of nutrient pollution in water systems in socially vulnerable communities is reduced.

Collaborative Conservation as a Tool

Collaborative conservation is a promising method to implement natural infrastructure practices. The wide-spread scale of flooding and nutrient pollution in Iowa motivates a variety of stakeholders with potentially conflict-ridden histories or competing interests. Collaborative conservation could be utilized as a tool to address the environmental issues in the UMRB while allowing for stakeholders to achieve mutually beneficial outcomes.

History of Collaborative Conservation

Collaborative conservation allows for communities to address contentious conservation issues by respecting diverse voices, needs, and challenges. Started in the early 1950s, collaborative conservation action was encouraged to involve multiple stakeholders to manage watershed resources (Ohio Forestry Association, 1955). In the 'watershed collaboration era' (the 1980s) the quality, and intentionality of these interactions were focused to include diverse stakeholders in deliberative forums. Further attention was invested in the last few decades along with the reduction of public resources and growing government distrust, especially in the western U.S. (Sabatier et al., 2005). The U.S. government then began to fund collaborative conservation action in multiple fields, such as water. All 50 states have funded watershed collaborative conservation. Technical assistance and training also came with the funding (Hardy & Koontz, 2008). After the 2000s, government-led, collaborative conservation was further explored as the approach to address public lands and endangered species concerns.

In 2008, the U.S. Government Accountability Office (GAO) reported on how federal agencies could support collaborative conservation efforts (GAO, 2008). GAO identified collaborative conservation as a promising tool for resource management and made the following recommendations for increasing federal agencies' support of collaborative conservation efforts: (1) disseminate tools to agencies to use on how to participate in collaborative efforts and how to sustain participation, (2) identify positive examples of collaborative conservation and share them as guidance for other groups, (3) hold national or regional conferences to bring collaborative groups together to share lessons learned, (4) evaluate legal and policy changes related to federal financial assistance to enhance collaborative efforts, and (5) provide structure and support for collaborative conservation groups by identifying goals, actions, and time frames needed to implement the Cooperative Conservation Initiative (GAO, 2008).

Many works of literature claim the benefits of collaborative conservation action. Additionally, collaborative handbooks have been developed and present useful information and key variables affecting collaborative efforts (Koontz, 2016). Multiple interacting variables were identified, such as trust, economic development, networking, and social leading. However, the growing research attention and literature highlights an implementation gap of collaborative conservation principles and practices. Nearly 2 out of 3 publications do not deliver effective actions (Knight et al., 2008). The overall research and description of collaborative conservation points out the necessity of including collaborative conservation in regional community projects.

Collaborative Conservation in the UMRB

Partnerships are growing as a medium to explore collaborative opportunities across the UMRB. For example, Fishers & Farmers Partnership is one of a groups formed by members of non-governmental organizations, tribal organizations, and state and federal agencies to empower landowners to achieve their goals and interests (Fishers & Farmers, 2020). Joining or establishing a cross-border collaborative is not unusual when seeking effective conservation in a large-scale region. The continuous flooding and water pollution problems in the UMRB may motivate community members to establish collaborative partnerships to address these issues across multiple watersheds.

The unique policy, environmental, and social structure differences across the U.S. create difficulties in comparing successful cases to one another. Additionally, the various motivations and interaction strategies of farmers, organizations, and federal agencies heighten the difficulty of creating successful collaborative partnerships. In order to replicate the success of existing collaborative partnerships, these projects should be studied. Examining a successful collaborative conservation project offers a way to observe and understand the key elements for successful collaborative conservation. For a robust understanding of the conditions for collaboration, a contrasting case should be examined for comparison.

Objectives

1. Identify Key Locations for Natural Infrastructure Interventions

Natural infrastructure can be a sustainable solution to mitigate flooding and nutrient pollution (The Nature Conservancy, 2020). A wetland is one of the effective types of natural infrastructure, providing freshwater regulation and management services. Wetland restoration is a common way to improve the water regulation function of historical wetlands. Due to the correlation of wetlands hydrology and hydric soil, this project evaluates the utility of hydric soil as a wetland restoration proxy in order to identify key locations for natural infrastructure practices. The objective of this analysis is to evaluate the accuracy of the proposed hydric soil proxy of restorable wetland identification by using the spatial analysis tool. Additionally, the report will address the promising proxy categories, potential application constraints, and implications for future wetland identification processes. Uncovering the restorable wetland proxy will eventually help in prioritizing the implementation of future natural infrastructure practices.

2. Evaluate the Flooding and Nitrogen Pollution Exposure of Socially Vulnerable Communities in Iowa

According to Cutter et. al., the resilience of a community is inextricably linked to the condition of the environment and the treatment of its resources (Cutter et al., 2008). So, building a community which is able to overcome environmental crises is essential to building a community that can succeed. Ensuring that this project is working to address inequality in the communities that it is studying is absolutely essential to creating sustainable communities through the implementation of natural infrastructure. Environmental justice should be considered a key issue, embedded in the entire project. To extend the benefit of natural infrastructure implementation to Communities of Color (COC), one must work on establishing shared interest and goals, and action guides with associated communities as a whole to face these shared environmental issues. This project examines the relationship between social vulnerability, nitrogen pollution, and flood risk in a spatial and statistical analysis.

3. Understand the Social and Political Conditions for Successful Natural Infrastructure in Iowa

There is often a disconnect between knowledge and action with regards to implementing natural infrastructure. By reducing this disconnect, sustainable actions such as implementing natural infrastructure are more likely. To understand the conditions that led to collaborative conservation in Iowa, this project will examine two case studies with different ecological and social outcomes. The first case study is the Middle Cedar Partnership Project (MCPP), a well-known collaborative in the Middle Cedar Watershed. The second case study is the Des Moines Water Works (DMWW) lawsuit, a notorious lawsuit that questions who bears the burden of nutrient pollution. The case study analysis utilized semi-structured interviews to examine the relationships between the stakeholders in each case. By examining two contrasting cases, a robust understanding of the conditions for successful collaboration can be developed.

4. Identify Policy Opportunities for Expanding Natural Infrastructure in Iowa

Since natural infrastructure has been identified as a beneficial solution to mitigate flood risk to local communities and mitigate nutrient loading into the rivers and stream systems of the Upper Mississippi River Basin (UMRB), the policy agenda for local, state, and federal governing bodies needs to incorporate natural infrastructure moving forward. To identify and consolidate this policy agenda, this research focuses on policy opportunities for implementing NI in the state of Iowa. The analysis uses semi-structured interviews with natural infrastructure professionals and previous research to identify the main barriers, current levers, and future opportunities to implement and adopt natural infrastructure policies in Iowa.

5. Propose Priorities for Future Natural Infrastructure Research and Advocacy

The key takeaways from Chapters I, II, and III are summarized and connected with policy recommendations from Chapter IV. The results are priorities for varied stakeholders and different levels of governments in future natural infrastructure implementation efforts. Additionally, examining the connection of three chapters assisted in checking the repeated gaps of natural infrastructure in different academic study fields. The analysis aimed to (1) identify the priorities of natural infrastructure implementation in each chapter, (2) acknowledge the connection between each chapter and with the policy recommendations, and (3) summary key takeaways for future natural infrastructure research and advocacy based on proposed policy levers and opportunities. In all, this chapter identified a list of priorities for future natural infrastructure implementation. For instance, reducing the administrative barriers, and creating a collaboration directory. Meanwhile, future decision-making and implementation of natural infrastructure should prioritize the assistance for POC and incorporate diverse voices, which will eventually benefit the social vulnerability communities.

CHAPTER I

EVALUATING THE ACCURACY OF PROXIES FOR RESTORABLE WETLAND IDENTIFICATION

WANYING WU

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EXECUTIVE SUMMARY

Wetland restoration is an approach to improve the ability of historic wetlands to regulate water quality and quantity. However, the location of historical wetlands does not necessarily indicate the location of restorable wetlands. This creates a challenge for decision-makers and managers in identifying areas with high potential for wetland restoration and their subsequent ecosystem service. Hydric soils have been shown to have a close hydrologic correlation with wetlands and often used as a potential proxy for wetland restoration. However, not all areas that have hydric soil qualify as wetland areas. Therefore, this report investigates the feasibility of using hydric soil as a proxy in wetland restoration estimation through spatial analysis techniques utilizing a case study of Minnesota.

Methods

A state-level histogram comparison and HUC watershed-level zonal distribution statistics were employed to investigate the association of each category of hydric soil (HS), digital elevation model (DEM), restorable wetland inventory (RWI). Then, the suitability of the statistical results were re-evaluated at the state-level using the same zonal statistics. Spatial location characteristics of the residential address, waterbody, and suitable HS proxy were then utilized to compute the acreage proportion of potential restorable wetland in two selected watersheds.

Result

The results of the various analyses either differed drastically or sequentially supported each other to decide if the initial evaluation is proper. The suitability analysis proved that the 90-100 HS categories can be a proxy of the 2-5 RWI categories, while elevation has no visible association with the RWI categories. Results from the watershed-scale analysis showed the HS proxy is suitable for both Des Moines and Cedar Rapids. The suitability of the 90-100 HS proxy increased with distance to aggregated residential regions. Therefore, the 90-100 HS proxy is predicted to be more useful in rural areas than in aggregated residential regions. Agricultural land, natural land, and waterbodies in Iowa have a greater chance of being identified as restorable wetlands than residential regions and barren lands.

Implications

A suitable proxy can reduce the time and effort needed to evaluate the restorable possibility of a certain location. Since the 90-100 HS proxy occupies a greater proportion of high RWI category than the 1-89 HS proxy, it indicates the measurement of 90-100 HS would most likely have a positive estimation result of restorable wetland location. Thus, it can assist in identifying suitable regions, reducing data processing steps, and analysis costs. The current Wisconsin DNR's wetland identification program requires $300/acre and 60 days reporting time. With the HS proxy, the identification fee and time should be reduced based on the amount of effort that has been saved.

Acronyms

Digital Elevation model (DEM)
Hydric Soil (HS)
Hydrologic Unit Code (HUC)
Percentage (PCT)
Restorable Wetland Inventory (RWI)

Purpose

The UMRB has several water quality issues. Two large issues are flooding and nitrogen pollution. Flooding is when water submerges land that is normally dry. Flash floods can cause damage to household and community property (Flood basics, 2021). In the City of Cedar Rapids, a 2008 flood largely impacted 7,198 parcels, including 5,390 houses. It dislocated more than 18,000 residents and damaged 310 city-owned facilities (City of Cedar Rapids, 2021a). Nitrogen pollution occurs when there is an excess of nitrogen in an environment, causing nitrogen run-off. It harms the somatic function of humans even at a low level. Excess nitrogen can damage one's ability to breathe, can cause certain cancers and 'Blue Baby Syndrome' (methemoglobinemia), and can harm soil health (Nutrient Pollution issue, 2019).

However, the natural infrastructure technique of constructing a restored wetland could be a good method to reduce flooding and mitigate nitrogen pollution. Restored wetlands provide multiple ecosystem services and functions, such as climate regulation, water regulation, nutrient cycling, water treatment, and water supply. Thus, it can be an effective option for regulating hydrological flows, water storage and retention, mobile nutrient recovery, and excess nutrient breakdown (Costanza et al., 1997). Wetland restoration entails altering a historical or a degraded wetland's physical, chemical, or biological characteristics to return to its natural conditions (Tang et al., 2012). However, the process of determining the potential location for a restorable wetland can not be based fully on historical wetland locations. That is because land use and land cover changes can obstruct the wetland restoration. For instance, using only the historical wetland locations can indicate restoring wetlands in residential, commercial, or transportation land use types, which increases the marginal costs and decreases the possibility of restoration. Besides, it can also be impeded by various factors, such as flooding and land filling (U.S. Fish and Wildlife Service, 2020). Hydric soils (HS) have been found to be closely correlated with wetlands, though not all areas that have hydric soil qualify as a wetland (USDA Natural Resources Conservation Service, 2017).

In this report, we examine the potential of hydric soil to serve as a proxy for wetland restoration mapping. Geospatial data in Minnesota and Iowa were utilized to determine and evaluate the accuracy of selected wetland proxies. Iowa was selected to correspond to the scope of Case Comparison and Policy Analysis in Chapters III and IV. Additionally, a set of geospatial data from Minnesota was selected for evaluation assistance because (a) the Restorable Wetland Inventory (RWI) data of Iowa was

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unavailable; (b) Minnesota's RWI and HS spatial data would most likely be similar to Iowa based on spatial autocorrelation theory[1] since it borders Iowa to the north and contains one of the main tributaries of the Mississippi River. In all, this report details the spatial analysis methodology and tools utilized to investigate the feasibility of using hydric soil as a proxy in wetland restoration estimation.

Geospatial Database Sources

The spatial scale of the databases varied from county to nation. In total, ten databases were utilized and are displayed as follows.

1. The restorable wetland inventory (RWI) data was developed by the Natural Resources Research Institute and collected from the Minnesota Natural Resource Atlas (Minnesota Natural Resource Atlas, 2021);
2. Wetland and watershed boundaries data was collected from the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service, 2021);
3. Digital elevation model data (DEM) was collected from the Minnesota Geospatial Commons (Minnesota Geospatial Commons, 2021a);
4. Minnesota state and county boundaries data was collected from the Minnesota Geospatial Commons (Minnesota Geospatial Commons, 2021b and 2021c);
5. Hydric soil data was collected from the Esri Hydric Soil Class (Esri, 2017);
6. Residential address and street data of Cedar Rapids was collected from the Linn County, Iowa GIS database (Linn County Iowa GIS, 2020);
7. Land use and land cover database of Des Moines was collected from the City of Des Moines GIS database (City of Des Moines, 2021);
8. Iowa state address data was collected from the U.S. Department of Transportation (U.S. Department of Transportation, 2021);
9. State boundary of Iowa data was collected from the IOWA Geodata (Iowa Geospatial Data, 2021);
10. National land cover data was collected from the U.S. Geological Survey (U.S. Geological Survey, 2021).

1 The theory of spatial autocorrelation is referring to "spatial data from distance from near locations are more likely to be similar than data from distance locations" (O'Sullivan and Unwin, 2010).

Analysis Mechanism & Discussion

The Association of Hydric Soil, Elevation, and Restorable Wetland Inventory

Methodology

The three databases frequently used in this section are the restorable wetland inventory data (RWI), Esri Hydric Soil data (HS), and Digital elevation model (DEM). **Table 1** displayed the category scope of HS, RWI and DEM database.

Table 1. The category scope of RWI, HS, and DEM database.

Name of Data	Category Scope	Unit	The Number of Category
Restorable wetland inventory	1 - 5	N/A	5
Esri hydric Soil	0 - 100	%	100
Digital elevation model (DEM)	590 - 2300	feet	1710

According to the metadata of Minnesota RWI category, RWI was ordered in 1-5 categories based on the probability of being a restorable wetland. RWI 1 has the lowest probability for being a restorable wetland while RWI 5 has the highest probability (Minnesota restorable wetland index, 2019). Esri HS category ranged from 0 to 100%, representing the percentage of a map unit that was occupied by hydric soil (Esri, 2017; USDA Natural Resources Conservation Service, 2018). Thus, the higher the HS category, the larger HS amount in this map unit. The map unit of measurement for Esri hydric soil data is 30 meters (Esri, 2017). Finally, the DEM data for Minnesota state is in the range of 590 to 2,300 feet, representing the elevation of Minnesota.

To examine the relationship of RWI and HS, each RWI category was applied to extract the HS category by mask (ArcMap, 2016a), then the corresponding HS category in each RWI category can be analyzed respectively via a histogram comparison with HS category as the x-axis and the number of RWI category as the y-axis. "Extract by Mask" is a tool from ArcGIS to extract a target raster layer data by the input raster layer. As both HS and RWI layers are raster, the tool was selected. Herein, RWI was utilized as an input raster, and HS was the target raster. Additionally, the spatial coordination and projection of two raster layers should be the same before conducting mask extract.

Additionally, zonal statistics were employed to gain a summary of the distribution trend of RWI, HS, and DEM, respectively. Zonal statistics is a tool in ArcGIS software to calculate the value for each zone based on values from another data set (ArcMap, 2016b). The distribution of HS or DEM in the category of RWI were summed and displayed in a percentage table to reflect HS or DEM's value on the range of minimum, quartiles, and maximum points in each RWI category. That is, the distribution value of HS or DEM in 0% (minimum), 25% (first quartile), 50% (median/second quartile), 75% (third quartile), and 100% (maximum) points will be shown. Quartile is a type of statistical concept that divides the number of data into four parts (BMJ, 1994).

Through zonal statistics, it can identify the restorable wetland proxy by comparing the distribution of HS or DEM in each RWI category. The HS or DEM category that clusters most on the high RWI would be considered as the proxy for wetland restoration.

Results

The histogram comparison of hydric soil and the restorable wetland inventory were used to observe the relationship between HS and RWI. The result is shown in **Fig. 1**.

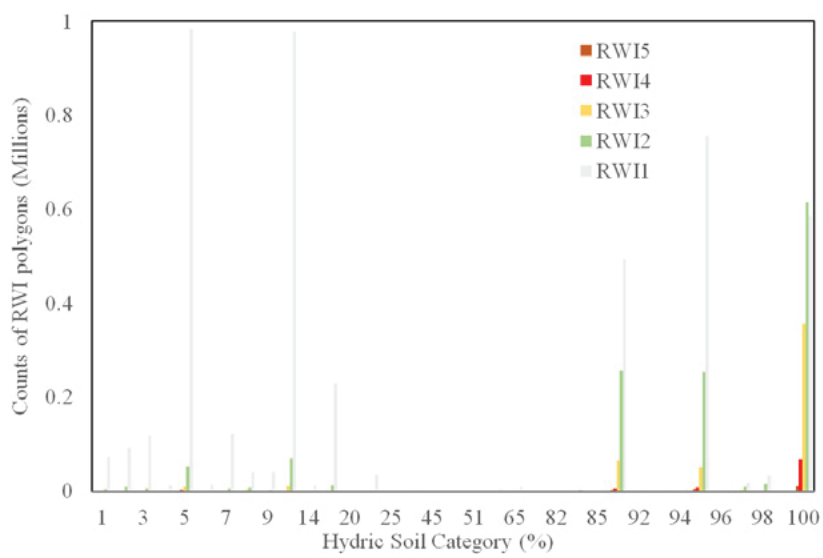


Fig. 1. The Distribution of RWI Categories to HS Categories in Minnesota.

RWI categories 1-5 have an irregular distribution to each category of HS (**Figure 1**) indicating there is no obvious clustered distribution that can be observed in histogram comparison. Due to the irregular distribution, the association in this analysis is unclear. Thus, zonal statistics between RWI and HS categories was employed. The statistics result of HS to RWI are shown in **Table 2**.

Category 1 of RWI indicates a low potential restorable level, has HS category 95 in its 3rd quartile. Therefore, HS categories that greater than 95 occupy 25% of RWI category 1 from its 3rd quartile to maximum. This shows that only 25% of the RWI category 1 includes the 95-100 HS categories. Then, 75% of RWI categories 2-5 have been occupied by the 90-100 or 95-100 HS categories. This occupation percentage displayed 90-100 HS has a very clear clustered distribution to the higher RWI categories 2-5 than that of RWI category 1. Therefore, 90-100 of HS categories could be a proxy for mapping the 2-5 of RWI categories.

Similar statistics were conducted to summarize the relationship of RWI and DEM **(Table 3)**. The 990-1558 and 1000-1558 of DEM indiscriminately took up nearly 75% of each RWI category number. Its distribution trend has no distinguishable difference between high and low RWI categories, which differs from the HS categories distribution. Thus, there is only modest evidence to conclude that DEM categories could be an indicator for mapping high RWI categories. The spatial relationships of HS, DEM and RWI in the HUC 07020007 watershed are shown in **Fig. 2**.

Table 2. The Relationship of HS and RWI in HUC 07020007 Watershed.

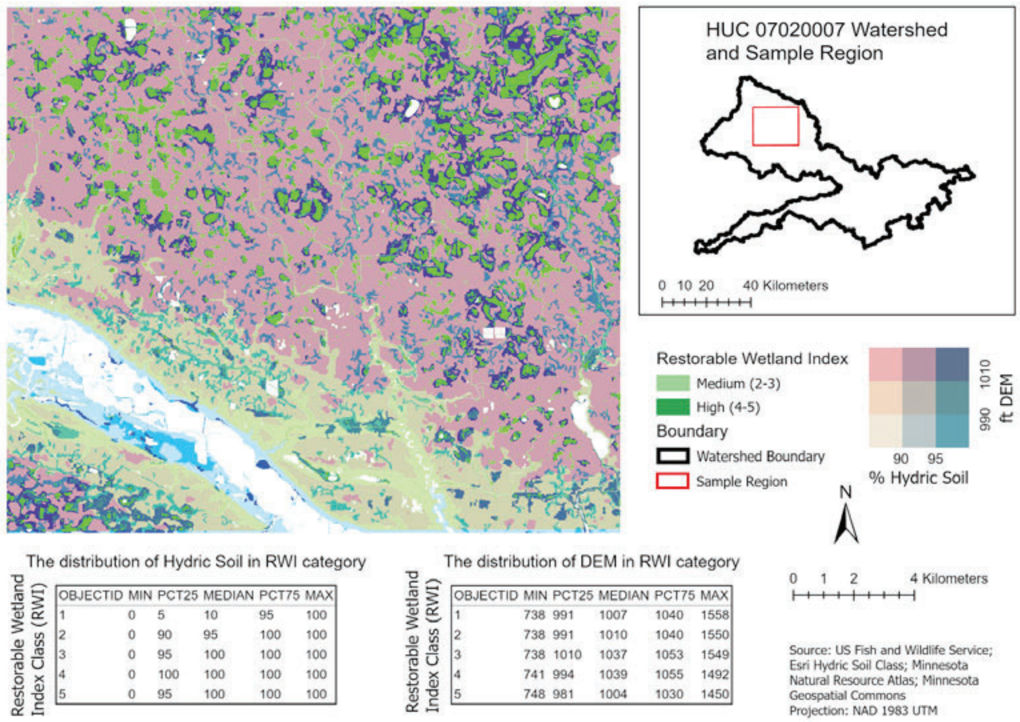
RWI Categories	PCT0[2] (%)	PCT25 (%)	PCT50 (%)	PCT75 (%)	PCT100 (%)	The Occupation Percentage of 90-100 or 95-100 HS Categories (%)
1	0	5	10	95	100	25% from PCT75 to PCT100
2	0	90	95	100	100	75% from PCT25 to PCT100
3	0	95	100	100	100	75% from PCT25 to PCT100
4	0	100	100	100	100	75% from PCT25 to PCT100
5	0	95	100	100	100	75% from PCT25 to PCT100

Table 3. The Relationship of DEM and RWI in HUC 07020007 Watershed.

RWI Categories	PCT0[3] (ft)	PCT25 (ft)	PCT50 (ft)	PCT75 (ft)	PCT100 (ft)	The Occupation Percentage of 990-1558 DEM Categories (%)
1	738	991	1007	1040	1558	Nearly 75% from PCT 25 to PCT100
2	738	991	1010	1040	1550	Nearly 75% from PCT 25 to PCT100
3	738	1010	1037	1053	1549	75% from PCT 25 to PCT100
4	741	994	1039	1055	1492	Nearly 75% from PCT 25 to PCT100
5	748	981	1004	1030	1450	Nearly 75% from PCT 25 to PCT100

2 PCT0 represents the value in 0% in the HS categories. That is, the minimum value of HS categories. Other abbreviations have the similar representative meaning of the value of 25, 50, 75, and 100% in the HS categories, respectively.

3 PCT0 represents the value in 0% in the DEM categories. That is, the minimum value of DEM categories in the feet unit. Other abbreviations have the similar representative meaning of the value of 25, 50, 75, and 100% in the DEM categories, respectively.



The distribution of Hydric Soil in RWI category

OBJECTID	MIN	PCT25	MEDIAN	PCT75	MAX
1	0	5	10	95	100
2	0	90	95	100	100
3	0	95	100	100	100
4	0	100	100	100	100
5	0	95	100	100	100

The distribution of DEM in RWI category

OBJECTID	MIN	PCT25	MEDIAN	PCT75	MAX
1	738	991	1007	1040	1558
2	738	991	1010	1040	1550
3	738	1010	1037	1053	1549
4	741	994	1039	1055	1492
5	748	981	1004	1030	1450

Fig. 2. The Relationship Map of Restorable Wetland, Hydric Soil and DEM in HUC 07020007 Watershed.

Evaluate the Suitability of Identified Proxies

Methodology

To evaluate the general applicability of identified restorable wetland proxy in the previous section, the state-level proxy was selected using the same approach and compared with the HUC watershed-level proxy. The zonal statistics in this section, however, have a finer analysis interval. The percentage table will display not only the same five value points just like in “The Association of Hydric Soil, Elevation, and Restorable Wetland Inventory”, but also display on 10%, 85% and 95%. If the proxy is generally applicable, state-level zonal statistics should have very similar results like in HUC watershed-level proxy. Possible explanation will be proposed if the HUC watershed-level proxy is found to be improper for estimating wetland location at the state-level.

Results

The statistical results for Minnesota state are shown in **Table 4**. The preliminary statistics at the HUC 12 watershed-level implied 90-100 HS categories had aggregated distribution on RWI categories 2-5 while elevation height didn't display an obvious aggregated distribution. To further address the reliability and universality of the "The Association of Hydric Soil, Elevation, and Restorable Wetland Inventory" result, the finer zonal statistics were repeated at a state scale.

Table 4. The Relationship of HS and RWI in Minnesota.

RWI Categories	PCT 0 (%)	PCT 10 (%)	PCT 25 (%)	PCT 50 (%)	PCT 75 (%)	PCT 85 (%)	PCT 95 (%)	PCT 100 (%)	The Occupation Percentage of 90-100 or 95-100 HS Categories (%)
1	0	0	3	7	30	91	96	100	Nearly 15% from PCT85 to PCT100
2	0	1	5	30	95	98	100	100	25% from PCT75 to PCT100
3	0	4	12	95	100	100	100	100	50% from PCT50 to PCT 100
4	0	5	50	98	100	100	100	100	Nearly 50% from PCT50 to PCT100
5	0	15	95	100	100	100	100	100	75% from PCT85 to PCT100

In **Table 4**, the distribution of HS categories to RWI categories has a finer division. In this division, the occupation percentage of 90-100 or 95-100 HS categories increases from 15% to 75% with increasing RWI categories. The highest occupation percentage reached 75% in RWI category 5, which is 5 times greater than that of RWI category 1. Thus, if the 90-100 HS categories were used as a proxy to filter the restorable wetland location in the state of Minnesota, then the filter result would have a stronger probability of locating at high RWI regions than if the 1-89 HS categories were used.

However, selected elevation height categories from the HUC watershed-level did not reproduce well at the state-level (**Table 5**). In the "The Association of Hydric Soil, Elevation, and Restorable Wetland Inventory" results of Association of Hydric Soil, Elevation and Restorable Wetland Inventory, the proposed value of 990-1558 from the HUC watershed-level did not work as an effective division of high RWI categories. Then in “Evaluate the Suitability of Identified Proxies” analysis of Evaluate the Suitability of Identified Proxies, the range of that elevation height also was not useful in summarizing the elevation height categories at the state-level. There are two possible causes.

Initially, the elevation height category was not distinct enough to display a clustered distribution to RWI categories, even at the HUC watershed-level result. Secondly, elevation height categories are different between the selected HUC 07020007 watershed and Minnesota state. The HUC 07020007 watershed has very low elevation while Minnetosa has relatively high elevation across central to the east-northern, west-south and east-south corner regions (**Fig. 3**). So, it is not surprising that it fails in the second evaluation. In **Table 5**, nearly 75-90% of RWI categories 1-5 are occupied by 1000-2300 feet DEM categories, showing an indiscriminate distribution to both low and high RWI categories. The relationship of HS, RWI, and DEM in Minnesota was mapped in **Fig. 4**.

Table 5. The Relationship of DEM and RWI in Minnesota state

RWI Catego-ries	PCT 0 (ft)	PCT 10 (ft)	PCT 25 (ft)	PCT 50 (ft)	PCT 75 (ft)	PCT 85 (ft)	PCT 95 (ft)	PCT 100 (ft)	The Occupation Percentage of 1000-2300 DEM Categories (%)
1	591	927	1033	1165	1344	1427	1618	2280	Nearly 75% from PCT85 to PCT100
2	598	972	1069	1228	1375	1458	1670	2300	Nearly 75% from PCT85 to PCT100
3	596	1014	1079	1232	1366	1437	1619	2218	Nearly 90% from PCT10 to PCT100
4	600	975	1059	1181	1318	1381	1514	2215	Nearly 75% from PCT85 to PCT 100
5	603	981	1114	1234	1320	1369	1441	2152	Nearly 75% from PCT85 to PCT 100

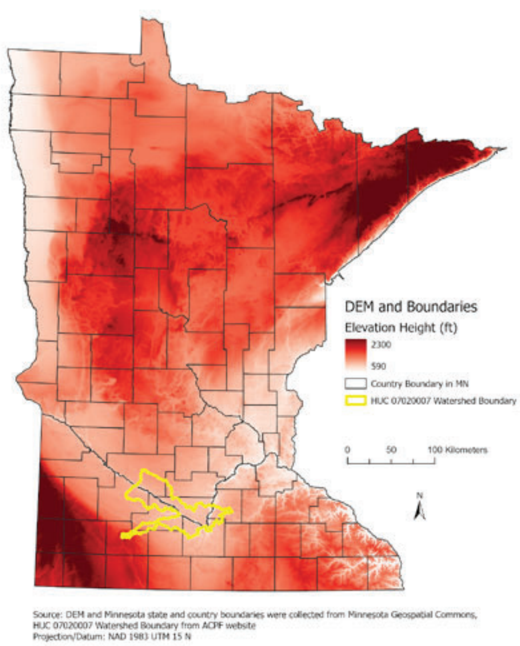
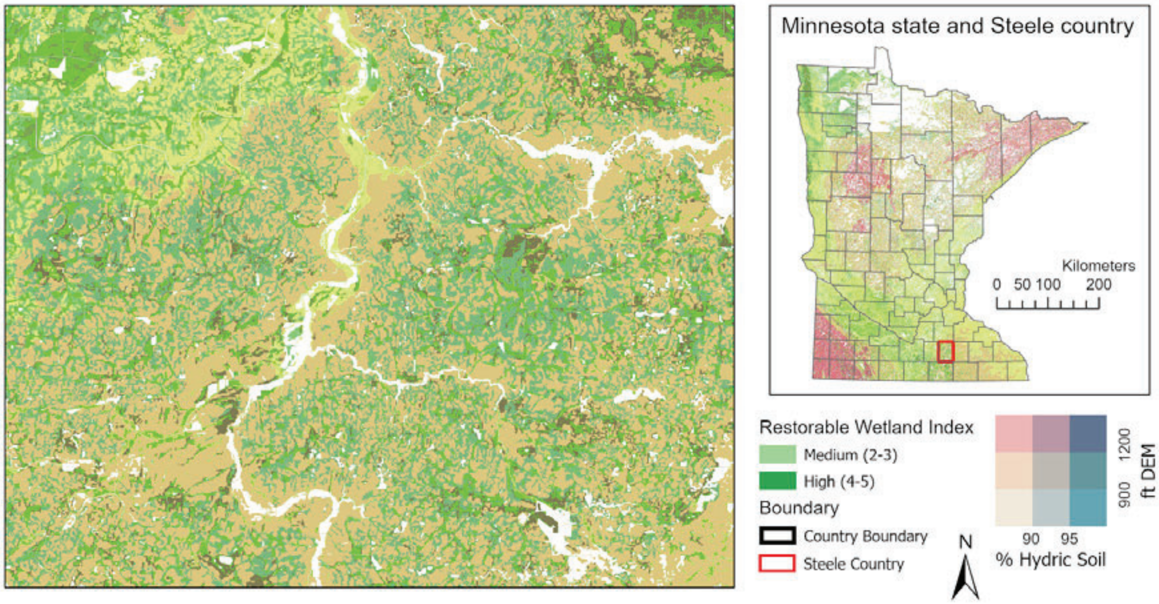


Fig. 3. The Location of HUC 07020007 in Minnesota.



The distribution of Hydric Soil in RWI category

Restorable Wetland Index Class (RWI)

OBJECTID	PCT10	PCT25	PCT50	PCT75	PCT95
1	0	3	7	30	96
2	1	5	30	95	100
3	4	12	95	100	100
4	5	50	98	100	100
5	15	95	100	100	100

The distribution of DEM in RWI category

Restorable Wetland Index Class (RWI)

OBJECTID	PCT0	PCT25	PCT50	PCT75	PCT100
1	591	1033	1165	1344	2280
2	598	1069	1228	1375	2300
3	596	1079	1232	1366	2218
4	600	1059	1181	1318	2215
5	603	1114	1234	1320	2152

0 1 2 4 Kilometers

Source: US Fish and Wildlife Service; Esri Hydric Soil Class; Minnesota Natural Resource Atlas; Minnesota Geospatial Commons
Projection: NAD 1983 UTM

Fig. 4. The Relationship Map of Restorable Wetland, Hydric Soil and DEM in Minnesota.

Estimated Restorable Wetland Location in the Selected Cities, Iowa

Methodology

After the HS proxy was verified in Minnesota, it was applied in Iowa, especially the City of Des Moines and Cedar Rapids, to display potential locations of wetland restoration. Additionally, the 'near' function was utilized to classify the closest land use type of the proxy. The 'Near' function calculates the distance among multiple target features and autoly provides the list of target features closest to the each category of input feature. In this analysis, HS proxy was utilized as an input feature while waterbody and residential address are target features.

Since restoring wetlands near a waterbody requires less marginal costs than doing so in residential regions (Boyer, 2003), waterbody and residential regions were selected as opposite land use features to determine if HS proxy has high suitability for picking low cost restoration regions. The acreage proportion of identified estimated proxy near the waterbody will be compared with that of the near residential region. The ideal proxy is predicted to have a higher acreage amount near a waterbody.

Results

The previous analysis indicated that the 90-100 of HS categories can be used as a proxy for estimating restorable wetland locations, but elevation height is not a suitable proxy. Two maps were created to display the estimated restorable wetlands using 90-100 HS proxy in the City of Des Moines and Cedar Rapids (**Fig. 5** and **Fig. 6**, respectively).

In **Figures 5 and 6**, most of 90-100 HS proxy are clustered around the upstream City of Des Moines and Cedar Rapids, where the Middle Des Moines watershed (HUC 07100004), North Racoon watershed (HUC 07100006), and Middle Cedar watershed (HUC 07080205) are located. The HS proxy is distributed along rivers and streams and gradually decreases downstream, such as in Saylor Creek-Des Moines River (HUC 071000041003; red HUC 12 boundary in **Fig. 5**) and Silver Creek-Cedar River (HUC 070802051507; red HUC 12 boundary in **Fig. 6**). Thus, the upstream HUC watersheds have a greater potential for restorable wetlands than the downstream HUC watershed.

In the zonal statistics, 90-100 HS categories were selected as a proxy because it clustered on high RWI categories. Theoretically, the HS proxy can assist in filtering the highly restorable probable wetland locations. However, in reality, the selection of restoration locations should also consider the effects of costs. Restoring wetlands in building footprints, streets, and roads is less reasonable than restoring near lakes, pools and streams. Therefore, land use data from the City of Des Moines GIS platform was applied. Using the ‘Near’ function, the area near or intersecting with residential regions was excluded and those near or intersecting with a water body were selected (**Table 6**). The acreage percentage of potential restorable location was computed by dividing the total acreage of HS beside a waterbody to the total acreage of HS within the watersheds.

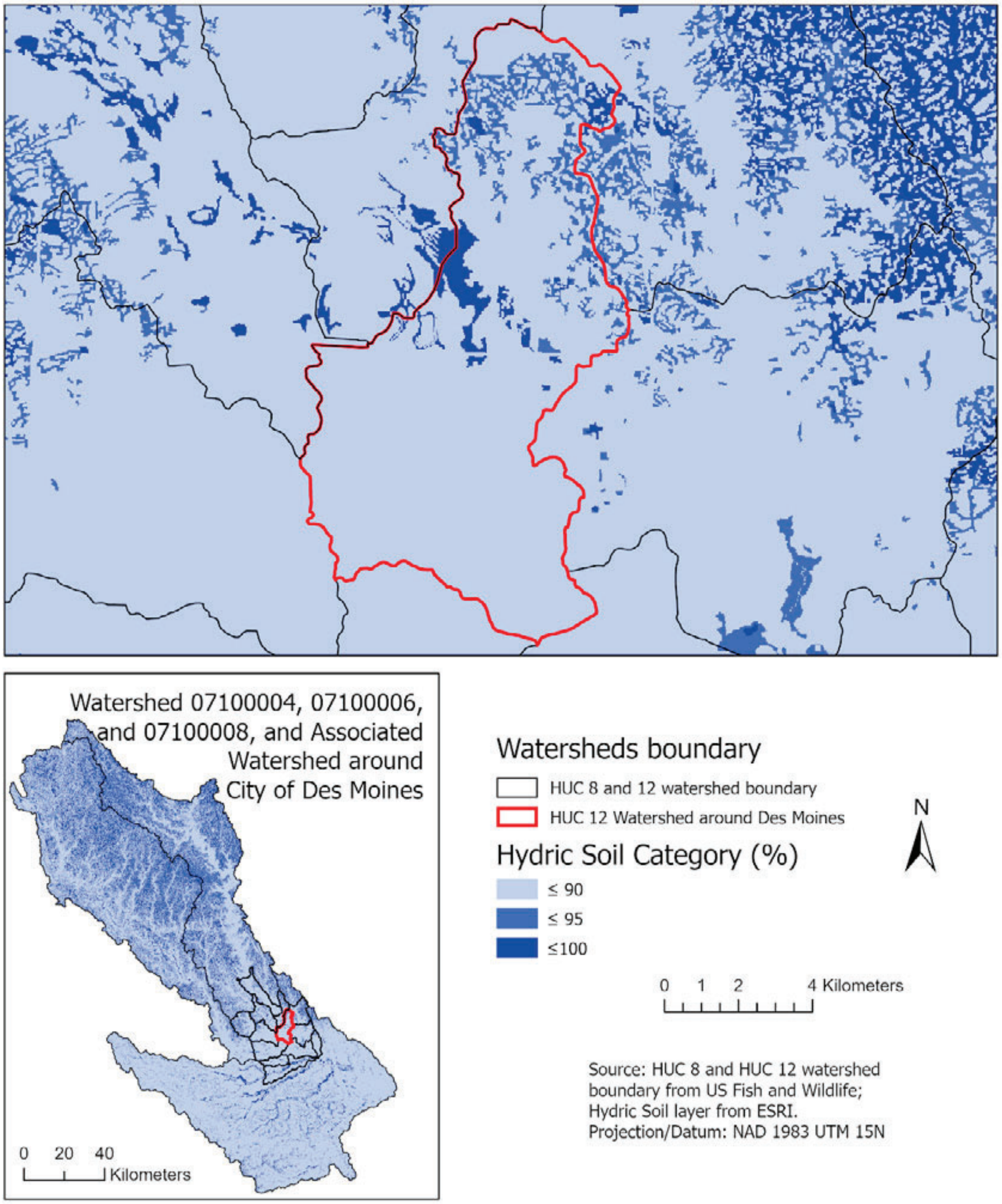


Fig. 5. The Hydric Soil Proxy in HUC 8 Watershed Around Des Moines.

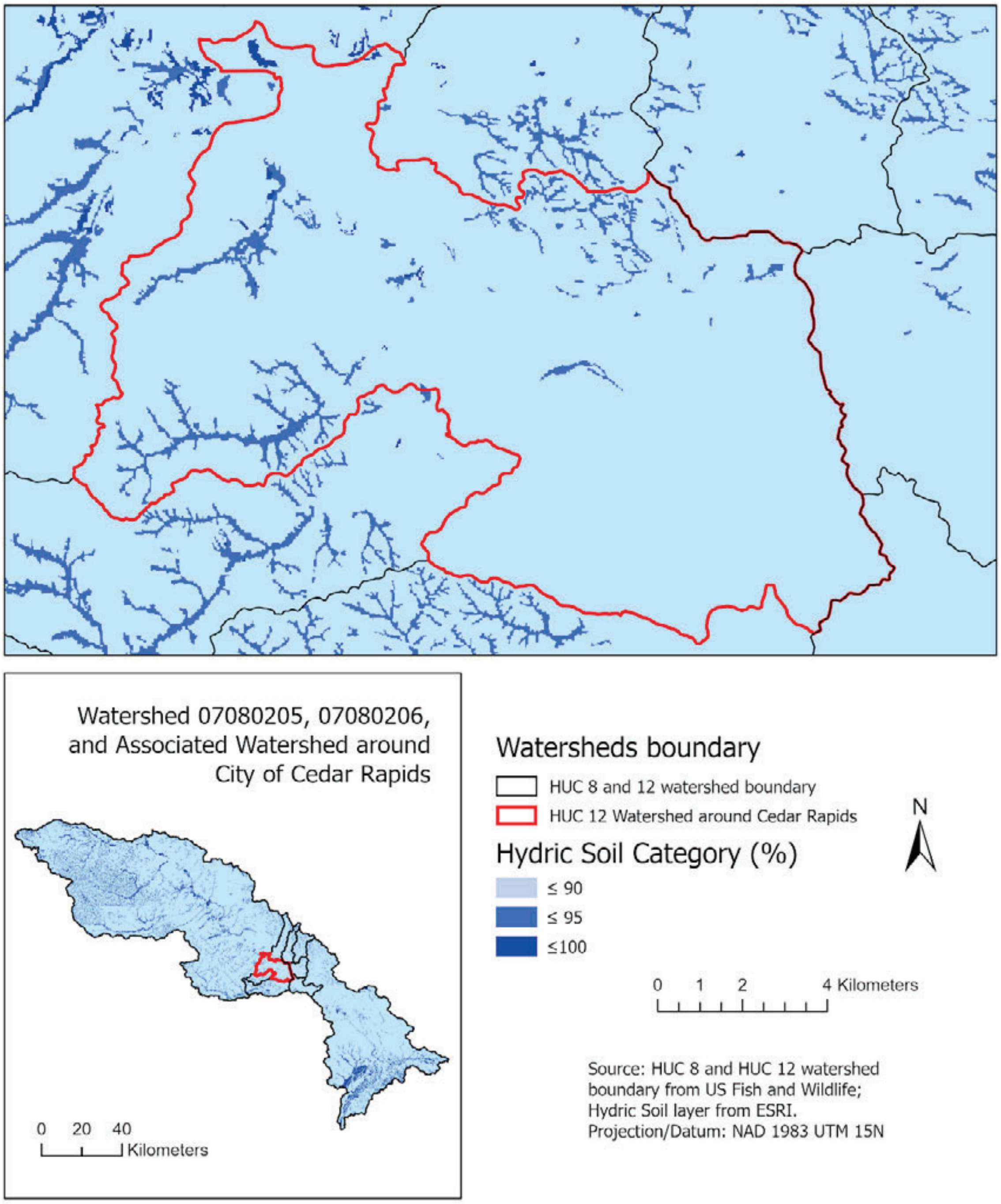


Fig. 6. The Hydric Soil Proxy in HUC 8 Watershed Around Cedar Rapids.

Table 6. The Proportion of Potential Restorable Area in HUC 071000041003 Watershed.

Hydric Soil (%)	Total Count (Acre)	Contain Residents (Acre)	Beside a Water Body (Acre)	Percentage of Potential Restorable Locations Acre/Total Location acreage (%)
1-89	31981.18	30538.04	1443.14	4.51%
90-100	4078.45	3828.48	249.97	6.13%

From **Table 6**, the percentage difference between the possible restorable wetland acres and the total location acres is around 1.6%. Under the 90-100 HS categories, the percentage of estimated restorable wetland area to the total 90-100 HS areas is 6.13%, which does not significantly differ from the 1-89 HS categories. This comparison didn't exhibit strong support that 90-100 HS proxy can assist in selecting restorable wetland locations that are near a waterbody. The related map (**Fig. 7**) shows only a few regions that are suitable for restoration at low marginal cost as selected by 90-100 HS proxy.

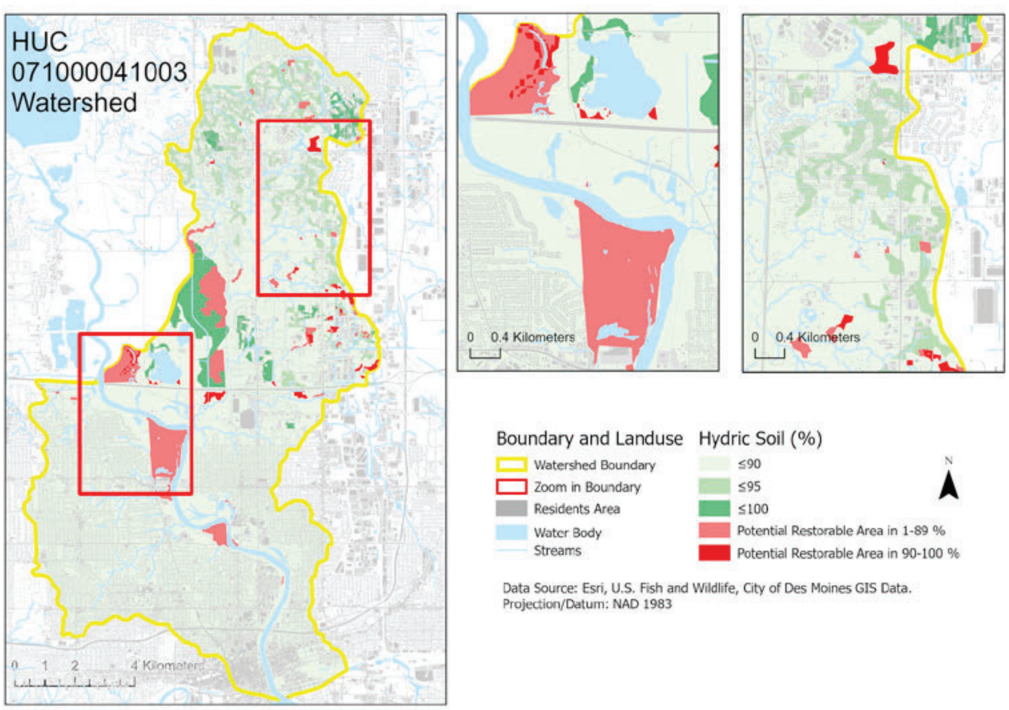


Fig. 7. Estimated Restorable Wetland Locations in HUC 071000041003 watershed

A similar analysis was conducted in Cedar Rapids (**Table 7** and **Fig. 8**). From **Table 7**, 33.09% of the total acres of 90-100 HS categories were identified as potential restorable regions, while only 6.50% of total acres of 1-89 HS categories were identified as potential restorable regions (**Fig. 8**). This result indicated that the 90-100 HS proxy is more suitable in identifying a restorable location near the waterbody within the Silver Creek-Cedar River (HUC 070802051507) watershed.

Table 7. The Proportion of Potential Restorable Area in HUC 070802051507 Watershed.

Hydric Soil (%)	Total Count (Acre)	Contain Residents (Acre)	Besides WaterBody (Acre)	Percentage of Potential Restorable Locations Acre/Total Location acreage (%)
1-89	55937.14	52302.24	3634.89	6.50%
90-100	9544.13	6386.38	3157.75	33.09%

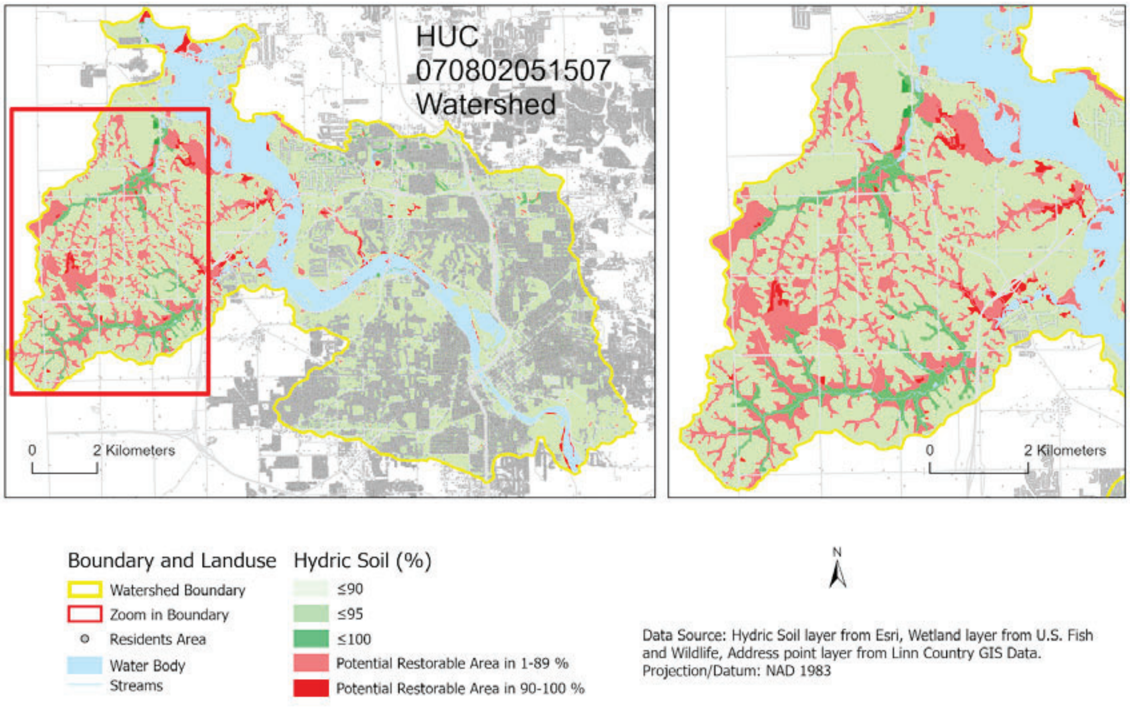


Fig. 8. Estimated Restorable Wetland Locations in HUC 070802051507 Watershed.

In sum, the distribution of the 90-100 HS proxy demonstrated a clustered distribution to high RWI categories and occupied the majority percentage of the high RWI. However, the quality of application in the two cities in identifying low-cost restorable wetland locations is highly unstable. The result of using the 90-100 HS proxy for mapping restorable locations is not universal for identifying both highly restorable probability and low cost restorable locations.

Distance Factor Impact on Suitability of HS Proxy

Methodology

The result of the prior suitability analysis displayed that the acreage proportion of 90-100 HS proxy in the City of Des Moines is less than that of the City of Cedar Rapids. Since the residential data was applied as one of the determinants in the potential restorable locations acreage comparison, it defaults that estimated restorable wetland locations will not be a priority wherever they are closest to or overlap with the residential buildings. Constructing wetland restoration closest to or overlapping with residences leads to the increase of marginal costs and relocation fee (Boyer, 2003).

To include the impact of distance factor into the HS proxy, address data from the U.S. Department of Transportation was employed. The 'near' function was again applied to measure the distance between the HS proxy to the introduced address data and to identify the distribution characteristic of land use closest to the HS proxy. The comparison of distance and the acreage percentage of potential restorable locations indirectly displays the distance impact in the HS proxy application.

Likewise, the county-level acreage proportion of identified estimated proxy is conducted again to re-evaluate the distance impact. Ten counties that surround the City of Des Moines and Cedar Rapids were selected as study areas. However, the address data from Linn county is not available at the Department of Transportation. Thus, Johnson county, which is just next to Linn county and includes the City of Iowa City, was selected due to spatial autocorrelation. This replacement aims to keep the residential regions' impact of a similar-size city in the calculation.

Finally, acreage proportion comparison was also conducted for different land use types. The acreage proportion of HS proxy in cropland, waterbodies, greenland, residential regions, and barren land was computed and compared with each other in order to uncover the restorable potential in different land use types.

Results

In **Figs. 7 and 8**, most of the identified restorable locations are distributed some distance away from residential regions, meaning the aggregated residential address. The suitable utilization condition of HS proxy can be specified if the changing trend of HS proxy's feasibility was measured with the increasing distance to residential regions. Thus, spatial data of address and waterbody was applied to compute the distance between the HS and the closet residential regions. The distance between HS proxy and the residential regions was computed under near analysis and displayed in **Figs. 9 and 10**.

Through the comparison of **Figs. 9 and 10**, it is known that the distance to residential regions in Saylor Creek-Des Moines River's (HUC 071000041003) to the 90-100 HS proxy is on average smaller than Silver Creek-Cedar River's (HUC 070802051507) HS proxy. This finding corresponds to the acreage proportion comparison result in **Table 6 and 7**. With those two results, it can be concluded that the closer HS proxy is to residential regions, a lower acreage proportion of restorable wetland was found. Thus, with a smaller distance between HS proxy and residential regions, the 90-100 HS proxy will be less suitable for estimating restorable wetland locations that are near a waterbody.

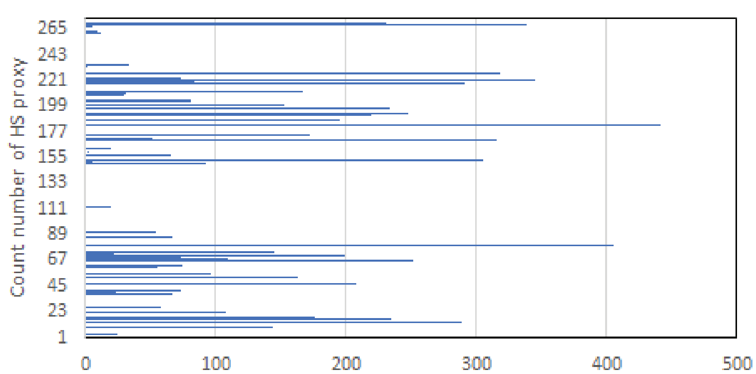


Fig. 9. The Distance between HS Proxy and Urban Regions in HUC 071000041003 Watershed.

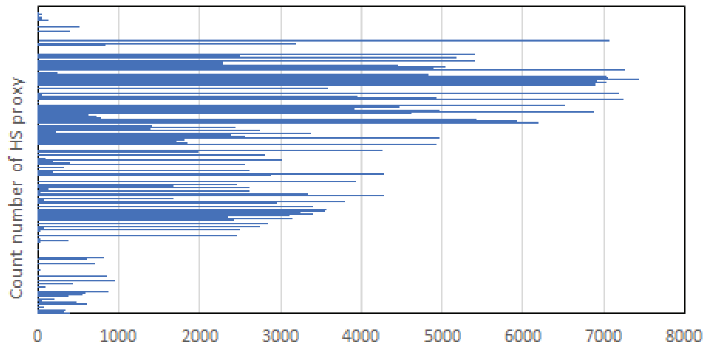


Fig. 10. The Distance between HS Proxy and Urban Regions in HUC 070802051507 Watershed.

Re-evaluation analyses were conducted again at the county-level. Counties next to the City of Des Moines and Cedar Rapids were selected (**Fig. 11**). Because the address data of Linn County was not available from the Department of Transportation, Johnson County, which is next to Linn county, was used to replace the missing data in Linn County. The proportion of potential restorable areas at the county-level are displayed in **Tables 7 and 8**.

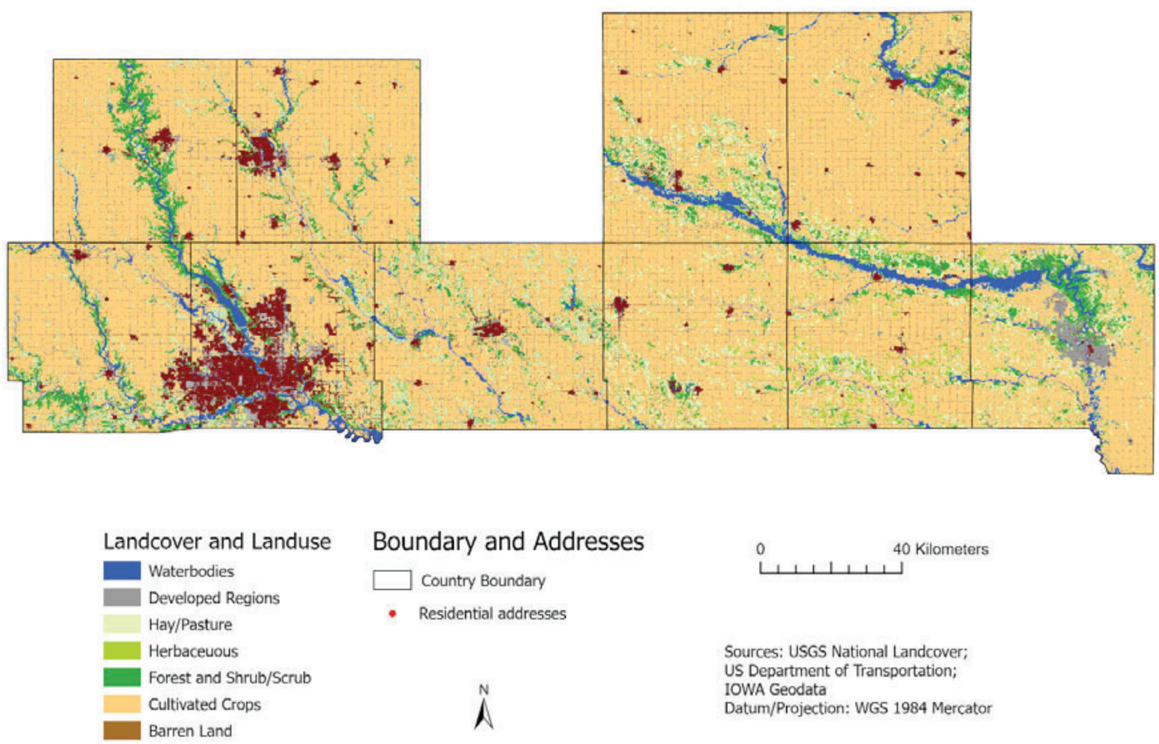


Fig. 11. The Land Cover and Land Use of Boone, Story, Dallas, Polk, Jasper, Benton, Tama, Johnson, Iowa, and Poweshiek Counties.

Table 8. The Proportion of Potential Restorable Areas in Boone, Story, Dallas, Polk, and Jasper Counties.

Hydric Soil (%)	Total Count (Acre)	Contain Residents (Acre)	Besides WaterBody (Acre)	Percentage of Potential Restorable Locations Acre/Total Location acreage (%)
1-89	2138386.63	1845025.79	293360.84	13.72%
90-100	945031.59	802567.14	142464.45	15.08%

Table 9. The Proportion of Potential Restorable Areas in Benton, Tama, Johnson, Iowa, Poweshiek Counties.

Hydric Soil (%)	Total Count (Acre)	Contain Residents (Acre)	Besides WaterBody (Acre)	Percentage of Potential Restorable Locations Acre/Total Location acreage (%)
1-89	3305019.48	2838258.23	466761.25	14.12%
90-100	432891.32	252875.69	180015.64	41.58%

The percentage of potential restorable location acres of the 90-100 proxy is not significantly larger than that of the 1-89 proxy in the counties surrounding the City of Des Moines (**Table 8**). The percentage of potential restorable location acres of the 90-100 proxy is almost 3 times greater than that of the 1-89 proxy in the counties surrounding the City of Cedar Rapids (**Table 9**). This county-level analysis further demonstrates that the 90-100 proxy would be more useful in non-clustered residential regions than in clustered residential regions.

Furthermore, restorable possibilities in different land use types were evaluated (**Table 10**). According to the comparative analysis of the above ten counties, cropland, waterbodies, and greenland land use types occupied a higher restorable possibility than residential regions and barren land. Therefore, restoration near streams, lakes, ponds, and in forests, shrubs, or even agricultural areas may have a higher restoration probability. As Iowa is an agriculturally abundant state, the edge-of-field practices of agricultural areas is a reasonable and easy method to mitigate nutrient pollution and flooding.

Table 10. The Proportion of Potential Restorable Areas in Ten Counties.

Hydric Soil (%)	Total-Count(Acre)	Residen-tial area or Barren Land (Acre)	Crops land, WaterBodies, natural land (Acre)	Percentage of Potential Restorable Possibility Acre/ Total Location acreage (%)
1-89	5895535.46	2074553.83	1489738.81	25%
90-100	1378729.43	331696.22	1046226.69	76%

Conclusion

This analysis found that the 90-100 hydric soil categories are a more suitable proxy than the 1-89 hydric soil categories in both watershed- and state-level zonal statistics analysis. When applied to the cities of Des Moines and Cedar Rapids, the 90-100 HS proxy estimates a larger acreage proportion of restorable locations near a waterbody in the City of Cedar Rapids than in the City of Des Moines. The distance measurement of the HS proxy to the residential region in the HUC watershed-level uncovered that the application of the 90-100 HS is limited. With increasing distance to residential regions, the suitability of the HS proxy increases. So, the 90-100 HS proxy has low suitability in aggregated residential regions. The county-level comparison of the percentage of potential restorable locations further demonstrated this dynamic.

The investigation of the restoration possibilities for different land use types demonstrated that agricultural, natural land, and waterbodies have a higher probability of successful restoration than residential regions and barren land. With those findings, the identification time and cost will be reduced to a great extent. Based on the official pricing researched by the Wisconsin DNR, the identification of wetland requires the cost of $300 per acre and 60 days reporting time (Wetland Identification Program, 2021). With the HS proxy, the estimated region can be narrowed in scope, reducing costs and processing time. In sum, this study helps efficiently identify restorable wetland locations and provides support for utilizing the HS proxy for future wetland restoration.

CHAPTER II

EXAMINING THE EXPOSURE OF SOCIALLY VULNERABLE COMMUNITIES TO FLOOD RISK AND NITROGEN POLLUTION IN IOWA

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EXECUTIVE SUMMARY

Socially vulnerable communities in the Upper Mississippi River Basin (UMRB) are at risk of exposure to nutrient pollution and flooding. In this project, the hazards examined are nitrite/nitrate pollution and flooding. This study aims to identify key locations for natural infrastructure interventions in Iowa, in a way which benefits Iowa's socially vulnerable communities. Specifically, the study examined which communities in the state are currently affected by flooding issues that can be mitigated by changes to upstream agricultural practices and which communities in the state are currently affected by nutrient pollution and nonpoint source pollution, particularly nitrite/nitrate pollution.

Methods

State-level maps of Iowa were created to demonstrate: (a) the relationship between current (2020) flood risk levels and social vulnerability factors; (b) the relationship between future (2050) flood risk projections and social vulnerability factors; and (c) the relationship between nitrite/nitrate pollution levels in groundwater wells and social vulnerability factors. Multilinear regressions were also performed to find correlations between social vulnerability, flood risk, and nitrogen pollution. Lastly, whether or not there was a significant difference between 2020 and the 2050 flood risk projection was determined.

Results

Statistically significant relationships were found between multiple social vulnerability factors, nutrient pollution, and flood risk. Each of these was statistically significantly associated with risk. The social vulnerability factors that were positively associated with risk were shown to be: single parent households, the number of people over 25 without a high school diploma, and those over age 65. Additionally, the spatial analysis indicated that areas where this correlation occurred were often downstream of the major rivers in the state. It was also found that flood risk in Iowa is very similar in 2050 as it was in 2020, according to the Flood Factor 2050 flood risk projection.

Implications

The findings of this analysis changed the general understanding of risk distributions in Iowa: while it is regularly understood that farmers are at risk of negative health outcomes due to the environmental hazards that are in place in conventional farming (Kirkhorn, 2001), the impacts created for communities downstream are rarely acknowledged. Moreso, it is rarely acknowledged or understood how much this environmental exposure differs between communities. This data is important to analyze and understand, so that these communities can be better informed and protected in the future from environmental degradation. This data can also be used by governing structures within the communities to both rectify past injustices and prevent future injustices. Through utilizing this data, decision makers will have an increased awareness of social vulnerability and environmental justice within their state, and priority can be placed on implementing natural infrastructure in a way that improves climate resiliency.

Acronyms

Center for Disease Control and Prevention (CDC)
Communities of Color (COC)
Department of Natural Resources (DNR)
People of Color (POC)
Social Vulnerability Index (SVI)
Socially Vulnerable (SV)
Upper Mississippi River Basin (UMRB)

Data Information

Table 1. Data Type by Unit of Measurement

Data Source	Variable	Unit of Measurement
Flood Factor	Flood Risk	Zip Code
CDC's Social Vulnerability Index	Social Vulnerability	Census Tract
U.S. Census Bureau Resident Race/Ethnicity Population Estimates	Race/Ethnicity Demographics	County

Purpose

Low income communities and Communities of Color (COC) are more likely to be negatively affected by issues related to pollution and flood damage risk (Struck, 2012). Socially vulnerable communities are identified as communities which are both socially vulnerable (SV) and are experiencing exposure to some risk or hazard. In the case of this project, the hazards examined are nutrient pollution and flooding. In Iowa specifically, these communities consist of People of Color (POC) that have been historically discriminated against via both physical violence and institutionally barred from tools that white inhabitants were given to better themselves. This study aims to demonstrate that these communities suffer from disproportionately high pollutant exposures as a result of agricultural runoff and nutrient pollution. Marginalized communities are also at higher risk of flooding. Due to these issues, when considering flooding and nutrient pollution issues in the UMRB, issues of environmental justice must be examined as well.

Natural infrastructure presents an innovative strategy for reducing flood risk and nutrient pollution. Natural infrastructure benefits socially vulnerable communities by helping to solve issues they face before they occur, and promoting community resilience. Through implementing natural infrastructure in agricultural areas, both the risk of flooding and nitrogen pollution can be reduced. Along with this, natural infrastructure lowers the amount of financial investment needed to defend against damaging floods, as many natural infrastructure methods are cheaper investments than traditional grey infrastructure such as flood dams and barriers (Adriaenssens, 2019). Natural infrastructure in agricultural fields can mitigate water quality degradation. For example, buffers in agricultural fields improve the infiltration of water through propagation matter, and can retain or remove nitrate by 60-90% (Canning & Stillwell, 2018). By reducing the amount of pollution created by agricultural lands, the risk of nutrient pollution in the water systems of socially vulnerable communities is mitigated. Additionally, Cunniff's 2019 report states that well-managed natural areas can absorb more precipitation and slow surface flow to reduce flood height and speed, reducing both runoff and flood risk (Cunniff, 2019).

In this study, key locations for natural infrastructure interventions were identified to benefit Iowa, in a way which benefits Iowa's socially vulnerable communities. The analysis uncovered (1) which communities in the state are currently affected by flooding issues that can be mitigated by changes to upstream agricultural practices, and (2) which communities in the state are currently affected by nutrient pollution and nonpoint source pollution, particularly nitrite/nitrate pollution. The correlation between social vulnerability, nitrogen pollution, and flood risk were used to determine who is benefiting from natural infrastructure implementation in Iowa. The analysis pays special attention to scenarios of inequity, and it aims to avoid enlarging these inequities and to ensure the protection of vulnerable communities.

Methodology

Data Acquisition

Nitrogen Pollution

As a common source of nutrient pollution, nitrite and nitrate contamination data (mg/L) were utilized to study the water pollution levels in Iowa. Nitrite and nitrate are harmful to humans in amounts over 10 mg/L. Nitrite and nitrate pollution data from 19,732 Iowan ground wells was acquired through Iowa Geodata (Iowa Geospatial Data, 2018). This database is maintained by the Iowa Department of Natural Resources (DNR). The data represent pollution levels from 2013 and 2018.

Flood Risk by Zip Code

Flood risk data at the zip code level was acquired from FloodFactor (First Street Foundation, 2020). Information relating to the unit of measurement and data sources for all data acquired can be found in **Table 2.** FloodFactor is a free online tool created by the nonprofit First Street Foundation. This tool was created for Americans to find their property's flood risk and understand how their flood risk has changed. According to First Street Foundation, "FloodFactor utilized the partnership of scientists, technologists and analysts to create the first publicly available peer-reviewed flood projection model" (Flood Factor, 2020). Floodfactor specifically depends on the FATHOM-US 2.0 model, which is a peer-reviewed hydraulic model that represents river and stream channels using a one-dimensional representation that enables river width to be decoupled from model grid scale and therefore allows any river size to be represented within the model. This allows for hydraulic calculations to occur for rivers either wider or narrower than the original resolution while making computation over large areas more manageable and practical (Flood Factor, 2020).

To create projections of future flood risk, Flood Factor's model used a baseline historical period of 1980-2010, creating a 30 year period of observed data. The Global Climate Model projections for 2020 allowed for the creation of a new climate that accounts for changes since the historical data was recorded. This model then utilized the Intergovernmental Panel on Climate Change's (IPCC) Representative Concentration Pathway (RCP) 4.5 carbon emissions scenario. This represented a middle-ground carbon emissions scenario (in which radiative forcing at 4.5 Watts per meter squared is met in the year 2100 without ever exceeding that value), to create a framework for 2030, 2040, and 2050 flood risk models (Flood Factor, 2020. This model is also regularly validated through a thorough review of the output in all areas for all hazard layers (Flood Factor, 2020).

CDC's Social Vulnerability Index by Census Tract

The CDC's Social Vulnerability Index was used to identify socially vulnerable communities in Iowa (Centers for Disease Control and Prevention/ Agency, 2018). The Agency for Toxic Substances and Disease Registry's (ATSDR) Geospatial Research, Analysis, and Services Programs (GRASP) created the Center for Disease Control (CDC) and Prevention Social Vulnerability Index (SVI) to help officials identify communities that may need support before, during, or after disasters. The CDC SVI indicates the relative vulnerability of every U.S. census tract using race/ethnicity data collected in the Census. This data was most recently updated in the 2014-2018 American Community Survey 5-year estimates. This analysis utilized the following subset of U.S. census variables that compose the SVI:

- Persons below poverty estimate per census tract
- Estimate of unemployed persons per census tract
- Per capita income estimate per census tract
- Persons over 25 without a high school diploma per census tract
- Persons over age 65 per census tract
- Persons who are legally disabled per census tract
- Single-parent Households estimate per census tract
- Persons in minority groups (all persons except white, non-hispanic) estimate per census tract
- Households without a vehicle estimate per census tract
- Household crowding (households with more people than rooms) estimate per census tract

This project also utilized the CDC's 'F_Total' dataset which identifies communities in the 90th percentile of all risk factors considered, indicating that these communities have the highest level of risk prior, during, and after a natural disaster.

Within this report, the term ‘socially vulnerable communities’ is used for data utilizing the ‘F_Total’ dataset, while the term ‘social vulnerability factor’ is used for data utilizing any of the above U.S. census variables.

U.S. Census Bureau, County Characteristics Resident Population Estimates by County

In order to compare flood risk and nitrite/nitrate pollution to different race/ethnicities in Iowa, the U.S. Census Bureau’s County Characteristics Resident Population Estimates were utilized. This data was collected by the U.S. Census Bureau Population Division and was released in June 2020. These are population estimates performed by the Population Division in order to determine potential changes in race/ethnicity data in between the decennial Census. The data utilized is the Population Division’s 2017 county estimates and the census variables utilized include those below:

- The Black and African American Population
- The Hispanic Population
- The Indigenous Population (as defined by the Census, American Indian and Native Alaskan)
- The Asian Population
- The Native Hawaiian and Pacific Islander Population
- The White Population

Table 2. Data Type by Unit of Measurement

Data Source	**Variable**	**Unit of Measurement**
Flood Factor	Flood Risk	Zip Code
CDC's Social Vulnerability Index	Social Vulnerability	Census Tract
U.S. Census Bureau Resident Race/Ethnicity Population Estimates	Race/Ethnicity Demographics	County

Spatial Analysis Methodology

Examining the Relationship between Nitrogen Pollution and Social Vulnerability

The amount of nitrite or nitrate (mg/L) in each of Iowa's 19,732 groundwells was overlaid on a choropleth map of the selected social vulnerability factors at the census tract level across all of Iowa. The nitrite/nitrate data was visualized using the optimized hot spot analysis tool, which uses parameters described from the Iowa DNR nitrogen pollution input data to create a map of statistically significant 'hot' and 'cold' spots using the Getis-Ord Gi* statistic (**Figure 1.1**). The social vulnerability factors were displayed using a graduated color scheme (**Figure 1.2**). In each map, the lighter color indicates a smaller value, while the darker color indicates a higher value. For race/ethnicity data, this method was also utilized, in which the lighter color indicates that the race/ethnicity being displayed is a smaller percentage of the population in the county, and a darker color indicates that the race/ethnicity being displayed is a larger percentage of the population in the county.

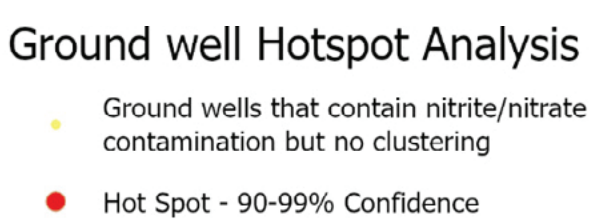

Figure 1.1. Nitrite/Nitrate Contamination Hot Spot Analysis Legend

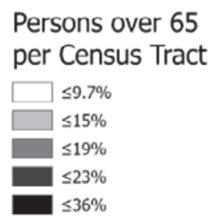

Figure 1.2. SVI Factor Graduate Color Legend Template

One map was created for each SVI factor compared to all groundwells that had any nitrite/nitrate contamination. One map was also created for each SVI factor compared to all groundwells that had dangerous levels of nitrite/nitrate contamination (10 mg/L), respectively. Total SVI factor nitrogen pollution maps were also created by utilizing the 'F_Total' CDC's dataset. Lastly, other maps were created for comparing race/ethnicity data to all contaminated ground wells and all groundwells with dangerous levels of nitrite/nitrate contamination (10 mg/L).

A multiple linear regression was then performed to find correlations between social vulnerability and nitrogen pollution. This was performed by regressing each SVI factor and race/ethnicity metric against the nitrite/nitrate pollution levels. The nitrite/nitrate (mg/L) data was log-transformed in order to normalize the data, and the SVI and race/ethnicity metric factors are standardized against the total population.

Examining the Relationship between Flood Risk and Social Vulnerability

These maps were created with the bivariate choropleth map tool. Bivariate choropleth maps combine two datasets into a single map to show relatively how much of X and Y exist in each enumeration unit. In these maps, the flood risk projection is represented by a scale from light yellow to teal, while the SVI factor is represented by a scale from light yellow to bright yellow, as can be seen in **Figure 2**.

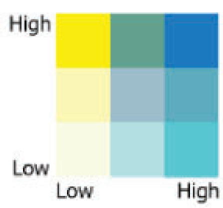

Figure 2. Bivariate Choropleth Map Legend

In the race/ethnicity maps, race/ethnicity data is also represented by a scale from light yellow to bright yellow. When these two values overlap, this is demonstrated by grey or dark blue. Maps were created for each SVI value for both the 2020 and the

2050 flood risk projection for a total of 20 maps. Total SVI factor flood risk maps were also created by utilizing the CDC's 'F_Total' dataset, which identifies communities in the 90th percentile of all risk factors considered. Lastly, maps were created by comparing the county-level race/ethnicity data to the 2020 and 2050 projection flood risk data.

A multiple linear regression between the SVI factors, race/ethnicity data, flood risk data and projections were then performed in order to find correlations between social vulnerability and nitrogen pollution. The SVI and race/ethnicity metric factors are standardized against the total population.

Results

The maps and the statistical analysis both illustrate that socially vulnerable populations are more likely to suffer nitrogen pollution and flood risk. Based on the results from the spatial analysis, it is clear that this is a statewide issue that crosses the urban/rural barrier. Vulnerability reduction should be a key consideration in policies created for natural infrastructure implementation.

Relationship between Nitrite/Nitrate pollution and Socially Vulnerable Communities

Spatial Analysis

The first set of maps were a hot spot analysis of ground wells contaminated with any amount of nitrite/nitrate pollution, followed by maps with more than 10 mg/L of nitrite/nitrate pollution. These maps display where nitrite/nitrite pollution is concentrated. In these maps, it appeared as if the most heavily concentrated areas are downstream of the Des Moines and Raccoon Rivers. This can be seen by the clustering around the central urban area of the state (Des Moines), which is just downstream of these two rivers. This is further illustrated by **Figures 3 and 4**, which displays a hot spot analysis of ground wells contaminated with more than 10 mg/L of nitrite/nitrate, as the largest cluster on the map is directly above Des Moines.

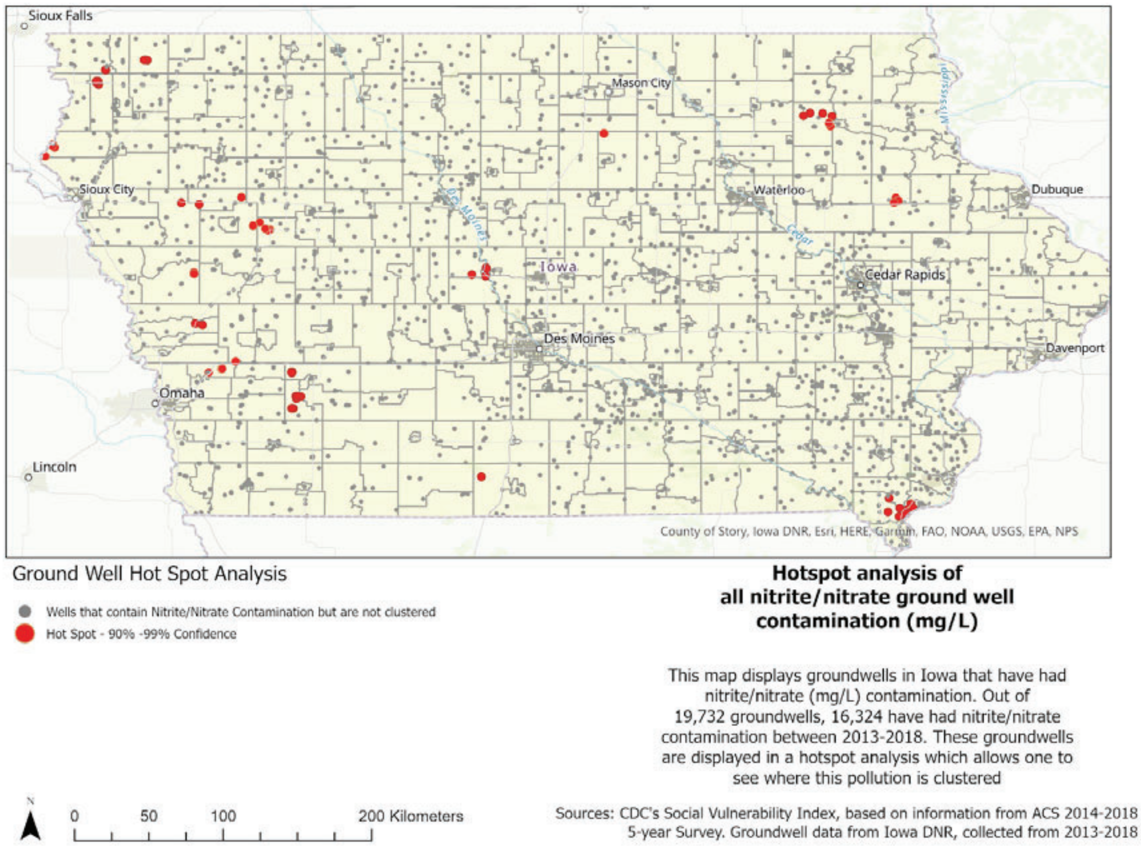

Figure 3. Hot Spot Analysis of Nitrite/Nitrate Contamination in Iowa

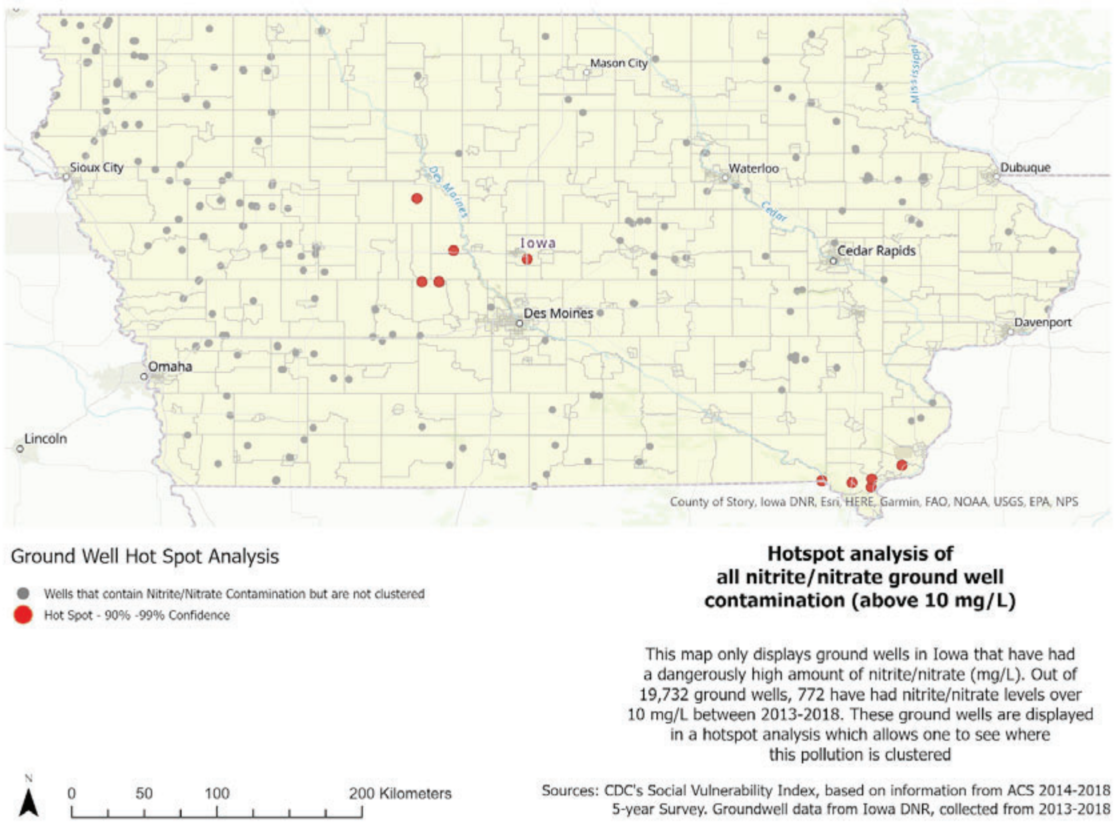

Figure 4. Hot Spot Analysis of Nitrite/Nitrate Contamination in Iowa over 10 mg/L

Then, maps were created to compare total communities in the 90th percentile of the CDC's SVI compared to total ground wells contaminated with nitrite/nitrate pollution and all wells with a nitrite/nitrate level above 10 mg/L (**Figure 5 and 6**). When examining the map displaying all wells with nitrite/nitrate pollution, it is difficult to visually identify census tracts that are more socially vulnerable and nitrite/nitrate pollution as there are simply so many wells that have experienced this kind of contamination. However, when one looks only at ground wells that have 10 mg/L or more of nitrite/nitrate pollution, the relationship can be visualized more easily.

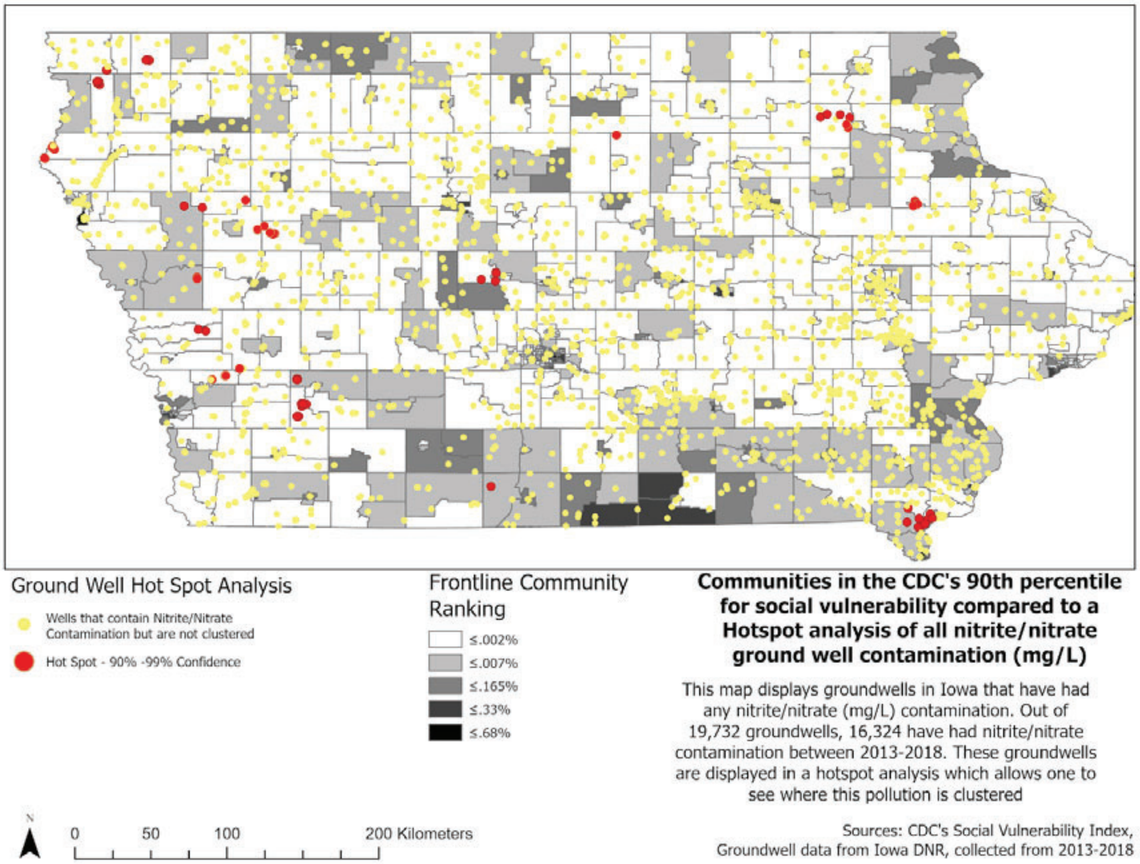

Figure 5. Communities in the CDC's 90th Percentile for Social Vulnerability Compared to Hot Spot Analysis (any level of contamination)

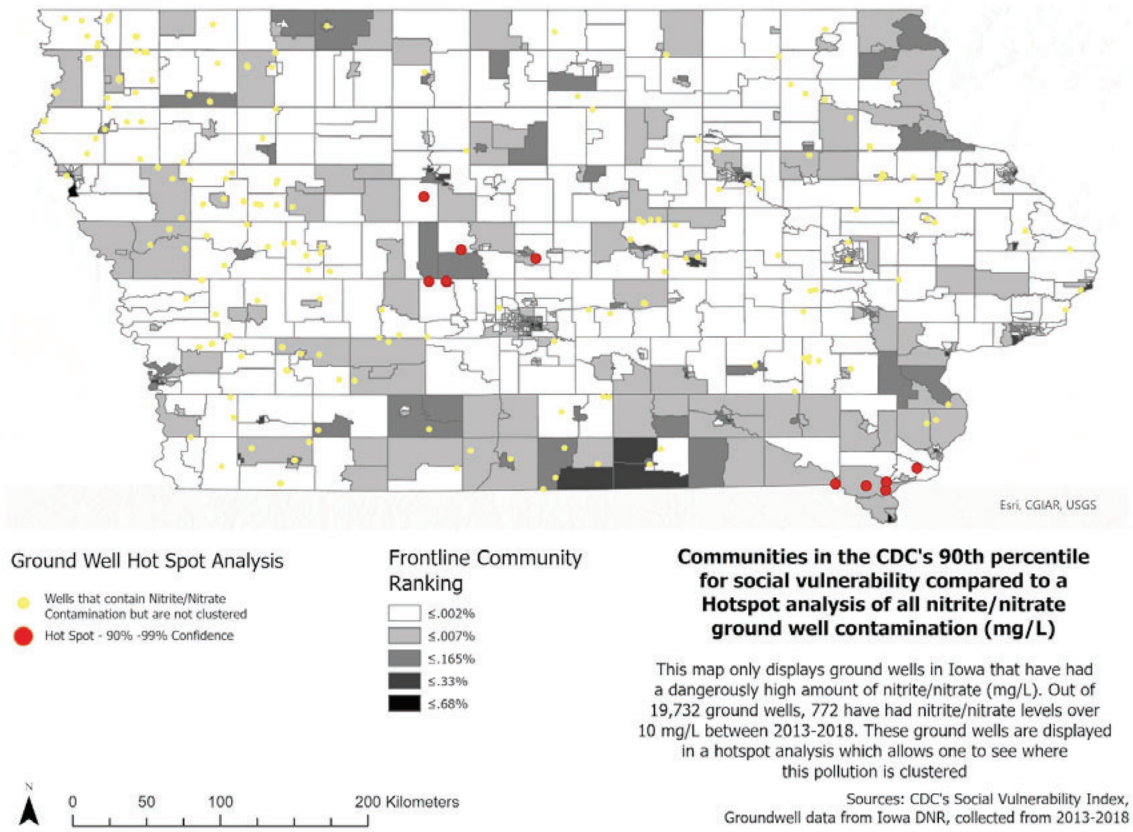

Figure 6. Communities in the CDC's 90th Percentile for Social Vulnerability Compared to Hot Spot Analysis of Nitrite/Nitrate Ground Well Contamination over 10 mg/L (dangerous level of contamination)

Individual maps for each social vulnerability factor compared to nitrite/nitrate contamination--both in total and above 10 mg/L--were also created. These maps can be found in **Appendix A** of this report. Individual maps for each race/ethnicity factor were also created **(Appendix A)**.

Individual maps for each race/ethnicity factor were also created, and can be found in Appendix A of this report. While many of these maps have statistically significant variables, the map displaying the white population per county compared to all nitrite/nitrate contaminated wells above 10 mg/L was particularly interesting (**Figure 7**). For this map, a lighter color indicates that the race/ethnicity being displayed is a smaller percentage of the population in the county and a darker color indicates that the race/ethnicity being displayed is a larger percentage of the population in the county. In **Figure 7**, it is clear that while there are several dangerously contaminated ground wells across the state, dangerous levels of nitrite/nitrate pollution are only clustered in counties where the percentage of white people is smaller. These counties are specifically: Story, Lee, Dallas, Webster, and Boone counties. **This finding means that there is a spatial correlation between Communities of Color (COC) and nitrogen pollution in Iowa, indicating that more nitrite/nitrate pollution is clustered in ground wells that are near or overlap with COC.**

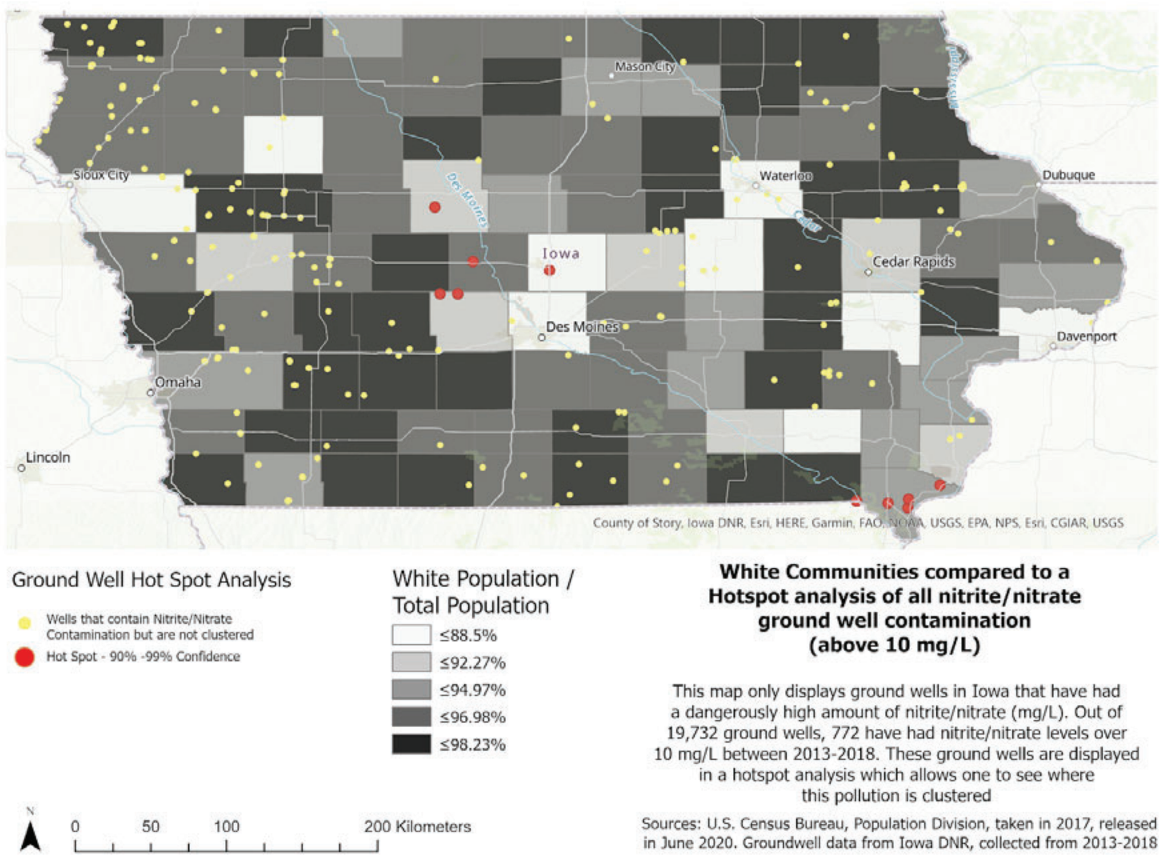

Figure 7. White population per County compared to all Nitrite/Nitrate contaminated wells over 10 mg/L (dangerous level of contamination)

Statistical Analysis

There was a significant relationship between nitrite/nitrate and per capita income per census tract ($p=<0.0001$), lack of high school diploma per census tract ($p=0.035019$), number of persons over 65 per census tract ($p= \leq 0.0001$), number of single-parent households per census tract ($p \leq 0.0001$), number of households without a vehicle per census tract ($p \leq 0.0001$), the total socially vulnerable population ($p \leq 0.0001$), and the total population ($p \leq 0.0001$) (as shown in **Table 3**).

There was also a significant relationship between nitrite/nitrate and the white population per county ($p \leq 0.0001$) (this is likely due to how large the white population is compared to the rest of the studied race/ethnicity groups), the Indigenous (American Indian and Native Alaskan) population per county ($p = 0.0003$), the Asian population per county ($p \leq 0.0001$), the Black population per county ($p \leq 0.0001$), and the Total population per county ($p \leq 0.0001$). The result is displayed in **Table 4**. **Figures 8 and 9** displayed where the estimates lay in relation to 0: variables with negative estimates are negatively associated, while variables with positive estimates are positively associated.

Table 3. Multiple linear regression results for social vulnerability and nitrite/nitrate pollution exposure

SVI Factor	Estimate	Std. Error	T value	P value
Poverty	-5.776e-02	5.065e-01	-0.114	0.909205
Unemployment	-3.106e+00	1.931e+00	-1.609	0.107705
Per Capita Income	-4.236e-02	6.702e-03	-6.320	2.72e-10
No High School Diploma	1.980e+00	9.391e-01	2.108	0.035019
Over age 65	2.450e+00	5.862e-01	4.180	2.94e-05
Legally Disabled	-7.461e-01	7.24e-01	-1.030	0.302961
Single Parent	-1.350e+01	1.610e+00	-8.384	< 2e-16
Minority Group (non-white population)	-1.992e-01	3.677e-01	-0.542	0.587975
No Vehicle	-3.740e+00	9.990e-01	-3.744	0.000182
Household Crowding	-4.991e+00	3.960e+00	-1.260	0.207601
F_Total	-2.545e+02	5.344e+01	-4.763	1.93e-06
Total Population	-5.080e-05	1.436e-05	-3.538	0.000404

Table 4. Multiple linear regression results for race and nitrite/nitrate pollution exposure

Race/Ethnicity	Estimate	Std. Error	T value	P value
Black and African American	6.217e+01	7.255e+00	8.570	< 2e-16
Hispanic	4.328e-01	3.648e-01	1.187	0.235
Indigenous (American Indian and Native Alaskan)	7.330e+01	7.715e+00	9.501	< 2e-16
Asian	4.762e+01	6.480e+00	7.349	2.13e-13
Native Hawaiian and Pacific Islander	1.044e+02	1.102e+01	9.474	< 2e-16
White	6.029e+01	6.080e+00	9.916	< 2e-16
Total Population	3.432e-06	3.668e-07	9.357	< 2e-16

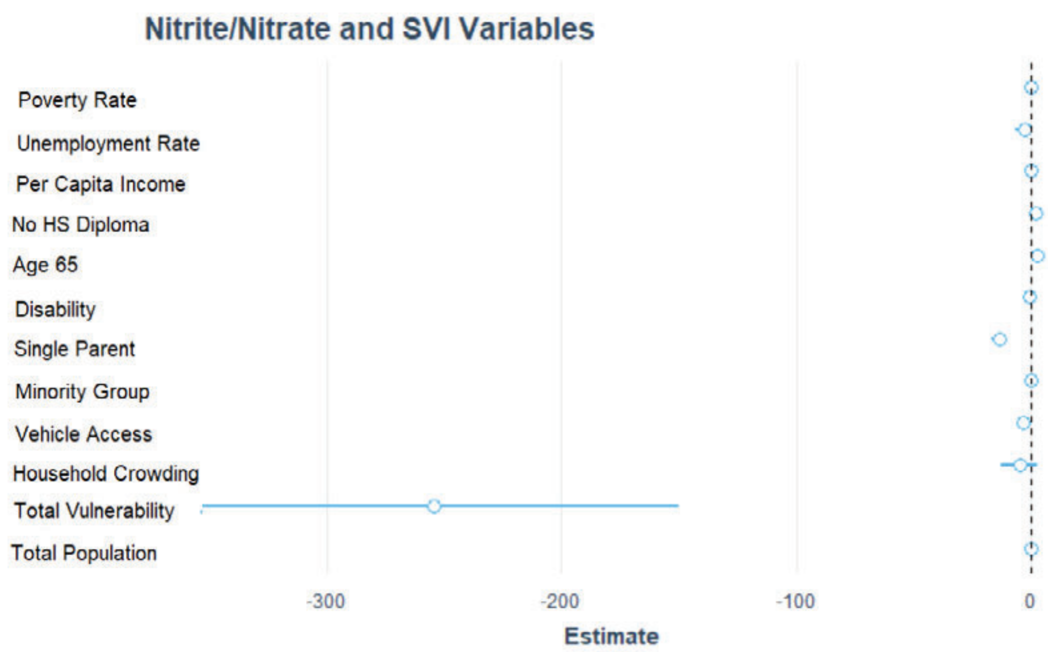

Figure 8. Standard estimates for **socially vulnerable** communities and nitrite/nitrate (mg/L) exposure

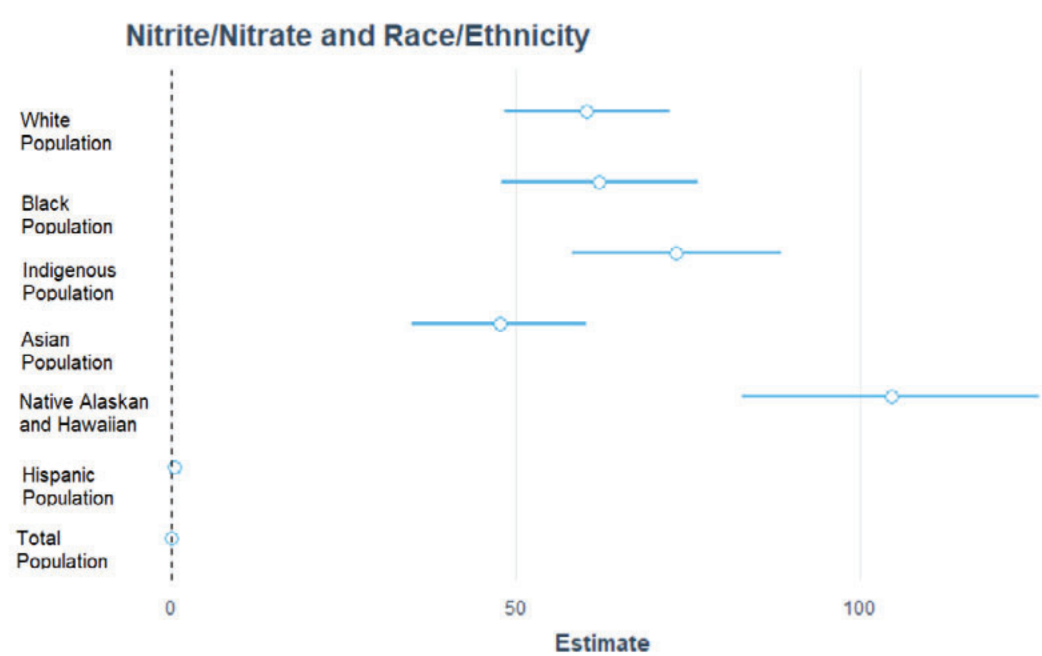

Figure 9. Standard estimates for race/ethnicity factors and nitrite/nitrate (mg/L) exposure

Flood Risk

Spatial Analysis

Flood risk maps for the 2020 flood risk data and the 2050 projection were created. In these maps, the darker colors denote areas where a greater amount of properties are at risk. When comparing the 2020 and 2050 flood risk maps, it is evident that very few areas change in risk from 2020 to 2050. Additionally, there is a higher likelihood for flood risk in rural areas, near where the Des Moines, Cedar, and Mississippi Rivers are (**Figure 10 and 11**).

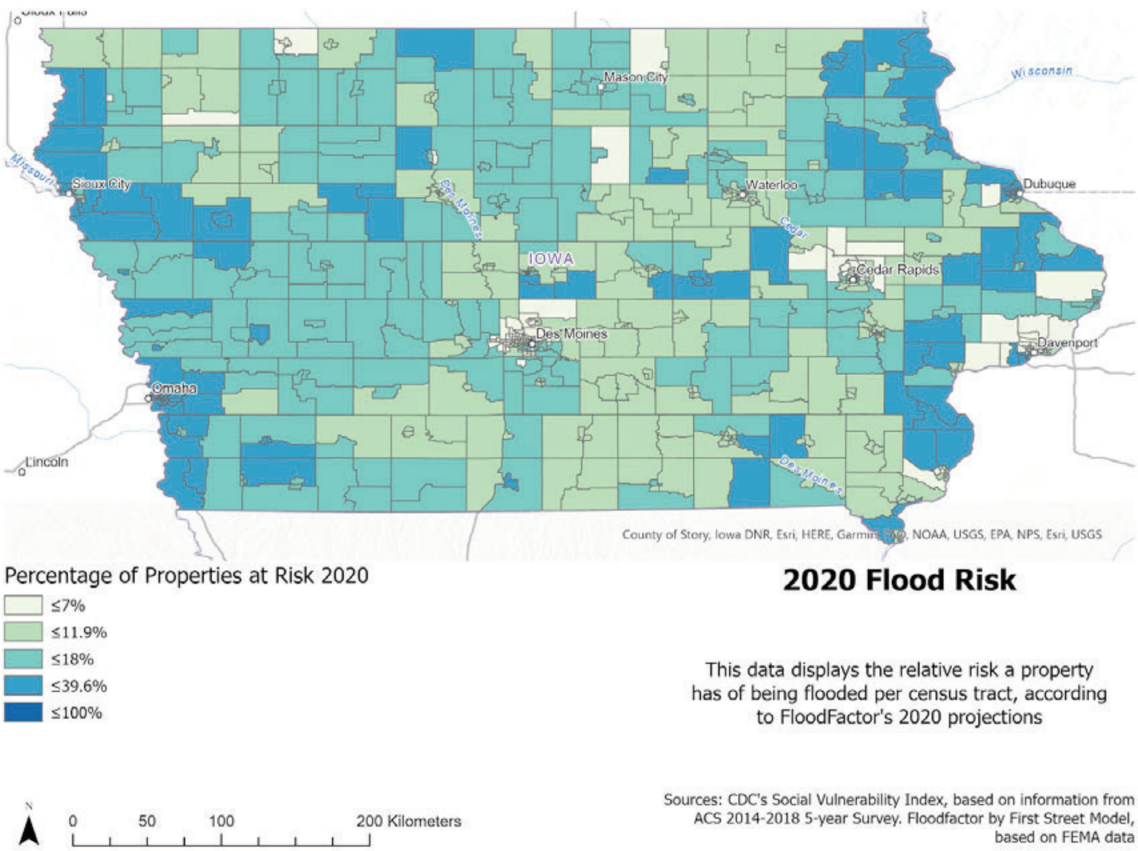

Figure 10. 2020 Flood Risk

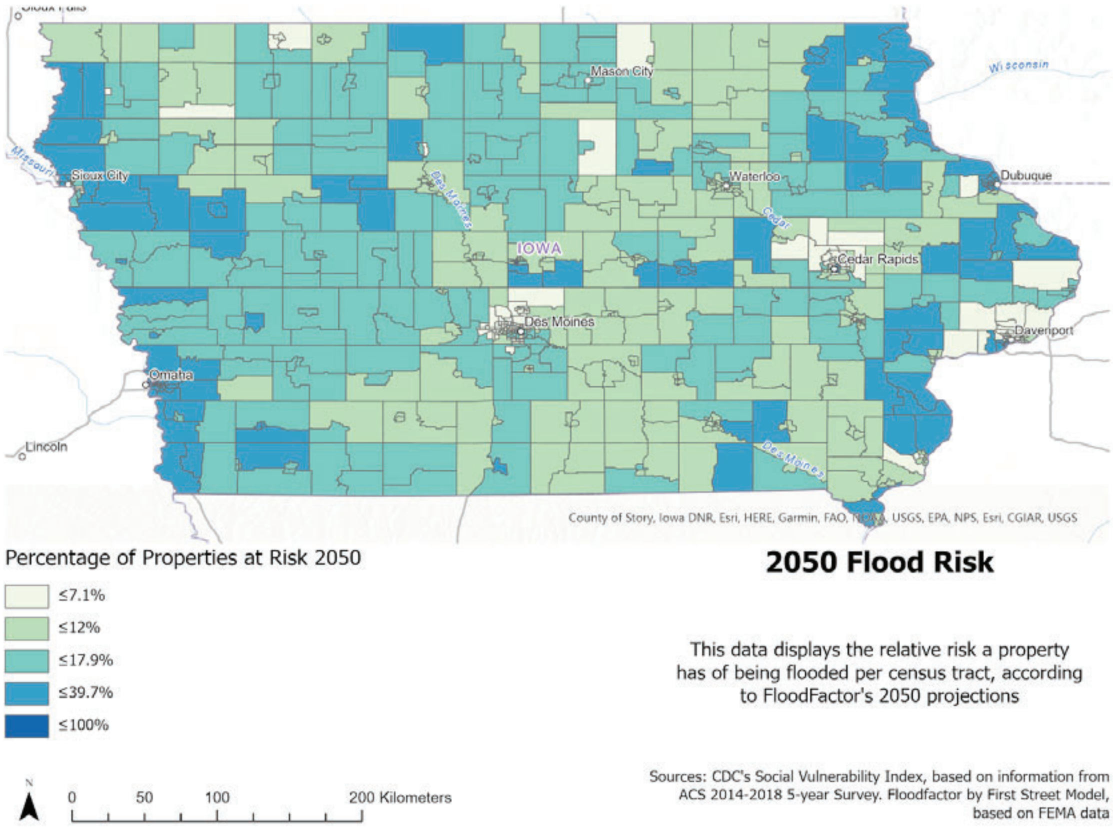

Figure 11. 2050 Flood Risk

Maps comparing 2020 and 2050 projected flood risk to socially vulnerable communities were also created (**Figure 12 and 13**). These maps demonstrated that there is a large correlation between the locations of socially vulnerable communities, the location of the Des Moines, Cedar, and Mississippi Rivers, and flood risk.

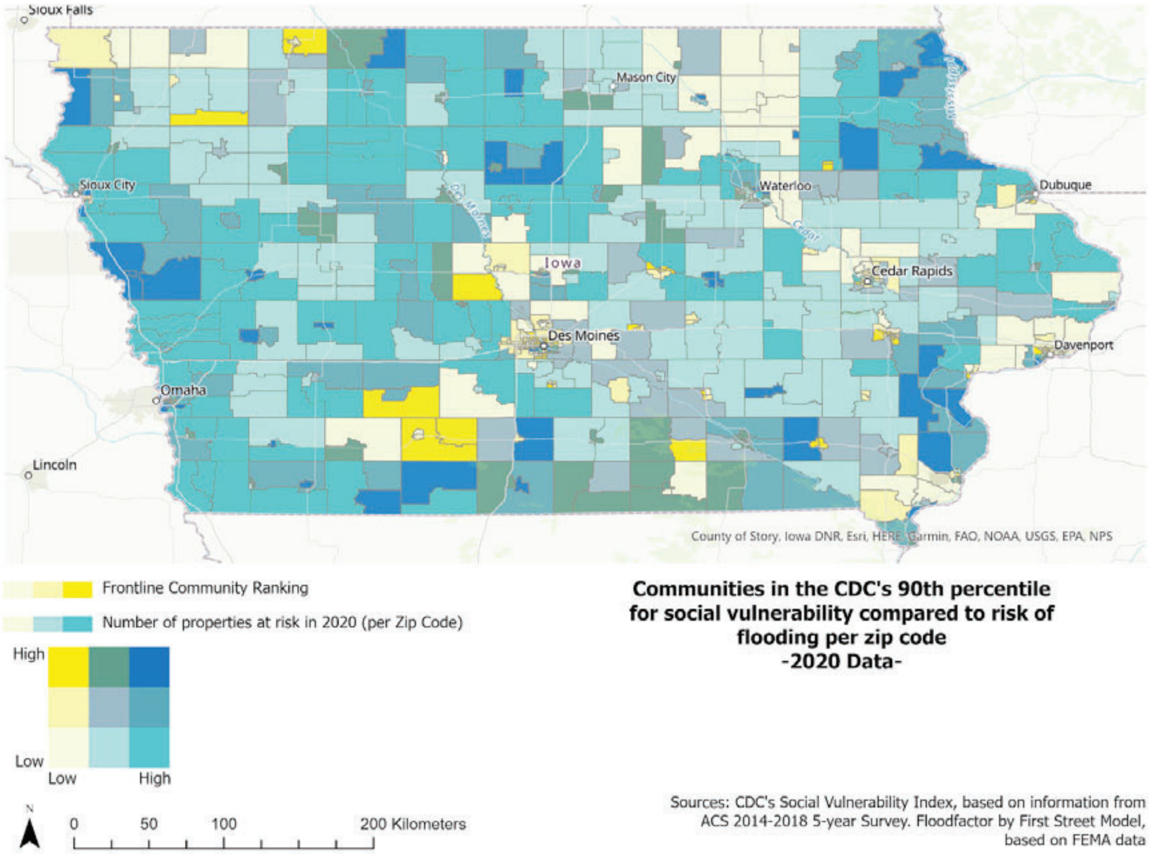

Figure 12. Communities in the CDC's 90th percentile for social vulnerability compared to 2020 flood risk projection

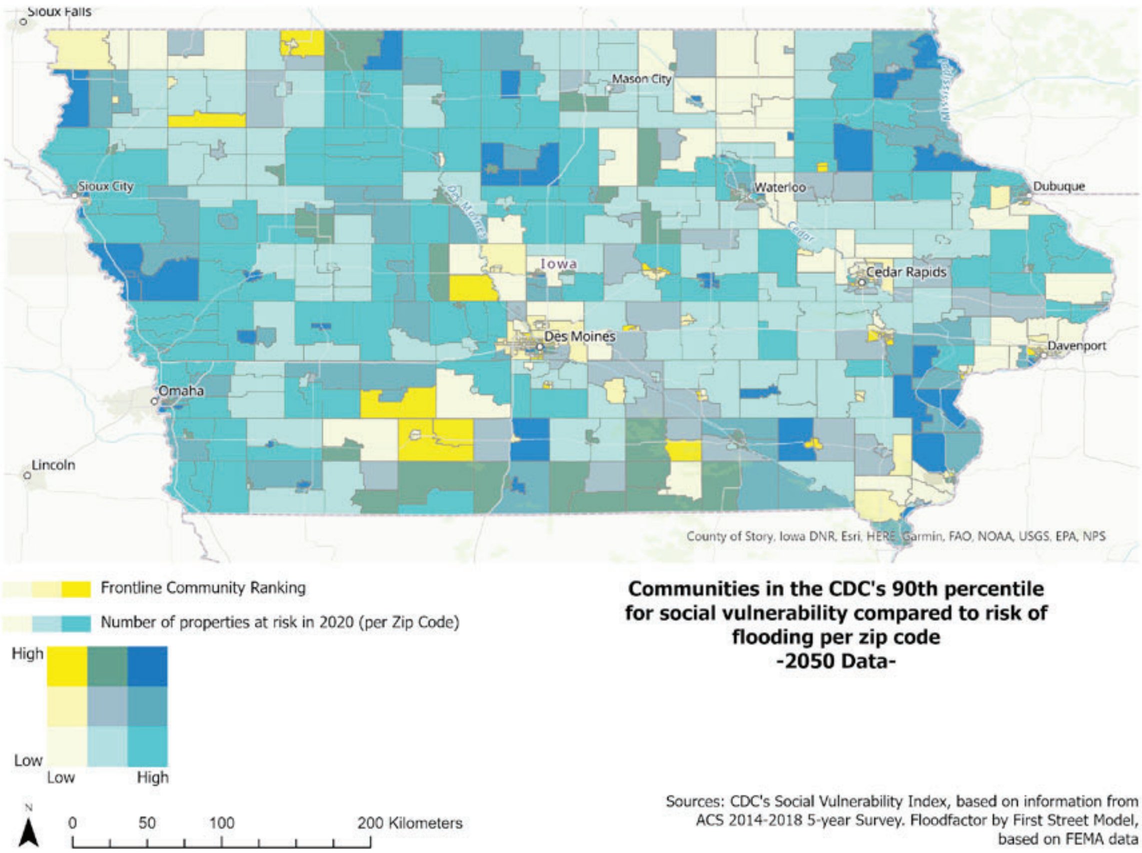

Figure 13. Communities in the CDC's 90th percentile for social vulnerability compared to 2050 flood risk projection

An individual map for each social vulnerability factor that was found to have a statistically significant correlation with 2020 or 2050 projection flood risk can be found in **Appendix A**.

Statistical Analysis

Relationship between socially vulnerable communities and 2020 flood risk

There was a significant relationship between flood risk and single parent households per census tract (($p=<0.0001$), and households with no vehicle per census tract ($p =0.0057$). There were no race/ethnicity variables that had a statistically significant relationship with 2020 flood risk. **Table 4 and 5** display the regression results. **Figures 14 and 15** display where the estimates lay in relation to 0: variables with negative estimates are negatively associated, while variables with positive estimates are positively associated.

Table 4. Multiple linear regression results for 2020 flood risk and social vulnerability.

SVI Factor	Estimate	Std. Error	T value	P value
Poverty	9.834e+01	5.479e+02	0.179	0.8576
Unemployment	2.113e+03	2.733e+03	0.773	0.4397
Per Capita Income	-1.993e+00	9.857e+00	-0.202	0.8399
No High School Diploma	1.570e+03	1.215e+03	1.292	0.1969
Over age 65	-1.076e+03	7.953e+02	-1.353	0.1765
Legally Disabled	1.943e+03	1.077e+03	1.804	0.0716
Single Parent	8.020e+03	2.035e+03	3.941	8.8e-05
Minority Group (non-white population)	-6.166e+02	3.924e+02	-1.571	0.1165
No Vehicle	-3.369e+03	1.215e+03	-2.772	0.0057
Household Crowding	-4.571e+03	5.069e+03	-0.902	0.3674
F_Total	4.850e+04	5.982e+04	0.811	0.4177
Total Population	-4.922e-03	2.089e-02	-0.236	0.8138

Table 5. Multiple linear regression results for 2020 flood risk and race/ethnicity

Race/Ethnicity	Estimate	Std. Error	T value	P value
Black and African American	-8.492e+03	2.584e+04	-0.329	0.743
Hispanic	-3.588e+02	1.353e+03	-0.265	0.791
Indigenous (American Indian and Native Alaskan)	-1.959e+03	2.697e+04	-0.073	0.942
Asian	-6.774e+03	2.227e+04	-0.304	0.762
Native Hawaiian and Pacific Islander	-3.073e+04	3.802e+04	-0.808	0.421
White	-6.395e+03	2.130e+04	-0.300	0.765
Total Population	3.757e-04	1.345e-03	0.279	0.781

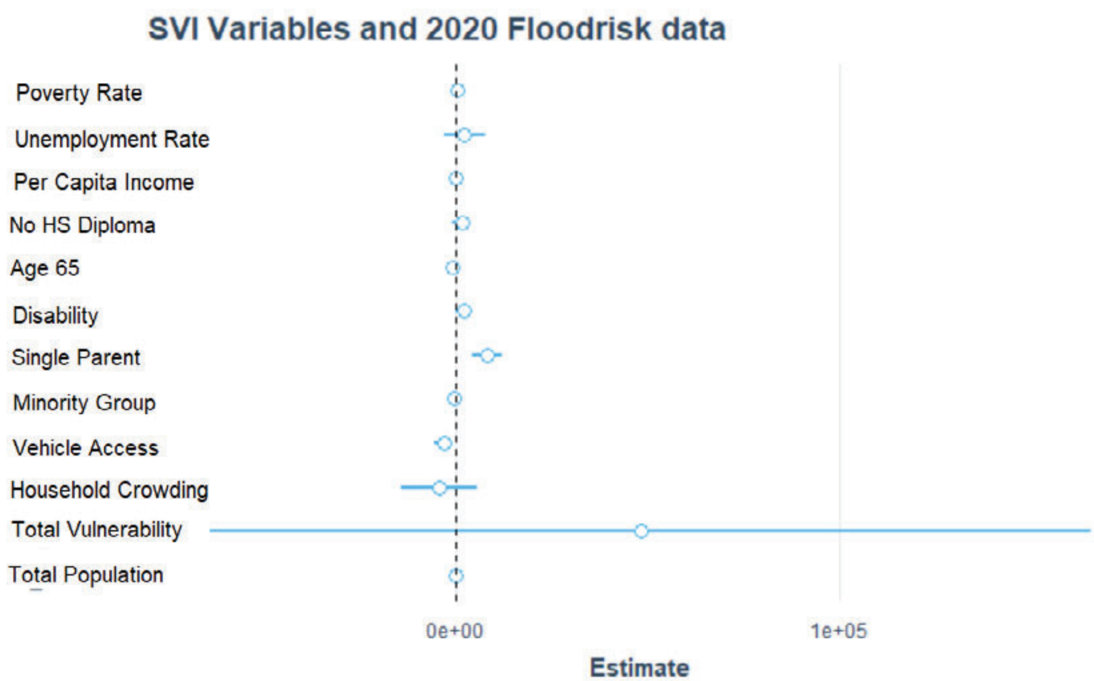

Figure 14. Standard estimates for social vulnerability and 2020 flood risk

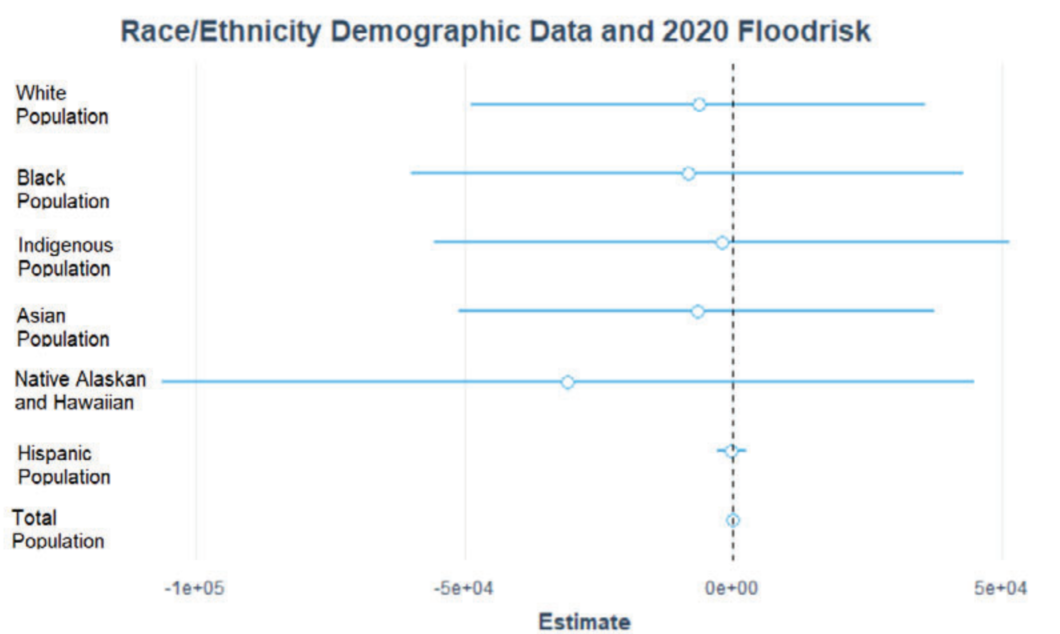

Figure 15. Standard estimate of race/ethnicity factors and 2020 flood risk

Relationship between socially vulnerable communities and projected 2050 flood risk

A multiple linear regression was carried out to investigate the relationship between projected flooding risk in 2050 and SVI factors (**Tables 6 and 7**). There was a significant relationship between flood risk and single parent households per census tract ($p=<0.0001$), and households with no vehicle per census tract ($p =0.006$). There were no race/ethnicity variables that had a statistically significant relationship with 2050 projected flood risk. **Figures 16 and 17** display where the estimates lay in relation to 0: variables with negative estimates are negatively associated, while variables with positive estimates are positively associated.

Table 6. Multiple linear regression results of 2050 flood risk projection and social vulnerability

SVI Factor	Estimate	Std. Error	T value	P value
Poverty	1.147e+02	5.519e+02	0.208	0.83539
Unemployment	2.151e+03	2.754e+03	0.781	0.43490
Per Capita Income	-2.325e+00	9.931e+00	-0.234	0.81498
No High School Diploma	1.568e+03	1.224e+03	1.281	0.20056
Over age 65	-1.050e+03	8.012e+02	-1.311	0.19024
Legally Disabled	1.924e+03	1.085e+03	1.773	0.07666
Single Parent	8.015e+03	2.050e+03	3.910	0.00010
Minority Group (non-white population)	-6.306e+02	3.953e+02	-1.595	0.11107
No Vehicle	-3.371e+03	1.224e+03	-2.753	0.00604
Household Crowding	-4.707e+03	5.107e+03	-0.922	0.35693
F_Total	4.912e+04	6.026e+04	0.815	0.41528
Total Population	-5.600e-03	2.104e-02	-0.266	0.79021

Table 7. Multiple linear regression results of 2050 flood risk projection and race/ethnicity.

SVI Factor	Estimate	Std. Error	T value	P value
Black and African American	-8.625e+03	2.592e+04	-0.333	0.740
Hispanic	-3.691e+02	1.357e+03	-0.272	0.786
Indigenous (American Indian and Native Alaskan)	-2.217e+03	2.706e+04	-0.082	0.935
Asian	-6.970e+03	2.234e+04	-0.312	0.756
Native Hawaiian and Pacific Islander	-3.072e+04	3.814e+04	-0.805	0.423
White	-6.585e+03	2.137e+04	-0.308	0.759
Total Population	3.268e-04	1.349e-03	0.242	0.809

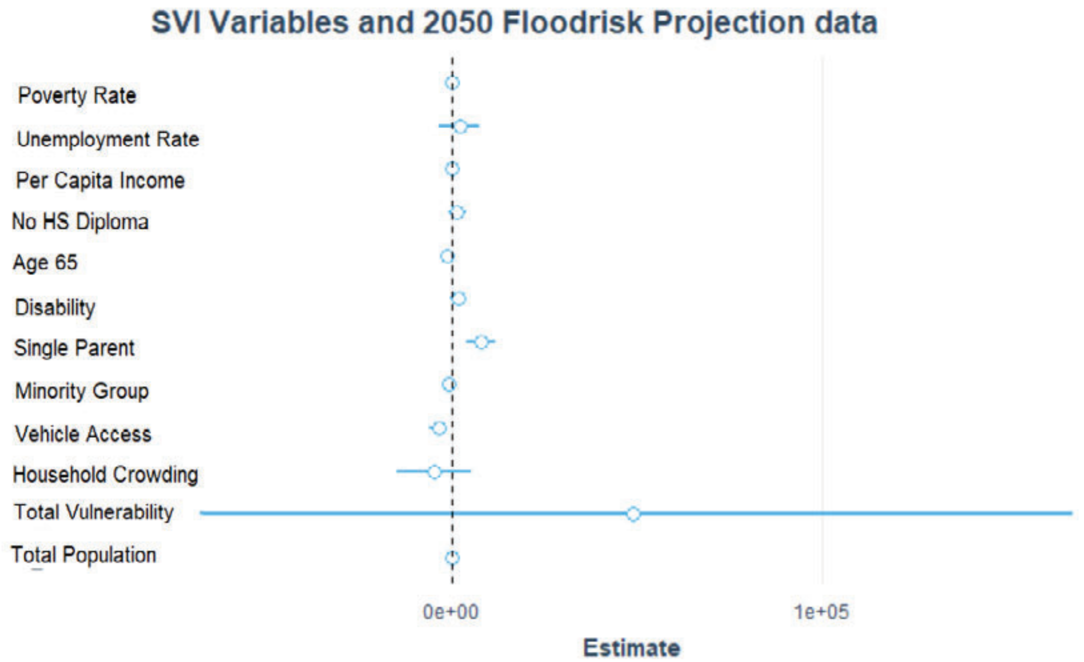

Figure 16. Graph demonstrating the standard estimate of social vulnerability and the 2050 flood risk projection

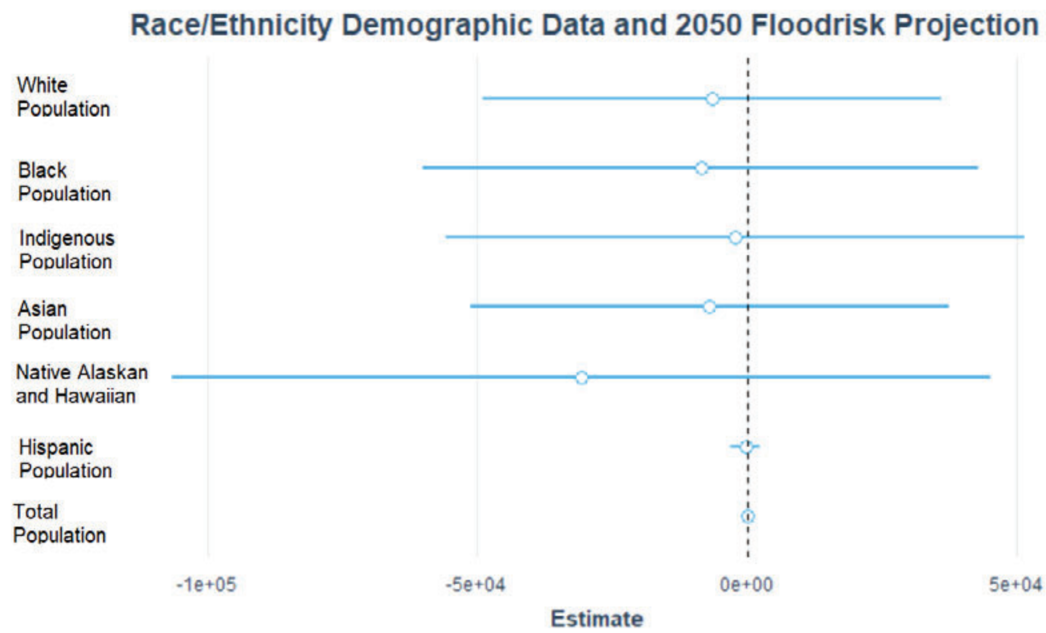

Figure 17. Graph demonstrating the standard estimate of race/ethnicity factors compared to the 2050 flood risk projection

Change in flood risk between 2020 and 2050:

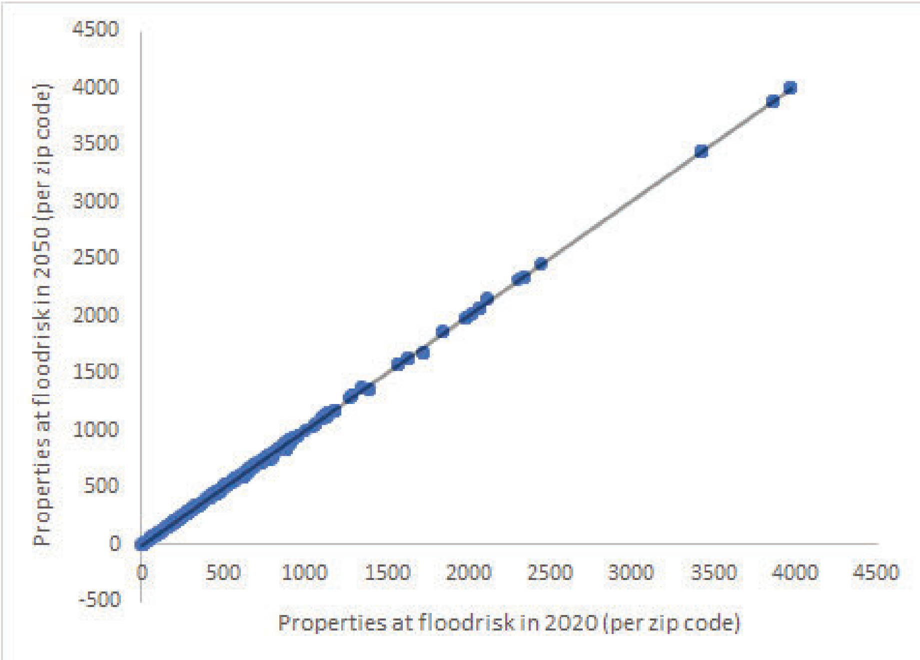

Figure 18. Scatterplot of Change in number of properties at risk between 2020 and 2050

In order to determine whether or not there is a significant difference between flood risk in 2020 and the 2050 projection, the number of properties at risk in each zip code in the 2050 projection was compared to the number of properties at risk in each zip code in 2020. This analysis yielded an average percentage of properties that were at risk in 2050 compared to the amount of properties that were at risk in 2020. This test yielded a mean change value of 0.998. Therefore, the overall level of flood risk in Iowa in 2050 is 99.8% the risk flood risk was in 2020, indicating that there is very little change between the two data sets. This is also demonstrated in **Figure 18**, in which each point is a zip code, and the x axis represents 2020 flood risk, and the y axis represents 2050 flood risk. The lack of deviation from the y=x line (black line) indicates that flood risk is not expected to change significantly in the next 30 years.

Discussion

First, nitrite/nitrate pollution in the state of Iowa is pervasive. Out of the 19,732 ground wells surveyed by the Iowa DNR between 2013 and 2018, 16,324 had anywhere between 0.01 and 9.99 mg/L of nitrite or nitrate (82.7%), and 717 had over 10 mg/L of nitrite or nitrate (3.4%). Second, the communities with the lowest percentages of white people (Story, Lee, Dallas, Webster, and Boone counties) were the ones that experienced the most nitrate pollution clustering. This finding indicates that there is a spatial correlation between COC and nitrogen pollution in Iowa, indicating that more nitrite/nitrate pollution is clustered in ground wells that are near to or overlap with COC.

Second, physical geography played a larger role in the distribution of flood risk. There is a higher likelihood of flood risk either on the borders of the state or in rural areas, and adjacent to the Des Moines, Cedar, Missouri, and Wisconsin Rivers. In the northern, upstream part of the state, areas with a higher risk of flooding were adjacent to the Missouri and Wisconsin rivers. This demonstrates that proper river management and natural infrastructure implementation upstream may improve flood risk in these areas. When looking closer at flood risk trends in Iowa, it was also clear that certain social vulnerability characteristics were associated with flood risks. Lastly, while the number of properties facing flood risk will not change between 2020 and 2050, this does not take into account the frequency or severity of the flooding. So if the same number of properties are at risk in 2020 and 2050, the two projections will look the same even if the flood risk in 2050 is more frequent and severe.

When looking closer at flood risk trends in Iowa, it was also clear that certain social vulnerability characteristics were associated with flood risk. Particularly, single parent households were positively correlated with flood risk. In addition to this, there were positive correlations between nitrite/nitrate pollution and the number of people over 25 without a high school diploma, and those over age 65. These social vulnerability characteristics display that there is a social vulnerability factor related to environmental risk. There are several connections that can be made connected to all of these social vulnerability factors individually.

Initially, the association between single parent households and flood risk indicated that there is a connection between environmental risk and gender that should be further explored. Within the United States, 53% of all single parents are mothers living independently, and 18% of single parents are mothers that are cohabiting either with a partner or with family members (Livingston, 2018). This aligns with the current research related to ecofeminism and environmental sexism, which has found that women and femme-presenting persons bear the burdens of environmental hazards in most if not all communities (Bell et al., 2016).

Additionally, the association between nitrate/nitrite pollution and the number of people over 25 without a high school diploma is quite ominous. Neural tube defects have been shown to be four times greater in the children of people whose public water supply contained nitrate above the EPA's recommended maximum contaminant level (Bondy & Campbell, 2017). In addition to this, the presence of nitrite/nitrate in a water system indicated agricultural runoff has entered the water supply, which may contain a large number of pesticides containing neurotoxic properties (Bondy & Campbell, 2017). A connection can be made between this pollutant exposure and cognitive outcomes in a community (Persico, 2019).

Lastly, the association between nitrogen pollution and those over age 65 may be connected to the phenomenon of "rural flight", in which young adults leave rural areas to seek out economic and social opportunities. Iowa's Department on Aging has stated that the state's population of adults over 65 will constitute 19.9% of the state population by 2050 (compared to the US average of 15.1%) (Iowa Department on Aging, 2021). Iowa produces more educated employees than its economy can utilize, and has fewer jobs that require a college degree compared to the national average (Swenson et al., 2017). As a result, younger populations leave rural areas that don't have jobs for their skill set, and those rural areas become impoverished, leaving those older than 65 at risk. Through creating policies dedicated to ensuring that jobs are available in rural areas, this "rural flight" phenomenon can be mitigated. If these communities are rejuvenated with economic growth and fresh opportunities, the community will have a higher adaptive capacity, allowing for support systems for people over 65 to be rebuilt and a community that is more able to implement natural infrastructure programs to combat their exposure to flood risk and nitrogen pollution.

This study aimed to identify key locations for natural infrastructure interventions in Iowa, in a way which benefits Iowa's socially vulnerable communities. The data found in this analysis can be used to better inform and protect these communities from environmental degradation in the future. This data can also be applied by governing structures within the communities to both rectify past injustices and prevent future injustices. Through utilizing this data, decisionmakers will have an increased awareness of social vulnerability and environmental justice within Iowa, and priority can be placed on implementing natural infrastructure so that it improves climate resiliency.

CHAPTER III

THE SOCIAL AND POLITICAL CONDITIONS FOR SUCCESSFUL NATURAL INFRASTRUCTURE IMPLEMENTATION IN IOWA:

COMPARATIVE ANALYSIS OF THE DES MOINES WATER WORKS LAWSUIT AND THE MIDDLE CEDAR PARTNERSHIP PROJECT

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EXECUTIVE SUMMARY

Collaborative conservation is the process of stakeholders working together in order to ensure that communities can address contentious conservation issues. Within the Upper Mississippi River Basin (UMRB), collaborative conservation can be utilized to address major ecological and environmental justice issues. This study aims to identify the key conditions for successful collaborative conservation and to understand the existing social structure and how it affects collaborative conservation. Two case studies were selected in the state of Iowa: the Des Moines Water Works (DMWW) lawsuit and the Middle Cedar Partnership Project (MCPP). These areas were selected due to differences in their approaches and outcomes to stakeholder engagement in regards to mitigating flooding and nitrogen pollution.

Methods

Semi-structured interviews were conducted over Zoom with interviewees and at least one of the project team members using interview guides in **Appendix** (Specifically **Appendixes B3** and **B4**). Eight interviews were conducted for the DMWW lawsuit case study, and six interviews were conducted for the MCPP. The purpose of these interviews was to identify (a) the water issues such as the mitigation of flooding and nutrient loading in Iowa; (b) the existing barriers and opportunities of natural infrastructure implementation in Iowa; (c) the collaborative conservation relationships among stakeholders. Each guide included three main parts, background questions, case related questions, and conclusion questions. Interviews were initiated by reaching out online and snowball sampling. Interviewees were asked about the existing relationships among the stakeholder groups and how the case/event in question impacted the adoption of natural infrastructure. All interviews were conducted confidentially, and all information was de-identified before analysis.

Results

The conditions for successful collaborative conservation found are trust, political support, stable and long-term funding, and hiring experienced professionals. Aspects of equity and environmental justice were also addressed throughout these interviews, specifically regarding the inclusion of diverse voices in decision making circles while the most of current decision making didn't consider the priority of inclusion.

Implications

Natural infrastructure implementation that positively benefits socially vulnerable communities is more likely to be possible when positive stakeholder networks exist and lines of communication are open. Firm trust network from the four conditions for successful collaboration proves its importance. Through comparative analysis, the most crucial factors for successful collaboration were revealed. Future collaboration that aims to create an effective natural infrastructure implementation plan would be benefitted by understanding the importance of these partnerships. With the particular conditions of collaboration that are pointed to in this report, time and cost for exploring new collaborations can be greatly reduced if these guidelines are followed.

Acronyms

Communities of Color (COC)
Des Moines Public Works (DMPW)
Des Moines Water Works (DMWW)
Environmental Defense Fund (EDF)
Government Accountability Office (GAO)
Iowa Drainage Districts Association (IDDA)
Iowa Soybean Association (ISA)
Iowa Watershed Approach (IWA)
Middle Cedar Partnership Project (MCPP)
National Pollution Discharge Elimination System (NPDES)
Natural Resources Conservation Service (NRCS)
People of Color (POC)
Regional Conservation Partnership Program (RCPP)
United States Department of Agriculture (USDA)
Water Quality Initiative (WQI)

Purpose

Collaboration is a strategy strategy that has shown promise to promote natural infrastructure implementation. Collaborative conservation is the process of creating a sustainable future for peoples and places by allowing communities to address contentious conservation issues while respecting diverse voices, needs, and challenges. This concept was recognized as important by the United States in the 1950s. The 'watershed collaboration era' then began in the 1980s. This era encouraged water conservation discussions to include diverse stakeholders in deliberative forums (Sabatier et al., 2005). In the 2000s, the U.S. Government Accountability Office (GAO) identified collaborative conservation as a promising tool for resource management and began recommending collaborative conservation as a tool in watersheds to improve the conditions of natural resources (GAO, 2008). Collaborative conservation has allowed researchers and practitioners to work together to create research projects with more effective research questions, and allowed practitioners to implement the most effective sustainable practices.

In the UMRB, community members have had different levels of success in collaboration for addressing the increased pressures encountered with flood risk and nitrogen pollution. The Middle Cedar Partnership Project (MCPP) is an example of a successful and well-known collaborative. Examining this successful network of multiple stakeholders engaging in a collaborative conservation partnership has offered a way to observe and summarize the key elements for successful collaborative conservation. However, the various motivations and interaction strategies of farmers, organizations, and federal agencies heighten the difficulty of collaborative partnerships. Because of this, the 2015 DMWW lawsuit was chosen as an example of a situation in which collaborative conservation was not achieved in a watershed.

The criteria for measuring successful collaboration should include the consideration of environmental justice to ensure inclusiveness and equity throughout the process. While environmental justice has yet to be recognized as an important part of the argument for natural infrastructure practices in many places, marginalized voices are essential in exposing the varied impacts of flood risk and nutrient pollution and in mitigating those impacts. While Iowa has not traditionally been viewed as racially diverse, it always has been and is becoming increasingly diverse. For example, since 2000, Iowa's Hispanic, Asian, and African-American communities have seen population growths of 116.6% percent, 110.8%, and 77.9% respectively (Barske, 2017). In our analysis we applied an environmental justice framework to understand how to utilize collaborative conservation practices effectively, in a way that will allow all voices to be heard.

The goal for this comparative analysis is to identify the key condition for a potential successful collaboration broadly and in ways that support environmental justice. To address this research goal, we compared two cases: MCPP and DMWW. Interview methods were used to determine the perspectives of stakeholders familiar with each case on why collaboration was or was not possible. The cases were first analyzed separately in the interview review section, then compared with each other in the discussion section. The similarities and differences are detailed in the conclusion section. Finally, the recommendations for future collaboration and the establishment of natural infrastructure in Iowa were proposed based on these findings.

Background Review of Cases

Des Moines Water Works Lawsuit

Des Moines is the capital and the most populous city of the state of Iowa, with an estimated population of 216,853 (U.S. Census Bureau, 2018). The city's median household income is $58,580, and median per capita income is $31,085 (U.S. Census Bureau, 2018). The city of Des Moines is a hub for several industries, most notably insurance and finance, with Wells Fargo & Co, the Principal Financial Group, Nationwide Insurance, and Blue Cross Blue Shield being top employers (Greater Des Moines Partnership, 2020). While Des Moines' urban area consists primarily of businesses and financial groups, the rest of the watershed is primarily rural and participates in industrial agricultural practices.

The City of Des Moines utilizes surface water from the Des Moines and Raccoon Rivers as drinking water for the more than a half million people residing in the City of Des Moines and its surrounding communities (Des Moines Water Works, 2021a). Because of the application of fertilizer and manure in the land upstream of Des Moines, the nitrate load to the City of Des Moines' water source has been rising since the 1970s (Hatfield, 2009). To solve this issue, the Des Moines Water Works (DMWW) implemented the world's largest reverse osmosis nitrate removal system to treat the water to make it safe for the public. DMWW claimed that despite investing millions of dollars in infrastructure over the past 30 years, record peaks in nitrate levels caused by the subsurface drainage systems threatened the water supply from the Racoon River (Des Moines Water Works, 2021b). As the reverse osmosis system began to be operated on more days of the year, the City of Des Moines began facing and continues to face the need to expand that facility. Installing a new reverse osmosis facility would cost roughly $70 million (**Figure 1;** Des Moines Water Works, 2021c). Due to the serious pollution, DMWW kept investing in solutions to remove nitrate pollution, and spent $1.2 million on operating costs for building up nitrate removal equipment in 2015.

While dealing with the consequences of this nitrogen pollution, the DMWW Board of Trustees had increased its dissatisfaction with the voluntary approach to water quality improvement for agriculture. To this day, there is nothing that legally requires farmers upstream of the Des Moines watershed to ensure that they are not polluting the waterways. Newly passed S.F. 512 only creates financial assistance in terminal wastewater treatment rather than addressing the accountability system (Reynolds 2017).

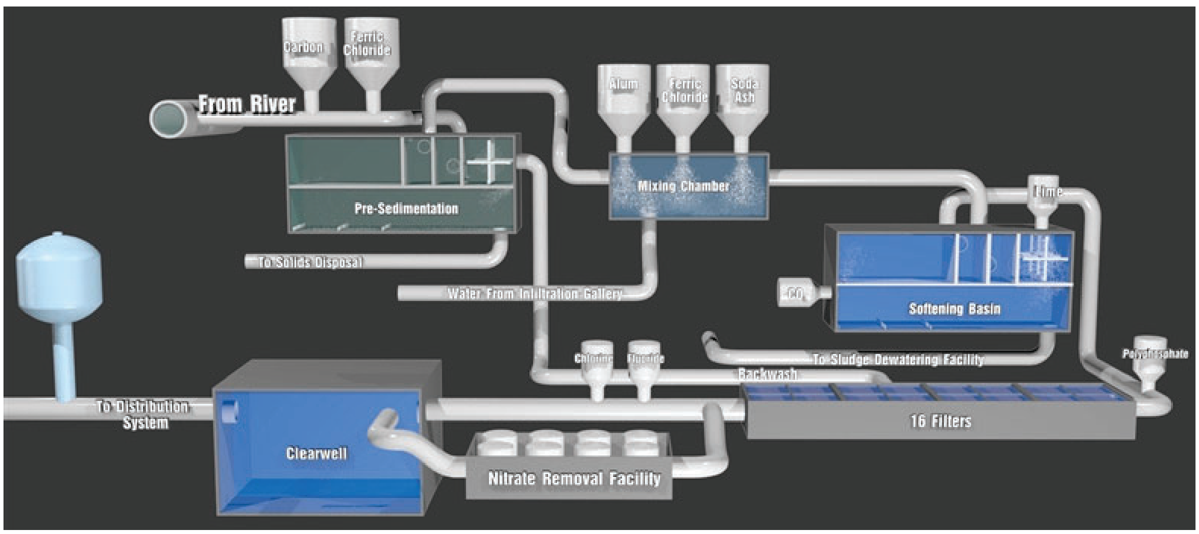

Figure 1. The water treatment process at the Des Moines Water Works showing the incorporation of the new reverse osmosis facility

In 2015, the DMWW Board of Trustees filed a complaint against the Drainage Districts of Sac, Calhoun, and Buena Vista counties for violating the Clean Water Act by failing to secure a National Pollution Discharge Elimination System (NPDES) permit for nitrate discharges and for violating provisions of the Iowa Drainage Code. In the view of some interviewees and the lawsuit ruling, the lawsuit is a violation of the Clean Water Act. When the lawsuit was filed, the DMWW contended that the drainage districts in the watershed, which consist of approximately 80-100 farmer families (based on an interviewee's estimate), drained their land into streams, creating nonpoint source nitrogen pollution. The Director of DMWW stated that the lawsuit data had been collected since 2014 with the assistance of the Iowa Soybean

Association (ISA) to show that drainage from agricultural lands in Sac, Buena Vista, and Calhoun counties sent polluted water into the Raccoon River (Mayer, 2020). However, DMWW didn't inform ISA before using the cooperatively collected data. In 2016, the District Court filed an order for the Iowa Supreme Court to answer four questions before commencing the federal trial. Two of the questions related to whether drainage districts had unqualified immunity, and two questions related to DMWW's ability to claim constitutional protections and whether DMWW's property interest in water could be "the subject of claim under ... [the] takings clause." The takings clause declares that private property shouldn't be used by the public without proper and just compensation. The term is originally from the Fifth Amendment of the U.S. Constitution (Agricultural Law and Taxation Blog, 2020). The Iowa Supreme Court answered all four questions in favor of the Drainage Districts, stating that Iowa legislation and court decisions have given drainage districts immunity because the service drainage districts provide is of great value to the citizens of the state. Furthermore, the court answered that both DMWW and the drainage districts were subdivisions of the state government, therefore they cannot sue each other. In 2017, the district court dismissed DMWW's case against the drainage districts, citing the Iowa Supreme Court's ruling. DMWW's Board of Trustees decided not to appeal the case (Board of Water Works Trustees of the City of Des Moines, Iowa vs. the Drainage Districts of Sac, Calhoun, and Buena Vista Counties, 2017).

Middle Cedar Rapids Partnership Project

Cedar Rapids, which is the seat of Linn County, is the second-largest city in Eastern Iowa. Additionally, it is in the city corridor of Linn, Benton, Cedar, Iowa, Jones, Honson, and Washington counties, and serves as an economic hub of the state. The major river in Cedar Rapids is the Cedar River, a major tributary to the Mississippi River. Additionally, this river runs through Cedar Rapids City from northwest to southeast, forming a developed river network and occupying 3.29 square kilometers of water areas (Cedar Rapids, Iowa, 2020). This broad scale of river networks based on the Cedar River raises a relatively high risk for watershed flooding. According to the flood document of Cedar River (Cedar River, 2020), three huge flooding disasters in 1993, 2008, and 2013 caused immense damage to coastal residences along the river. Most notably, the 2008 Cedar River flood caused the greatest impact on Cedar Rapids City. This flood crested 31.21 feet high flood water, and penetrated 10 square miles. 14% of the city was affected by this flood, including 7198 parcels, 5390 households, 18000 residents, and 310 city facilities (City of Cedar Rapids, 2020).

To mitigate future floods and pollution resulting from agricultural runoff (particularly nitrogen and phosphorus pollution), the City of Cedar Rapids led a five-year community-based collaborative action plan (City of Cedar Rapids, 2020), known as the Middle Cedar Partnership Project (MCPP), which initiated in June 2015 (**Figure 2**) (City of Cedar Rapids, 2018). This project aimed to unite the downstream water users, upstream conservation entities (i.e., Benton Soil and Water Conservation District, Tama Soil and Water Conservation District, Black Hawk Soil and Water Conservation District, etc), and local farmers around the Middle Cedar Watershed to install natural infrastructures, such as cover crops, bioreactors, saturated buffers, and etc. Beginning on June 5, 2015, the MCPP took Rock Creek-Cedar River, Pratt Creek, Wolf Creek, Miller Creek, and Headwaters Miller Creek as focus watersheds which are predominated by row crop corn, and soybeans. Throughout this collaborative effort, the project expanded its collaborating partners to 17 members, including farmers, the Iowa Farm Bureau, the Iowa Department of Natural Resources, and the U.S. Natural Resources Conservation Service. To date, the project has received $278 thousand from the City of Cedar Rapids, $1.3 million from collaborating partners, and $1.6 million in financial support from the Regional Conservation Partnership Program (RCPP) (City of Cedar Rapids, 2018).

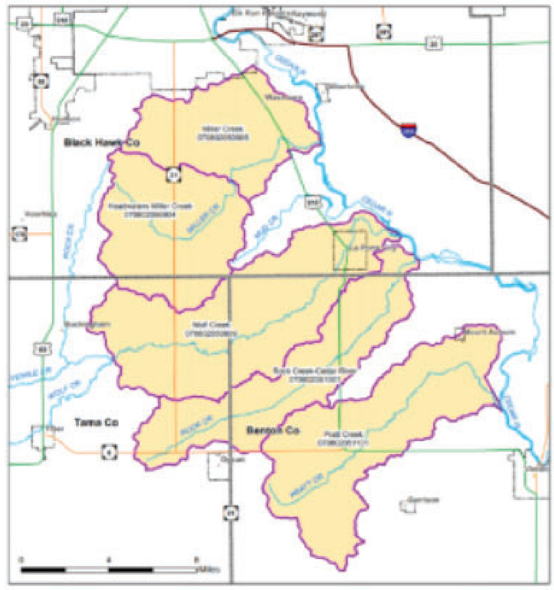

Figure 2. The Middle Cedar Rapids Watershed

While the overall project goal was focused on flood risk and nutrient pollution reduction, MCPP also raised the the following action goals: (1) develop monitoring and evaluation (involved a watershed plan), (2) implement Best Management Practices with financial and technical assistance, and (3) outreach to landowners and producers in five HUC 12 watersheds. Additionally, the project used water quality monitoring to quantify Best Management Practices results. The Benton/Tama Nutrient Reduction Demonstration project took responsibility to monitor water quality weekly from drainage tile outlets and at several tributaries of the Middle Cedar River. Those aggregated results can be used to track improvement in the field and practice scale.

Methodology

Semi-structured interviews were selected as the primary method of data collection for this comparative case study analysis. The purpose of the interview process was to identify (a) the water issues such as the mitigation of flooding and nutrient loading in Iowa; (b) the existing barriers and opportunities of natural infrastructure implementation in Iowa; (c) the collaborative conservation relationships among stakeholders based on the diverse perspectives from interviewees upon the cases' outcomes. Due to COVID-19, all interviews were conducted online via Zoom. Interviewees were recruited via email according to their relationship with the DMWW lawsuit or Middle Cedar Partnership Project. All of the interviewees were recruited via online email connection. The recruitment email templates for Des Moines and Cedar Rapids interviewees can be found in **Appendix B1 and B2,** respectively. All the interviews were recorded after gaining oral permission from the interviewee and their names and occupations have been kept confidential. Additionally, the selection list was built based on (a) existing connections with Environmental Defense Fund (EDF), and (b) snowball sampling. The types of organization involved in the interviewees list are displayed in **Table 1**.

Two interview guides were developed; one for Des Moines and one for Cedar Rapids (**Appendix B3 and B4,** respectively). Each guide included three main parts, background questions, case related questions, and conclusion questions. All of the interview questions were open-ended questions, which were sequenced from broad to narrow. Case-related questions were aimed at gaining information about the existing relationships among the stakeholder groups of both cases and how the event will impact the adoption of natural infrastructure. The ultimate goal for the case comparison and this overall project was always in line with understanding the past event with a neutral attitude. Thus, the report does not include the personal views from the project team about the stakeholders in either case.

Table 1. The summary of case study interviewees' organizational types

Organization level	Organization Type	Number of Interviewees
Federal	Non-profit organization	2
State	Government	1
	Non-profit organization	5
	Research institutions	2
Local	Non-profit organization	1
	Public utility	1

Canvas and Zoom were employed for transcribing the interview recordings. All the recordings were de-identified before they were uploaded to the private Canvas media branch. Only the project team has access to the raw recording video and audio. NVivo software was utilized to analyze the interview transcripts based on a codebook (**Appendix B5**). The codebook was developed based on interview questions. The following analysis is mainly based on the interview data categorized by the codebook, which identified themes. Additionally, some quotes are cited, in accordance with the interviewees permission, to support the analysis.

Results

Stakeholder relationships in the City of Des Moines

In the DMWW case, there are two main stakeholder groups - defendants and plaintiffs. The plaintiffs of the lawsuit were the Des Moines Water Works Board of Trustees. The defendants in the lawsuit were the 13 drainage districts in Sac, Calhoun, and Buena Vista counties. The lawsuit has brought a lot of attention to Des Moines and Iowa. Lots of news and reports analyzed the process and impact of the DMWW lawsuit. For instance, the Iowa Public Radio News claimed the lawsuit has disappointed the agricultural groups while Iowans also want cleaner water; Mr. Art Cullen also published a well-thought report about the lawsuit, which won a Pulitzer Prize (Kotlowitz, 2018). In sum, this complex and conflicting social dynamic has garnered lots of media attention for the lawsuit, with articles appearing in state and regional papers, academic studies appearing at agricultural schools such as Ohio State University, and national environmental organizations such as the Sierra Club publicly stating their opinion on the topic. Since the lawsuit, the rift between the DMWW and the agricultural community has persisted.

Due to the lawsuit, group interactions are disjointed and tense. Interviewees across the board stated that there was not any trust between the two sides early on and that trust was further eroded by the unexpected lawsuit. Specifically, landowners and farmers felt as if their trust had been breached by the lawsuit, as data from their land was used against them. This has caused a lot of distrust and alienation. The interviewees' perspectives are varied.

One interviewee thought there was a clear and compelling case for farmers to take responsibility for reducing N pollution:

> *"Why did they not win the lawsuit? There's two wrongs. The first wrong is the farmers are the polluters....is it the public that pays in the city of Des Moines*

for treatment, or should it be the polluter that pays? I think it's very difficult in the U.S. to find any other situation where the polluter does not pay. That's the case here. The polluter does not pay. So there's no incentive for the polluter to stop polluting because they're not paying for anything. " (Personal Interview, 10/27/2020)

Others felt the lawsuit was not the right approach:

"I don't think there should have been a lawsuit filed. We've maintained from the very start that if you want to sue somebody, you're suing the wrong people. If you want to sue somebody, go after the regulators. Because what you're really seeking is regulation of drainage districts. " (Personal Interview, 09/30/2020)

Interviewees also stated that the lawsuit brought the issue of nutrient pollution in the watershed into public awareness. More specifically, the lawsuit prompted the passing of Iowa S.F. 512, dedicating $282 million to implement the Nutrient Reduction Strategy. This Act amends the wastewater treatment financial assistance program, creates a water quality infrastructure fund, establishes a water quality financing program, provides for cost-share programs for infrastructure on agricultural and urban land under the water quality initiative, and creates a water service excise tax (Reynolds, 2017). However, the lawsuit did very little in regards to engaging farmers to change their practices in a watershed-scale approach. Farmers in the Des Moines case are varied in their approaches to natural infrastructure and conservation practices, approaching such practices as individuals. Additionally, Des Moines area farmers still have little support in implementing any practices that may reduce flood risk or nitrogen pollution.

With the passage of time and a change in directorship and membership of the Board, DMWW has more recently worked to seek collaboration in solving nitrogen pollution issues in the watershed. However, the rift that was created by the lawsuit has yet to disappear. This can be seen through the actions of these seven Des Moines area counties: Buena Vista, Calhoun, Carroll, Palo Alto, Pocahontas, Sac and Webster. According to the demographic from the 2010 Census, Buena Vista and Webster counties are more urban while Calhoun, Carroll, Palo Alto, Pocahontas and Sac counties are more rural (Iowa State University, 2021). These counties have passed resolutions saying they will not support the proposed North Raccoon watershed plan if Dallas and Polk Counties remain part of the coalition (Eller, 2020). **These concerning resolutions demonstrate that while the lawsuit was beneficial in increasing public**

awareness about water issues, the damage caused has been lasting. This breach of trust will make it very difficult for the watershed to band together to address their commonly shared environmental issues.

Collaborative conservation faces a variety of social barriers in the City of Des Moines, which may inhibit the implementation of natural infrastructure. In addition to the aforementioned resolution, the lawsuit was funded through taxpayers' money (based on an interviewee's statement), making the people of Des Moines resentful of the DMWW. This relationship cannot be repaired fully within a short time. The DMWW will have to invest in continuous efforts to reconnect and find common ground with Des Moines residents and the agricultural community alike.

Another barrier is that those who support natural infrastructure practices are less likely to be heard by the regulators and policymakers, while the voices of opponents of natural infrastructure are readily heard by regulators and policy makers, such as some major commodity groups. (Reports & White Papers of Open Markets, 2019). Regulators and policymakers must be invested in listening to constituent concerns beyond the agendas of 'Big Ag' (large-scale agricultural organizations), as they have the vote right now and thus impact the legislation. For instance, the 2017 census result showed that 152 organizations that own 5,000 acres or more land control the same amount of land of the 9,120 small farms in the state (USDA, 2017). This concern is also identified by one of interviewees.

The willingness to engage in collaborative conservation is also indirectly affected by power differences.

> " *If a group has the policymakers' ear, policymakers are supporting their policy goals. They don't see a need to collaborate. Why do we need to collaborate? I've already got the policymakers here, and they're going to do what I want to do. So there's really no incentive for them to collaborate. We would love to collaborate. We would love to be at the table. But they [stakeholders in case] don't see a need because we don't have the ear of the leaders that can make a difference.*" (Personal Interview, 11/10/2020)

Making sure that socially vulnerable groups--which are more heavily affected by the outcomes of nitrogen pollution and flood risk--are given consideration during policy decision-making regarding natural infrastructure is essential to equity and justice. The participation of trusted agriculture organizations and experienced watershed coordinators could strengthen the trust of farmers in conservation initiatives and convince them to adopt natural infrastructure.

Middle Cedar Rapids Partnership Project

There were more stakeholder groups in the MCPP case than in the DMWW; with a total of 13 groups and organizations involved. First, the MCCP was led by the City of Cedar Rapids. Other stakeholders included; local conservation partners, farmers, and landowners in the watershed. This list included: the Iowa Department of Natural Resources (DNR) and Iowa Department of Agriculture and Land Stewardship (IDALS), the Iowa Pork Producers Association, the Iowa Soybean Association, Iowa State University Extension and Outreach, the Iowa Corn Growers Association, the Sand County Foundation, the Black Hawk Soil and Water Conservation District, the Benton/Tama Nutrient Reduction Demonstration Project, the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS), and the Iowa Farm Bureau (City of Cedar Rapids, 2018).

The main differences between the DMWW lawsuit and the MCCP are: political will, funding, effective communication and advertising. With regards to funding, the City of Cedar Rapids obtained a competitive and extensive Regional Conservation Partnership Program (RCPP) grant. The goal of the RCPP fund was to encourage collaboration. With this funding, the MCPP hired water, soil, and agricultural experts as watershed coordinators in order to promote farmer participation and build farmer trust in the project. By acquiring funding, collaborating with stakeholders throughout the watershed, and by hiring experts who were adequately funded and paid for their time, the MCPP was able to implement significant differences in the watershed.

The MCPP fostered collaborative conservation through adding positions and recruiting experts who supported communication and conservation. For the watershed coordinators, farmers were more willing to listen to someone that works closely with them and has experience in conservation practices rather than those who only had theoretical knowledge. For example, key individuals from Des Moines Public Works (DMPW) and the Iowa Soybean Association (ISA) (e.g., Jonathan Gano and Roger Wolf) helped to make collaboration possible because of their good working relationship with farmers. The network and the social capital built by the MCPP will be a great start for future collaborations, as people and organizations tend to collaborate with actors they know and have worked with before. This is connected to the "Know, Like, Trust" principle, which states that networking is most effective when trustworthy, genuine relationships are built (Burg, 2016). These relationships were built in several ways including, but not limited to: (1) field days in which participants could learn from each other, (2) quarterly meetings in which information about the project was shared, (3) advertising on local media, e.g., radio works and local TV, (4) sponsored events, e.g., the lunch networking. Through finding interested parties and getting them in the same room, this project was able to foster a positive environment for change. This project was also immensely benefited by the fact that it was heavily funded. It is crucial to remember that these connections were largely created through events and advertisements that were generously funded. The amount of funding directed towards these projects allowed collaborative conservation to occur.

Creating cost-sharing goals between each stakeholder allowed for a strong foundation for the adoption of natural infrastructure. This can be seen in the success of the Middle Cedar Partnership Project; through the creation of a well-funded project that works with a large variety of conservation partners, real change can start to be seen in the watershed as a whole. Projects similar to the MCPP will only be benefitted by the inclusion of more voices. However, it can be difficult to create a conservation project at this scale, with so many stakeholders involved, sustainable over a long period of time. **The end of RCPP funding for the MCPP may result in the suspension of the project and a change of the project's goals.** Even if alternative funding is found, the MCPP may not be capable of maintaining the vision of the Partnership Project. Changing the direction of the project could be detrimental to collaboration with farmers. Strengthening the voices of collaborative networks, and passing their message on to legislators and policy-makers can provide great opportunities for the adoption of natural infrastructure.

A few interviewees excitedly stated the results of the project: it improved conservation on over 4 million acres and added 17,000 acres that implemented cover crops. (Official results forthcoming late 2021 (City of Cedar Rapids, 2018)). However, the nitrate load in this area has increased by 100.4% from 2003 to 2019 (Jones, 2019). This suggests that practices implemented by farmers individually are not able to compensate for the damage done by state-wide agricultural practices. This also displays that there are many ways of defining success, and that one can reach different conclusions when using different metrics of success. While the MCCP may be successful from a watershed perspective, it would be considered unsuccessful from a statewide perspective.

The participants of the MCPP selected a relatively slow, but long-lasting approach for mitigating flood risk and nitrogen pollution, that put collaborative conservation at the forefront of the project. Natural infrastructure practices implemented through this project did improve the water quantity and quality of the Middle Cedar River. The MCPP project, under the guidance of the Iowa Watershed Approach (IWA), has also influenced other conservation efforts as nearby watersheds and cities, such as the cities of Dubuque, Ames, and the Clear Creek watershed, were working to establish a similar partnership project (Iowa Watershed Approach, 2021). The MCPP not only improved the environment, but also it provided a framework for future collaborative conservation efforts in Iowa.

Similarities between DMWW and MCPP

First, issues relating to nitrogen-heavy fertilizer application, such as nonpoint source pollution, began affecting the City of Des Moines in the 1970s. In 2013, Iowa adopted a voluntary Nutrient Reduction Strategy with a goal of achieving a 45% reduction in discharges of nitrogen and phosphorus with no target date assigned. However, the water quality in both the Raccoon River and the Des Moines river have not improved under the voluntary approach.

Along with this, issues regarding including a diverse set of stakeholders' perspectives were prevalent in both cases. While interviewees differed on whether or not they thought that there were any missing voices in discussions related to flooding and nitrogen pollution, they made it clear that People of Color (POC) and socially vulnerable community voices were excluded from collaboration networks. POC voices are not prominent at the agency levels (i.e., USDA, NRCS, Farm Service Agency, IDALS, etc). More specifically, one interviewee pointed out there is not a single black person on the State Technical Committee for the Natural Resources Conservation Service (NRCS) (Technical Committee Members, 2020). The membership of most agricultural organizations and agencies in the state is primarily white. Only a few POC were admitted to serve as Water Resources Commissioners. The representation of minority and disadvantaged farmers in these organizations and agencies is lacking. Furthermore, the lack of diversity is rarely addressed in these spaces. Meanwhile, within the City of Cedar Rapids, flooding mostly occurs on the banks of the river, where the city is zoned for affordable housing (City of Cedar Rapids, 2021b). Socially vulnerable communities suffer more due to flood events, but are not represented in flood management conversations.

In both the Cedar Rapids and Des Moines cases, more efforts need to be made to reach out to marginalized communities and Communities of Color (COC). When communities are not represented in environmental programs, programs that do not adequately meet the health and environmental needs of these communities are created (Chavez-Dueñas & Adames, 2015). Through the creation of comprehensive and participatory approaches that establish collaborative partnerships with marginalized communities and COC, new solutions can be found that benefit everyone within the watershed.

The last issues related to the inclusion of all voices are the way in which indigenous communities are treated in both cases. The Meskwaki (officially known as the Sac & Fox Tribe of the Mississippi in Iowa), the only federally recognized indigenous group in Iowa, are also regularly excluded from decisions regarding conservation. For example, this was seen when the Dakota Access Pipeline was being constructed (a 1,172 mile long underground oil pipeline that runs diagonally across the entire state of Iowa, hitting both Des Moines and Cedar Rapids). There were protests by the Meskwaki to the Iowa Utilities Board surrounding the fact that the pipeline was running directly through tribal lands and were completely ignored, even though the pipeline was breaking treaties dating back to the 1830s and 1840s (Petroski, 2015). Iowa also contains indigenous communities that are not federally recognized, who have even fewer opportunities for participation than the Meskwaki. Of the 17,060 people who are indigenous in the state of Iowa, only 1,058 are members of the Meskwaki nation, indicating that there is a large portion of this population that is entirely unheard (State Library of Iowa, 2020). In 2019, the Meskwaki Nation received the authority to administer water quality standards on their own lands, after two years of petitioning and applications (Meskwaki Nation, 2019). While this does not solve the issue that the State of Iowa has regularly ignored the informed opinions of the tribe, it helps give the tribe the power to work against future encroachments on their sovereignty in relation to increasing flood risk and nitrogen pollution.

Differences between DMWW and MCPP

There are several key differences between the two cases, including political will, funding, effective communication (under the assistance of experienced professionals) and advertising, the timing (**Figure 3**), drainage infrastructures, and local economies.

Timing

A key difference is that the DMWW lawsuit (March 2015) happened earlier than the MCPP (June 2015) and the impact from the lawsuit might have influenced the establishment of the MCPP even though there is no direct information showing they are connected. A few interviewees speculated DMWW lawsuit facilitated the creation of the MCPP as a counterexample, stating the possibility that Cedar Rapids learned from the lawsuit and wanted to seek a more collaborative direction. This resulted in the City of Cedar Rapids leading the collaborative conservation effort and cooperating with a wide range of agricultural organizations, farmers, landowners to implement natural infrastructure for improving water quality, flood management, and soil health. This five-year project received funding from the RCPP program and has achieved a positive social effect.

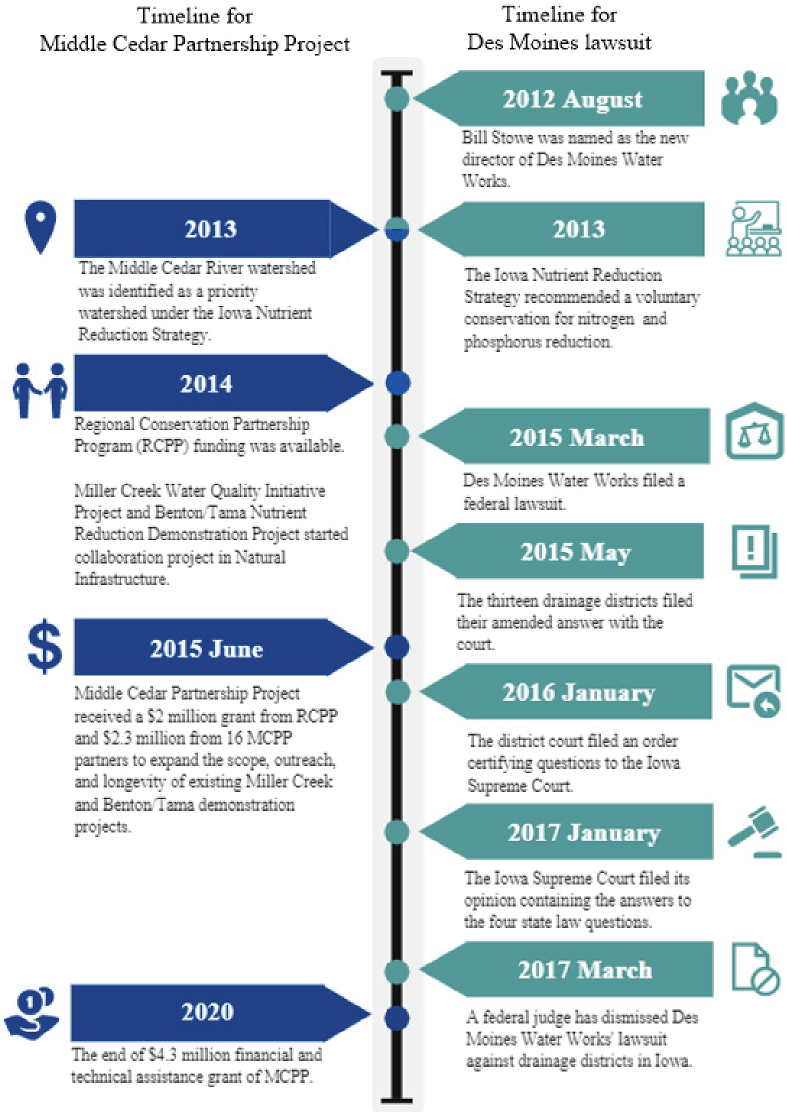

Figure 3. Timeline for Lawsuit and MCPP

Drainage Infrastructure

Another identified difference by interviewees is the intensive agriculture and runoff in drainage infrastructure between the cities of Des Moines and Cedar Rapids. For instance, the city of Des Moines is located downstream of Des Moines River, which is a larger river with more drainage, while the city of Cedar Rapids is located downstream of Cedar River. Properly managed drainage infrastructure can reduce localized urban flooding and harmful environmental impacts (Arisz & Burrell, 2006).

> *"The big difference between Cedar Rapids and Des Moines is the drainage infrastructure is different. Because now we've got single fields being tiled versus a large tile infrastructure. We've got a much bigger watershed in the Cedar Rapids area that's coming from other parts of Iowa that aren't as agriculturally intensive as they are in Des Moines...."* (Personal Interview, 10/27/2020)

Along with this, Des Moines has suffered from years of nonpoint pollution because of an ineffective federal regulation on nutrient pollution from agricultural sources and outdated state drainage legislation. Therefore, all the nutrient pollution from the upstream portions of the Des Moines watershed, especially the Racoon River, eventually entered the City of Des Moines. Without effective regulation, the complaints from the City of Des Moines become stronger every day.

At this point, the Director and the Board of Trustees at the DMWW desired legal mandates to reduce the amount of agricultural runoff their facilities were having to treat. Meanwhile, it proposed the appeal for the federal Clean Water Act to regulate the drainage districts and farmers as point source pollution. Multiple interviewees suggested that the DMWW Director's bold and confrontational personality was a catalyst for the proposal of lawsuit. A catalyst that poisoned the trust relationship between DMWW and agricultural groups in Iowa. In January 2017, the lawsuit was dismissed by a federal judge, who determined that these water quality problems are for the State Legislature to resolve. In the end, the lawsuit cost the Board of the DMWW $1.35 million, and breached the trust between the DMWW, agricultural groups, and the 13 Drainage Districts involved, which has created an insurmountable divide between the groups ever since.

In other cases collaboration has thrived after the creation of the Iowa Nutrient Reduction Strategy. The MCCP has motivated the growth of collaboration networks, covering a wide range of stakeholders, such as wastewater and stormwater utilities, and attracting varied partners, such as the Iowa Soybean Association, Capital Crossroads, the Great Outdoor Foundation, state-wide urban and rural agricultural organizations. Many entities were engaged and working together around a common goal.

Local Economies

Finally, economic differences also led to various social changes. In Cedar Rapids, a heavily agriculturally based economy tying the rural and urban communities closely together and providing opportunity for social change. Other factors that contributed to the success of the MCPP were the collaborative networks between the various agricultural groups, collaboration within the broader Middle Cedar River community, and obtaining technical and financial support for the project. However, we must be aware that under different circumstances, the collaboration in Cedar Rapids could have ended in tension. Likewise, the tension in Des Moines, under a different timeline and with different variables, could have ended up with collaboration.

Four Conditions for Successful Natural Infrastructure Implementation

Implementation of natural infrastructure requires more than a strong and trusting relationship among stakeholders. From analyzing the success of the MCPP, four main conditions were identified as the keys for successfully implementing the natural infrastructure.

First, **firm trust in collaborative networks** are essential to the prosperity of collaboration. As a city highly dependent on agricultural commodities, the City of Cedar Rapids has built a strong agricultural alliance and network with agricultural organizations, environmental groups, and farmers. This stable relationship enables stakeholders to build a highly trusted network and allows them to collaborate and leverage new ideas or implementation strategies. Additionally, the Middle Cedar River Watershed was involved in the IWA. The IWA is a state-wide approach, targeting watersheds, led by the University of Iowa Flood Center. Thus, the City of Cedar Rapids can also collaborate with academic institutions to reduce downstream flooding and improve water quality. On another side, potential collaboration partners are also available with the Iowa Drainage Districts Association (IDDA). The IDDA has abundant outreach experience and could identify those willing to adopt natural infrastructure among Iowa's farmers; and it also has facilitated the adoption of natural infrastructure in the late adopters. Drawing on this strong and extensive collaborative network, the MCPP was able to deliver technical and financial assistance, and cost-sharing options to farmers.

Second, **good timing of political support** is important. As stated above, the MCPP project was proposed and began after the DMWW lawsuit was announced, which is suspected to be a large motivator of the creation of the project. Along with this, the call for more effective water quality management had been growing stronger and stronger in the state since the MCPP was proposed. This was a result of several environmental headlines breaking within the state. First, in 2016, the Iowa

Environmental Council published "Nitrate in Drinking Water: A Public Health Concern for All Iowans", which reviewed findings of research conducted in Iowa, the U.S. and abroad found that nitrate in drinking water was associated with several birth defects, bladder cancer, and thyroid cancer (Iowa Environmental Council, 2016). Immediately after this report was released, the EPA sent an official letter to the Iowa DNR, stating that the state was violating federal Clean Water Act regulations (Nemes, 2017). All of these events could be seen as large motivating factors to push the project forward.

Third, **stable and long term funding in both federal and individual levels** is crucial. In 2013, the United States Department of Agriculture (USDA) made RCPP funding available through a special application to support the establishment of the MCPP. The MCPP project has leveraged $2.3M in contributions from 16 MCPP partner organizations, and has been secured a $2M grant through the USDA-NRCS as part of the RCPP. A total of $4.3M in grants were secured throughout the five-year Middle Cedar Partnership Project. The Middle Cedar River Watershed was identified as a priority watershed under Iowa Nutrient Reduction Strategy in 2013. In 2013, the statewide Water Quality Initiative (WQI) selected five HUC 12s in the Middle Cedar River Watershed for the initial implementation of projects aimed at improving water quality.

The final condition for success was **hiring an experienced professional** in a long-term position who is skilled at building relationships with different demographic groups. For example, the city of Cedar Rapids hired watershed coordinators experts for facilitating the collaboration conservation. A part of project funding has been well organized to invest in people and positions. The MCPP hired experienced water, soil, agricultural experts as watershed coordinators, who assisted in exploring and expanding relationships and facilitating collaboration.

Another aspect that must be considered is the fact that those who hold positions of power regarding natural infrastructure implementation do not reflect the demographics of those who are affected by these issues. Interviewees have stated that POC are not prominent at the agency levels, small growers and minority farmers in Iowa are not consulted about collaborative plans, and the poorest communities are not surveyed about how they are affected by these issues. **Ensuring that inclusion and equity are present** in this process are essential in future projects regarding natural infrastructure implementation.

The implementation of natural infrastructure is an expensive and time consuming process, however, both sets of interviewees agreed that we are all winners after the successful implementation of natural infrastructure, as the positive results can be seen for all stakeholders. Therefore, a relationship that allows for natural infrastructure implementation would be a mutually beneficial relationship. Natural infrastructure implementation is more likely to become common practice when positive stakeholder networks exist and lines of communication are open.

CHAPTER IV

POLICY OPPORTUNITIES FOR IMPLEMENTING NATURAL INFRASTRUCTURE IN IOWA

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EXECUTIVE SUMMARY

Natural infrastructure (NI) implementation provides co-beneficial solutions to Iowans throughout the UMRB as it is an investment in the water quality and quantity of the river basin. Institutional change often leads to durable, long-term change and is facilitated through policy. Therefore, this chapter provides results and recommendations for policy reforms and initiatives that can facilitate the implementation of natural infrastructure.

Methods

We conducted 13 interviews with stakeholders from Iowa. The interviewees were selected based on EDF referral, their expertises in the field, and by a review of key organizations working in the field of natural infrastructure. Interviewees were asked a variety of questions semi-structured interview guides **(Appendix C2)**. For example, interviewees were asked what in their opinions were the impactful policies, initiatives, and stakeholders in the natural infrastructure space, what are the biggest barriers to policy reform, and which stakeholders were currently being excluded from the decision-making process. The interviews were then transcribed, de-identified, and coded into NVivo for analysis to identify common themes and patterns from the interviews. We also reviewed previous policy analysis conducted by EDF and Purdue researchers.

Results

Based on the NVivo analysis, five main policy themes were identified from the interviews conducted. These themes include: reducing administrative barriers to natural infrastructure implementation, incentivizing long-term planning & funding, facilitating coalition building and trust building, prioritizing environmental justice, and capitalizing on Farm Bill opportunities coming with the change in administration and Democratic control of Congress.

Reduce Administrative Barriers to Natural Infrastructure Implementation

We found agreement that the current system has too many administrative hurdles. Process redesigns should include (1) re-evaluating federal requirements for conservation programs and practices, and (2) reviewing the accessibility of information on federal program's websites for clarity, transparency, and navigability. Additionally, the U.S. Army Corps of Engineers (USACE) should develop a nationwide permit (NWP) to have a similar low barrier permit process like that of gray infrastructure. Moving forward, the federal discount rate should reflect equitable assessments of long-term investments rather than favoring lower up-front costs.

Incentivize Long-Term Planning & Funding

Without secured long-term funding, there can be no long-term planning. Therefore, funding cycles for natural infrastructure grants should be extended and additional funding sources should be established to diversify funding sources. Additionally, federal and state agencies should reorient their mindset to proactively prepare for oncoming extreme events. Reactionary policies such as FEMA do not currently allow for increased resiliency of rebuilt structures. Finally, practice incentive payments (PIP)

and other economic incentives for conservation among producers should be increased as a part of Biden's 30 by 30 plan (The White House, 2021).

Facilitate Coalition Building and Trust Building

The adoption rate of new NI policy by practitioners will likely continue to remain low until major groups from the agricultural community endorse natural infrastructure practices. To build coalitions of diverse actors in Iowa, message framing and tools like a collaboration directory will be pivotal. Messaging about NI should be inclusive of all actors and not imply regulative authority. A collaboration directory would be a relational database that increases transparency of communication, ensuring all the key stakeholders are aware of collaboration efforts and equipping farmers and practitioners with a starting point to gain more information and resources.

Prioritize Environmental Justice

15% of Iowa's population are POC with over 500 farmers of color (USDA, 2017). Moving forward, awareness of social vulnerability and EJ issues within Iowa needs to increase among decision-makers. Then, priority should be placed on implementing natural infrastructure in socially vulnerable communities to increase their disaster and climate resiliency. Additionally, the Farm Bill EQIP program that supports underrepresented groups with upfront subsidies should be evaluated for lessons learned and best practices for similar initiatives.

Capitalize on Farm Bill Opportunities Coming with the Change in Administration and Democratic Control of Congress

The Farm Bill continues to pose a significant barrier to natural infrastructure as there are only limited incentives or signals for long-term priorities for natural infrastructure (7% of the overall budget) (Congressional Research Service, 2019). Congress should increase tax incentives and federal subsidies for practitioners and ag retailers that implement natural infrastructure practices such as Iowa native plants and perennials for in-field cover crops and edge-of-field buffer strips. Additionally, natural infrastructure messaging should address environmental justice issues through the EPA's Justice40 initiative scorecard to highlight how investments are relevant to environmental justice (The White House, 2021).

Implications

Natural infrastructure has proven to be a viable option to address the pitfalls and environmental degradation that gray infrastructure, nutrient loading, and climate change produces. By addressing the barriers presented, capitalizing on current policy levers, and investigating the policy opportunities presented, stakeholders will be more able to implement natural infrastructure in Iowa. Overall, these recommendations will reduce environmental hazards, increase the ecological health of Iowa, and improve the quality of life for all Iowans.

Acronyms

Building Resilient Infrastructure and Communities (BRIC)
Conservation Activity Plan (CAP)
Cost-Benefit Analysis (CBA)
Communities of Color (COC)
Environmental Quality Incentives Program (EQIP)
Federal Emergency Management Agency (FEMA)
Interagency Working Group (IWG)
Natural Resources Conservation Service (NRCS)
Nationwide Permit (NWP)
Memorandum of Understanding (MOU)
People of Color (POC)
Practice Incentive Payments (PIP)
Socially Vulnerable (SV)
Sustainable Iowa Land Trust (SILT)
Technical Service Provider (TSP)
U.S. Army Corps of Engineers (USACE)
Upper Mississippi River Basin (UMRB)

Purpose

As an investment in the water quality, flooding mitigation, and environmental health of Iowa, natural infrastructure provides co-beneficial solutions to Iowans throughout the Upper Mississippi River Basin (UMRB). Through qualitative research methods and interviews with professionals implementing natural infrastructure in Iowa, this chapter provides results and recommendations for policy reforms and initiatives that can facilitate the implementation of natural infrastructure. By addressing these gaps in Iowa's current policies with natural infrastructure solutions, it will effectively improve the quality of life for all Iowans, reduce environmental hazards, and increase the ecological health of Iowa.

Methodology & Prior Research

Interviews with Stakeholders in Iowa

Selection of Interviewees

The research team conducted interviews with Iowan stakeholders (**Table 1**) to gain their insight about policy barriers and opportunities in the state for natural infrastructure implementation. The initial set of interviewees were identified through recommendations from EDF and by a review of organizations and agencies currently working in the natural infrastructure space (or related fields) in Iowa. This list of interviewees was built upon utilizing snowball sampling by asking the interviewees to recommend other individuals or groups for interviews, resulting in a total of 13 interviews. Interviewees were asked to participate via email. The recruitment email draft can be found in **Appendix C1.**

Table 1. The summary of policy interviewees' organizational types

Organizational Level	Organization Type	Number of Interviewees
National	Non-profit	1
State	Government	4
	Non-profit organization	4
	Research Institution	3
Local	Private	1

Interview Guide Development

The interviews were semi-structured. Each interview was conducted using the same interview guide (see **Appendix C3**) and the semi-structured nature allowed for questions to be built upon and tailored to the individual interviewee. The interview guide was developed based on a review of previous work related to natural infrastructure adoption. The interview questions came from 3 core themes: water issues, natural infrastructure opportunities and barriers, and specific policy questions (i.e. policies that are most beneficial or detrimental to natural infrastructure adoption).

Interview Analysis Methods

After the interviews were conducted, the team transcribed the interviews utilizing a combination of the transcription services provided by Zoom and Canvas. The transcripts were then edited for spelling and de-identified to ensure the anonymity of the interviewees. Next, the transcripts were uploaded to NVivo for analysis. The interview transcripts were coded with the codebook detailed in **Appendix C3**. This codebook was developed based on the interview questions and was used to identify patterns and themes across the transcripts.

Building on Previous Analysis

After the common themes and patterns from the interviews were identified, these findings were combined with the previous analysis conducted by the McLellan et al. and Helmer et al. research. To combine the results of these previous studies and this body of research, team members identified key findings from McLellan et al. and Helmer et al. reports and cross referenced them with the key themes and patterns identified by the interviews conducted. Over the past year, Environmental Defense Fund has commissioned two reports with recommendations on improving the UMRB through natural infrastructure. These reports are *Mitigating Flood Risk and Improving Water Quality in the Upper Mississippi River Basin using Natural Infrastructure: Opportunities* (McLellan et al., 2020) and *Challenges* and *Identifying Structural Barriers and Motivations to Adopt Natural Infrastructure* (Hemler et al., 2020). By drawing on natural science, policy, and social science perspectives, these reports assess the opportunities and challenges for natural infrastructure practices in the UMRB.

The teams who conducted this research did so through literature reviews, a series of case studies, and by using focus groups. The policy section of the reports provide; an overview of a variety of policies related to natural infrastructure, identifying reforms to existing policies, opportunities to leverage, and barriers to implementation throughout (Hemler et al., 2020; McLellan et al., 2020). This aspect of the project bolstered previous studies qualitative interview methods to glean insights from both professionals and practitioners on the ground. Individual interviews are an effective method to understand the diverse perspectives and experiences of various stakeholders. Our objectives were to understand (1) the landscape of opportunities and barriers of existing natural infrastructure policies and programs, and (2) the decision-making considerations of stakeholders. The resulting five policy recommendations of the combined research are covered in detail in the section below. The recommendations incorporate past findings, build on a year of tumultuous political climate, and contextualize implementing natural infrastructure in Iowa through the addition of quantitative SVI and Hydric Soil research that supports environmental justice policy interventions.

Policy Recommendations

Based on the recurrent themes from the interview results and the review of previous analysis, the following recommendations were developed: (1) reduce administrative barriers to NI implementation, (2) incentivize long term planning and funding, (3) enable coalition building and trust building, (4) prioritize environmental justice, and (5) capitalize on the opportunities coming with the change in administration. Each of these recommendations includes details about their associated barriers, opportunities, and levers. We define (a) an opportunity as a new policy, program, relationship, or tool that should be created and (b) a lever as an existing policy, program, relationship, or tool that should be leveraged for increased natural infrastructure implementation. The ultimate goal of our project was to approach conflict and competing interests with a neutral view. Therefore, this report contains recommendations on how best to accomplish natural infrastructure outcomes that benefit all.

Reduce Administrative Barriers to Natural Infrastructure Implementation

Barriers

In order to receive approval for implementing a natural infrastructure practice under many federal programs, producers must undergo a lengthy technical process that often requires creating a conservation plan and/or gaining engineering approval. The length of the process (often multiple years from indication of interest to breaking soil) and the program requirements are a deterrent to the adoption of natural infrastructure.

> *"I would say there are also impediments in terms of the red tape that farmers have to go through to access funding ... We make farmers and partners jump through too many hoops to actually get practices installed on the ground."* (Personal Interview, 10/15/2020)

For a federal level example of how the approval process impedes natural infrastructure adoption, the Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) is a voluntary program that provides funding for farmers to implement conservation practices. EQIP requires the development of a conservation activity plan (CAP) with a technical service provider (TSP), a third party (USDA Natural Resources Conservation Service, 2020). These requirements increase the time and effort for obtaining approval. In comparison, the process for implementing gray infrastructure through nationwide permit (NWP) 40 for agricultural activities, which includes the construction of drainage tiles and levees, is shorter than the process for EQIP approval to implement natural infrastructure. To obtain NWP 40 approval from the U.S. Army Corps of Engineers (USACE), the permittee only needs to submit a permit application and pre-construction notification which is then reviewed by a district engineer (U.S. Army Corps of Engineers, 2021).

An additional federal administrative process barrier is the selected discount rate for cost-benefit analysis (CBA) of potential projects. The discount rate determines the value of present benefits and costs versus the value of future benefits and costs. Higher discount rates place lower value on future benefits and costs, while lower discount rates place higher value on future benefits and costs. Most federal programs have used a 7% discount rate since 1992 (Congressional Research Service, 2015). The current discount rate favors low up-front cost projects which can be detrimental to sustainable development. This temporal valuation is inherently problematic given that the issues of the climate crisis are going to increase in the future. Utilizing a higher discount rate creates an ethical dilemma where current generations are valued more than future generations. To further complicate matters, U.S agencies typically do not consider distributional impacts across the population in CBAs, therefore CBAs do not consider equity within the present population (Fleurbaey & Abi-Rafeh, 2016).

Opportunities

By emulating ecological, biological, and chemical processes, natural infrastructure practices offer a multitude of benefits, including climate resiliency, that gray infrastructure cannot (for a review of the natural infrastructure benefits see the introduction section). Therefore, NRCS and USACE should ensure that their program and permitting requirements do not favor traditional gray infrastructure practices over natural infrastructure practices in terms of both stringency and accessibility. This can be accomplished by (1) re-evaluating their requirements for conservation programs and practices and (2) reviewing the accessibility of information on their websites for clarity, transparency, and navigability. An added benefit of this review is that the process timeline for natural infrastructure implementation will likely be reduced.

Levers

The USACE could create NWPs pertaining to natural infrastructure to reduce the time and capacity stakeholders currently spend applying for individual project permits. This would reduce barriers for natural infrastructure implementation and reduce the difference between how gray and natural infrastructure are valued. Additionally, NRCS could leverage their existing relationship with TSPs to streamline the application process and remove a barrier for their conservation programs. Currently, a stakeholder loses eligibility for EQIP funding if they've contacted a TSP prior to NRCS. The stakeholder must be put in contact with the TSP through NRCS channels. By removing this requirement, TSPs could provide outreach for NRCS as well as technical assistance for stakeholders. The TSP could also help the stakeholder navigate the various NRCS programs to find a suitable match.

To prioritize investments in climate adaptation and resiliency projects like natural infrastructure practices, the federal discount rate should be lowered. By lowering the discount rate, future benefits and costs will be valued over current benefits and costs, a fitting valuation for combatting the climate crisis.

Incentivize Long-term Planning and Funding in Federal Programs

Barriers

Without secured long-term funding, there can be no long-term planning. Many conservation programs have funding for limited periods of time, often as one-year, three-year, and five-year programs. This limits programs to either short-term goals or slow progress, neither of which are suitable for the scale of Iowa's flooding and nutrient pollution issues. Funding cycles for conservation programs should be extended to allow for long-term planning. Additionally, short term funding prohibits the necessary trust building between stakeholders. For example, watershed coordinators operate on three-year grant cycles and are responsible for securing their own funding. This point was discussed by many of our interviewees as demonstrated by this quote:

> *"It's the funding mechanism for Watershed Management Authorities. It's a three-year grant funded position … You can't build a relationship in three years … if the grant renews, you're there for another three years, but that's not a commitment to a community. That is not a commitment to building relationships."* (Personal Interview, 10/07/2020)

Another barrier to long term planning stems from reactive policy-making and funding measures. The reactionary mindset these policies and programs stem from is detrimental to building climate resilience. With the increasing urgency of the climate threat, federal and state agencies should reorient this mindset to proactively prepare for oncoming extreme events. For example, the Federal Emergency Management Agency (FEMA) offers exemptions for properties within the floodplain and allows for properties to be rebuilt after a disaster, but only to the value of the damaged property. This allows for properties to be rebuilt in flood-prone areas, but does not allow for properties and infrastructure to be built back with resiliency to future disasters. Furthermore, limiting the value of protection unjustly prioritizes protecting higher income households over lower income ones (Wilensky, 2019).

Opportunities

The Farm Bill currently does not have robust conservation initiatives. This is in part because the Trump Administration cut back on many programs (McLellan et al., 2020) and in part because of the lack of priority given to conservation in past bills. Therefore, to build back existing conservation programs, the Biden Administration should reinstate the incentives and programs cut by the previous administration. For example, through discretionary cuts the Trump Administration reduced practice incentive payments (PIP) for producers from 40% to 5%[4]. To prioritize conservation in the 2023 Farm Bill, the Biden Administration should pair its "30 by 30" conservation initiative, which seeks to place 30% of U.S. land into conservation practices by 2030, with new federal programs for conservation in agriculture.

Levers

FEMA's new Building Resilient Infrastructure and Communities (BRIC) program is a cost-share program to fund communities' infrastructure planning and capacity building (Federal Emergency Management Agency, 2021). BRIC prioritizes socially vulnerable communities. This prioritization should extend to Communities of Color (COC). Because the BRIC program provides funding for planning and capacity building for socially vulnerable communities, it is a long-term investment in those most vulnerable to climate change and extreme events. This program should be used as a model for policies and programs in other agencies that are seeking to accomplish conservation, climate adaptation, and environmental justice.

Facilitate Coalition Building and Trust Building

Barriers

Natural infrastructure adoption will likely continue to remain low until major groups from the agricultural community endorse natural infrastructure practices. For example, 50% of interviewees identified the Iowa Farm Bureau as the largest barrier to natural infrastructure implementation, due to their significant political clout within the agricultural community. While the Iowa Farm Bureau did collaborate in the MCPP included in the case study section of this report, NGOs and EDF should explore additional opportunities to onboard members of the agricultural community. To address this issue, collaboration initiatives that allow all stakeholders an equal voice for policy solutions and compromises should be created around a common goal: improved water quality and reduced flooding.

Based on response from interviewees, when agricultural groups feel as if they are having regulations imposed on them, they are likely to push back or disengage. For example, the Watershed Management Authority programs are poorly perceived in some local areas because of the connotation of the word "authority."

> *"And people in the city of Ames said, we are going to have this Watershed Management Authority. They said okay farmers up in the watershed, come and learn about the Watershed Management Authority. Well, the feedback was don't do it that way. You need to engage those groups so that they feel a part of it. Because when you already say, 'we have this Watershed Management Authority...authority over what? So, it raises questions." (Personal Interview, 11/02/2020)*

Through less regulatory language and project onboarding NI advocates can encourage engagement from the agricultural community from occurring. For example, **a program that is framed around sustainably maximizing yields would speak to the interests of the agricultural community and may be an inroad to more stable collaborations with farmers in the future.** However, economic incentive policies such as subsidies on native perennials for buffer strips should be pursued in tandem with coalition building efforts to appeal to the interests of practitioners and make natural infrastructure implementation a viable option economically as well.

Opportunities

While building trust and collaboration with the agricultural community is a significant project for increasing NI implementation, even groups who are actively supporting NI may have trouble getting plugged into NI initiatives. Navigating the sheer volume of organizations that have some hand in the process of implementing natural infrastructure in Iowa takes significant time and energy. A project that could help foster collaboration in the future would be to create a **collaboration directory**. This directory would show what categories of actors are involved in what levels and in which areas of Iowa. For example, this program might be owned by the Iowa land-grant college, Iowa State University, and could leverage extension offices to collect information about local groups actively supporting natural infrastructure. Through survey inputs, members of the directory would be able to designate key search terms associated with their organization and specify what policy priorities and collaboration opportunities in which they are most interested. Other organizations in academia have already made efforts to establish similar directories such as the Vermont Biomedical Research Network, which seeks to incentivize collaborative biomedical research (Vermont Idea Program Collaboration Directory, 2021). Within the agricultural community, there is the Agriculture Network Information Collaborative, founded in part by Iowa State University's Dr. Nancy Eaton in 1995, but this program is focused more on collaboration between libraries to aid research in different agricultural issues (AgNIC, 2021). Having a relational database focused on action instead of strict research would increase the transparency of communication, ensure that collaboration projects in the future have all the key stakeholders, and equip farmers and practitioners with a starting point to gain more information and resources.

Levers

In order to build trust among stakeholders, educating all parties on what natural infrastructure practices are and how they appeal to various stakeholders' interests will be essential. The Practical Farmers of Iowa are an example of a group that is actively trying to educate practitioners on the importance of natural infrastructure practices through farmer field days (Practical Farmers of Iowa, 2021). These field days are hands-on learning opportunities for farmers to gain first-hand experience learning about in-field and edge-of-field natural infrastructure practices. These field day programs should be expanded in the future to include landowners and non-farming citizens as well. With the help of a collaboration directory, this type of knowledge-sharing would be more transparent among stakeholders as all parties could be easily contacted and onboarded to promote field day education programs and other knowledge sharing resources.

Prioritize Environmental Justice

Barriers

When asked about how prominent questions of racial and economic justice are in water policy discussions: 50% of interviewees stated they were not very prominent, 35.7% said that Iowa was not a diverse state, and 35.7% said there was a growing interest to address racial and economic justice. The notion that Iowa and its producers are not diverse is evidence of the lack of representation of historically marginalized groups such as People of Color (POC). In fact, only 85% of Iowa's population identifies as white with 4.1% identifying as Black, 2.7% as of Asian descent, 0.5% as Native American, 0.2% as Native Hawaiian or Pacific Islander, 6.3% as Hispanic or Latino, and 2.0% as two or more races (US Census Bureau, 2019). It is important to note that poverty rates for this 15% of the population is drastically higher than it is for Iowa's white population: 32.3% for African Americans, 14.7% for Asian Americans, 18% for Latinx, 24.1% for Native Americans, while only 9.3% for the white population (Talk Poverty, 2018).

Additionally, 0.37% of Iowan producers identify as POC (USDA National Agricultural Statistics Service, 2017). While this may seem to be a small percentage it represents over 500 Iowan producers. As Iowa's population grows and becomes increasingly diverse, so will its producers. The lack of awareness of the existence of POC in Iowa and the lack of their representation in decision-making spaces across all levels of government contributes to their erasure. This lack of awareness amongst stakeholders and decision-makers can lead to policies and programs that perpetuate or exacerbate inequalities.

Opportunities

There are two priorities for incorporating environmental justice into natural infrastructure policy in Iowa: (1) rectify past injustices and (2) prevent future injustices. In this first aspect, decision-makers need to have an increased awareness of social vulnerability and environmental justice issues within their state. To accomplish this in Iowa, the Iowa Civil Rights Commission in partnership with Iowa's Economic Development Authority should undertake an educational effort to inform the Iowa Legislature as well as state agencies about the state's demographics. This effort could take place in conjunction with required annual diversity training.

Then, priority should be placed on rectifying past injustices by implementing natural infrastructure in socially vulnerable communities to increase their disaster and climate resiliency. Federal and state agencies should utilize the social vulnerability (SV) methodology documented in Chapter II of this report to target socially vulnerable communities with natural infrastructure practices in order to mitigate their exposure and build their resiliency. In Iowa the SV methodology could be paired with S.F. 512, a water quality bill that passed in 2018, to prioritize watersheds. S.F. 512 has the potential to greatly improve water quality in the state by creating two water quality agriculture infrastructure programs and an excise tax to support the programs (Iowa General Assembly, 2018). However, the act does not currently identify priority watersheds.

Another opportunity for rectifying past injustices is to create new federal programs that provide opportunities for historically marginalized groups. In the 2018 Farm Bill, EQIP was updated to allow "historically underserved participants [to be] eligible for advance payments to offset costs related to purchasing materials or contracting through EQIP" (USDA Natural Resources Conservation Service, 2020). As this option has been available for three years now, the program should be evaluated for lessons learned and best practices. These insights then should be applied to create similar programs and opportunities for historically marginalized groups.

To prevent future injustices, the representation of POC needs to be improved in all levels of decision-making. This could be accomplished by creating policies to diversify representation by requiring membership across sectors and geographic regions with measures taken to guarantee that the decision-making body accurately represents its corresponding population. Additionally, the barriers to participation, such as limited time and resources, must be removed. For example, a portion of funding could be dedicated to compensating stakeholders for their time, their travel expenses, or to providing child care during meetings.

Levers

Incorporating environmental justice in federal agencies is not new. Executive Order 12898, which was signed by President Clinton in 1994, directed federal agencies to create environmental justice strategies and created the Interagency Working Group (IWG) on Environmental Justice (The Executive Office of the President, 1994). In 2011 the IWG, established a Title VI Committee to "address the intersection of agencies' environmental justice efforts with their [Civil Rights Act] Title VI enforcement and compliance responsibilities" (U.S. Environmental Protection Agency, 2021). Title VI of the the Civil Rights Act which prohibits discrimination based on race, color, and national origin while the Executive Order 12898 mandates that federal programs "consider [the] disproportionately high adverse human health and environmental effects on minority and low income populations" (U.S. Environmental Protection Agency, 2021). Additionally, in 2011, seventeen federal agencies signed a Memorandum of Understanding (MOU) to rededicate themselves to environmental justice and the objectives outlined in Executive Order 12898 (U.S. Environmental Protection Agency, 2011). These seventeen federal agencies should work to further develop their environmental justice strategies and additional agencies should sign the MOU to signal their commitment to historically marginalized communities. These two actions would strive to prevent future injustices.

Another lever for environmental justice is through local movements and community organizing. For example, Middlebrook, Iowa is an 'agrihood', or town farm (Eller, 2019b). Conceptualized by Steve Bruere, this agrihood is built on 400 acres, and is an organized community that integrates agriculture into a residential neighborhood in order to facilitate food production while at the same time providing beauty, environmental protection, and recreation to members of the community. Through incorporating agriculture and other land uses into what would typically be a standard suburb, the community utilizes natural infrastructure in order to reduce both urban and rural runoff while reducing flood risk in the neighborhood. This kind of community organizing can give people, who normally would not have a voice on land use issues, a way to become involved and invested in solutions to flood risk and nitrogen pollution.

Additionally, the Sustainable Iowa Land Trust (SILT) was founded in 2016 with a mission to permanently protect Iowa land to grow “nature-friendly table food” (SILT, 2021). Since its inception, SILT has helped to protect 12 small farms totaling 1,085 acres across Iowa, and is a partner with Middlebrook. SILT also offers long-term leases that farmers can pass on as long as the family members inheriting the land want to farm the land sustainably, creating generational farms that have implemented natural infrastructure solutions.

Capitalize on Farm Bill Opportunities Coming with the Change in Administration and Democratic Control of Congress

Barriers

The Federal Farm Bill is a large piece of legislation ($867 billion in 2018) and sets the policy priorities for the entire agriculture community in the United States (Stein, 2018). Of that $867 billion, only 7% of the overall budget was tied to conservation initiatives (Congressional Research Service, 2019). Additionally, this piece of legislation is dense and difficult to navigate, with the 2013 Farm Bill being 959 pages long (Kurtz, 2018). There are a myriad of groups with interest in the bill, which means it is highly susceptible to “rider” clauses and lobbyist funding. In 2008, lobbyist groups from across the political spectrum spent 173 million to influence the policies of the 2008 Farm Bill (Food and Water Watch, 2016). In 2017, it was the 4th most lobbied bill in Congress with 500 different lobbyist groups advocating for some addition or subtraction from the bill (Evers-Hillstrom, 2019). Since there are competing interests among lobbyist groups, as EDF coordinates their Farm Bill lobbying strategy, the issues disaggregated below should be considered high priority for NI implementation. Additionally, with a tenuous majority in the Senate, lobbyists’ ability to target politicians who may be on the fence about policies will be elevated. An example of a potential target is democratic Senator Joe Manchin (WV), who has already signaled that he may not vote party lines on key legislation (ProPublica, 2018).

These factors contribute to seven main issues with the Farm Bill: (1) Complexity & lack of transparency, (2) Insufficient financial incentives, (3) Outreach & enrollment, (4) Design, siting, construction, & maintenance issues, (5) Red tape, uncertainty, delay, and lack of predictability, (6) Permits, and (7) Lack of consistent leadership signal (McLellan et al., 2020). With a change in the make-up of Congress (Democratic majority) and a new Farm Bill on the horizon (2023), significant resources should be devoted to address these issues in the Farm Bill. While addressing all of these issues would increase overall support for conservation initiatives within the Farm Bill, focusing on tax incentives and subsidies for NI practices would result in more immediate benefits for NI implementation.

Opportunities

President Biden is governing during a time of heightened party politics and party line voting. Due to this increased partisanship of Representatives and Senators, environmental issues serving as a key platform point for the Biden campaign, and a Democratic majority in the House of Representatives and the tie-breaking vote in the Senate, the conditions are right for significant environmental legislation to be passed during this administration. In other words, the political will for environmental policy will likely increase due to the prominence of climate change on Biden's platform for Democrats. However, a majority of the top 10 congressional districts that represent agricultural interests (Iowa, Kansas, Minnesota, Missouri, Montana, Oklahoma, and North Dakota) have Republican representatives in Congress (Beck, 2019). Party dividing lines have been especially stark on the issue of climate change, for which agricultural adaptations for resilience such as natural infrastructure may be framed. Therefore, crafting sustainable farming policy that speaks to the interests of the agricultural community may build bipartisan coalitions that will increase the likelihood of NI implementation.

With this change in administration, there will be an increased number of opportunities for natural infrastructure jobs and investments from the executive branch. Notably, Biden has already committed under Executive Order the Justice40 Initiative. Justice40 is a commitment to ensure that 40% of renewable energy federal investments directly benefit impoverished communities that face environmental justice issues through an environmental justice scorecard (The White House, 2021). **Therefore as EDF and other NGOs supportive of NI implementation apply for federal funding for projects, they should frame their messaging and initiatives around how natural infrastructure addresses issues of environmental justice.**

Additionally, Biden has started to address racism within the agricultural community through overhauls of the USDA. In the last century, African American farmers have decreased from 14% of farming operations to 2% (Cho, 2021). To address this, the USDA will likely provide additional subsidies and support for farmers who have been traditionally discriminated against (Cho, 2021). Finally, the Biden administration has created an Environmental Justice Screening Tool (EJScreen) that will be monitored by the EPA (The White House, 2021). **The social vulnerability**

framework presented in Chapter II of this report should be used in tandem with this screening tool to identify and effectively address issues of environmental justice within Iowa.

Levers

While the Federal Farm Bill poses significant barriers to natural infrastructure implementation, it also is a policy lever that should be capitalized on to ensure the success of natural infrastructure policies. The Farm Bill provides not only financial support and incentives to the agricultural community but also sets long-term priorities in agricultural policy. **The Farm Bill should increase tax incentives and federal subsidies for farmers and landowners that implement natural infrastructure practices.** These incentives could include tax breaks for farming operations that implement edge of field buffer strips or increase in-field cover crops that reduce the amount of nitrate leaching into river systems. By signaling NI support in the Farm Bill, farmers and practitioners will view NI practices as long-term priorities for farming operations and emphasize the importance of not only maximizing yield but also sustainable farming.

Additionally, the Farm Bill should increase subsidies for agricultural retail companies that sell Iowa native plants and perennials for in-field cover crops and edge-of-field buffer strips. Through incentivizing these practices in agricultural retail, it will increase positive exposure to NI practices with a trusted source for farmers and practitioners. As a result, NI practices may become more normalized among farm operations. This bifurcated approach of incentivizing these practices at both the practitioner and retail level will signal the long-term priority of implementing natural infrastructure practices.

Conclusion

The recommendations stated above are the culmination of 13 interviews with Iowan stakeholders, a year of tumultuous social and political action, and turnover in executive and legislative leadership at the federal level. There is reason to believe that there are a multitude of opportunities for progress on issues of the environment and justice. If implemented, these recommendations would lead to increased natural infrastructure implementation with a focus on equity, justice, and accessibility.

CHAPTER V
PRIORITIES FOR FUTURE NATURAL INFRASTRUCTURE RESEARCH AND ADVOCACY

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Introduction

The objective of this chapter is to (1) identify the key insights from each chapter; (2) discuss their connection(s) with policy; and, (3) propose priorities for future natural infrastructure research and advocacy.

Using the Hydric Soil Proxy

In Chapter I, the 90-100 hydric soil (HS) categories were proven to be an effective proxy for identifying restorable wetland locations. The general applicability of the hydric soil proxy can be utilized to achieve the first policy recommendation from Chapter IV - Reduce administrative barriers to natural infrastructure implementation.

The hydric soil proxy has the potential to shorten the process to identify locations for wetland restoration and to reduce the costs associated with this process. According to the annually updated and public National Soil Information System (NASIS) database (USDA, 2019), hydric soil data is not difficult to obtain and process utilizing GIS tools. Compared to the price and required reporting time of the current wetland identification processes, such as the Wisconsin DNR's Wetland Identification Program (Wetland Identification Program, 2021), the hydric soil proxy provides more flexibility during the location identification and data processing steps as well as reduces analysis costs. In comparison, running a simple operation for HS in a state requires less than 30 minutes of operation time in ArcGIS with the publicly available spatial data layers of hydric soil and state boundary prepared ahead. Utilizing the hydric soil proxy for wetland location identification is an easier approach and employing the publicly available GIS data can shorten the processing time and reduce costs. Furthermore, applying the hydric soil proxy will reduce the overall implementation process for natural infrastructure. Therefore, wetland restoration programs should begin to apply the hydric soil proxy to expedite the identification process and reduce costs. While the hydric soil proxy is able to identify restorable wetland locations for both agricultural and residential land uses, the proxy is more suitable for agricultural lands.

Wetland restoration programs should prioritize applying the hydric soil proxy on agricultural lands. The hydric soil proxy results show that certain land use types, such as agricultural land, natural land (including hay/pasture, herbaceous, shrub/scrub, and forest), and lands near water bodies (including open water, woody wetlands, and emergent herbaceous wetlands), have a greater restorable possibility than residential regions and barren land. Since cropland, forestland, pastureland, and rangeland are the dominant land uses in the United States (USDA, 2021), applying the hydric soil proxy will be useful to quickly select potential locations for wetland restoration on agricultural lands, facilitating natural infrastructure implementation by displaying a variety of restoration possibilities and ecological benefits.

According to the suitability evaluation of the hydric soil proxy, it is more difficult to identify possible restorable wetland locations in residential areas. This difficulty stems from the need to relocate homes and businesses to implement a larger natural infrastructure practice. Therefore, it is essential to collaborate among stakeholders including city governments, homeowners, and business owners to successfully implement natural infrastructure in residential areas but not damage the interests and rights of residents. Smaller natural infrastructure practices such as permeable pavement and driveways, green roofs, rain gardens, and etc are more easily implemented in residential areas (NOAA, 2021).

Several interviewees mentioned that there is minimal public land in Iowa. In total the state has 36 million acres of land. Of that total, 85% or more than 30 million acres of Iowa's land is farmed. Iowa ranks 49th in land owned by the federal, state, or local government with only 1% of overall lands being public (Sierra Club Iowa Chapter, 2020). The hydric soil proxy can help identify critical areas of land that would be most beneficial to restore, enabling the land to provide sustainable benefits for all. These lands would contribute to flood and/or nutrient management and could provide recreation services.

Overall, the hydric soil proxy can shorten the planning process and reduce costs. The cost reduction will increase the funding available for other budget items such as hiring a watershed coordinator for stakeholder engagement. Additionally, the cost reduction will increase the accessibility and attainability of natural infrastructure practices for smaller organizations and agencies who cannot afford to utilize the current process. The shortened process will likely lead to increased retention of stakeholders who are interested in adopting natural infrastructure practices, but are discouraged by the lengthy processing time of current methods. Given the benefits of utilizing the hydric soil proxy, natural infrastructure advocacy organizations should adopt this tool to identify potential locations for wetland restoration.

Using a Social Vulnerability Framework

While it is regularly understood that farmers are at risk of negative health outcomes due to the environmental hazards that are in place in conventional farming

(Kirkhorn, 2001), the impacts created for communities downstream are rarely acknowledged. Moreso, it is rarely acknowledged or understood how much these environmental exposures differ between communities. Communities downstream - notably downstream of the Des Moines River - and the socially vulnerable are more likely to experience both flood risk and nitrogen pollution in Iowa. To address the disproportionate effects of flood risk and nitrogen pollution in socially vulnerable communities, policies should focus on: (1) prioritizing environmental justice; and, (2) capitalizing on Farm Bill opportunities coming with the change in administration and Democratic control of Congress.

There are two major points to be made when considering nitrogen pollution in Iowa's water system. First, it must be stated that there is a large amount of nitrite/nitrate pollution in the state of Iowa. Out of the 19,732 ground wells surveyed by the Iowa DNR between 2013 and 2018, 16,324 wells (82.73%) had anywhere between 0.01 and 9.99 mg/L of nitrite or nitrate, and 717 wells (3.63%) had over 10 mg/L (what the EPA considers dangerous) (Nitrate/nitrite Fact Sheet, 2021) of nitrite or nitrate. Second, the communities with the lowest percentages of white people (Story, Lee, Dallas, Webster, and Boone counties) were the ones that experienced the most nitrate pollution clustering. This finding means that there is a spatial correlation between Communities of Color (COC) and nitrogen pollution in Iowa, indicating that more nitrite/nitrate pollution is clustered in ground wells that are near to or overlap with COC.

At first glance, physical geography played a larger role in determining flood risk. There appeared to be a higher likelihood of flood risk either on the borders of the state or in rural areas, and risk was higher adjacent to the Des Moines, Cedar, Missouri, and Wisconsin Rivers. The northern Iowa zip codes that were at a higher risk of flooding were downstream of the Missouri River and the Wisconsin River. This means that proper river management and natural infrastructure implementation upstream may improve flood risk in these areas. When looking closer at flood risk trends in Iowa, it was also clear that certain social vulnerability characteristics were associated with flood risk. Particularly, single parent households were positively correlated with flood risk. In addition to this, there were positive correlations between nitrite/nitrate pollution and the number of people over 25 without a high school diploma, and those over age 65. These social vulnerability characteristics display that there is a social vulnerability factor related to environmental risk.

Future natural infrastructure programs should prioritize providing assistance to POC and seek to incorporate diverse voices, especially POC, in natural infrastructure decision-making and implementation. Future development priorities of natural infrastructure should consider the participation of socially vulnerable communities and COC in the decision-making process. The key to the overall success of natural infrastructure implementation is not reinforcement of the strengths, but improvement of the deficiencies. The focus on environmental justice enables the necessary reaching out to communities most in need and those in vulnerable environments, leading to stronger stakeholder networks and environments. To do that, each level of government and organization should deliberately open positions and equitable opportunities to COC.

An example of the way that environmental justice issues can be addressed through federal initiatives is through executive orders, such as Executive Order 14008 which created the Justice40 initiative (Executive Office of the President, 2021). This is a commitment to ensure that 40% of federal renewable energy investments directly benefit socially vulnerable communities, and its performance is tracked through the establishment of an Environmental Justice scorecard. (Executive Office of the President, 2021). This could be used as a template for sustainable agriculture policies on a federal level as well. Through implementing sustainable agricultural policies that create investments into natural infrastructure implementation on a large scale, and tracking its performance on reducing environmental risk in socially vulnerable communities through the use of an Environmental Justice scorecard, major changes could be made in the way that natural infrastructure is viewed and utilized in Iowa.

On a state and local level, legislatures can emphasize the importance of educational investments in equity and environmental justice and increasing diverse decision-making processes. Creating environmental educational opportunities can allow community-members to learn more about their environment and what causes flood risk and nitrogen pollution. An educational space would also allow for communities to come together, fostering diverse collaborations and bolstering relationships among stakeholders. To reinforce diverse collaborations with COC, governing bodies should be intentional about increasing representation among decision makers and reduce barriers for these groups by offering monetary compensation and/or child care during meetings.

Applying Lessons Learned from the Case Studies

The comparative analysis (Chapter III) identified the following items as conditions for success: (1) firm trust in collaborative networks, (2) political support,

(3) stable and consistent funding, and (4) involvement of experienced coordinators. When paired with the policy recommendations (Chapter IV), these conditions for success provide greater insights for future natural infrastructure research and advocacy. Specifically there is overlap between the conditions for success and the following policy recommendations: (1) incentivize long-term planning and funding, (2) enable coalition building and trust building, (3) prioritize environmental justice, and (4) capitalize on Farm Bill opportunities coming with the change in administration and Democratic control of Congress.

Consistent messaging and priority setting from the Biden administration on conservation can lead to increased implementation of natural infrastructure practices. The findings from the case studies indicate that political will and funding are key enabling conditions for successful collaboration. Since the Biden administration has placed a high priority on the environment and conservation, the time is ripe to obtain both political and financial support from the federal government, and potentially state and local governments that follow this signaling. With support from the Biden administration, natural infrastructure projects can gain stable and long term funding for developing implementation plans, recruiting experts, and creating strong stakeholder networks. In sum, both political and financial support from the Biden administration are catalysts of future natural infrastructure implementation.

Additionally, trust building and targeted partnership establishment are important levers for future natural infrastructure implementation. A collaboration directory would be a useful tool to display the collaborative potential and status of organizations, lower the barriers for collaboration, and increase transparency in order to help select collaboration partners. With the key take-aways from Chapter III, the core for facilitating collaborative conservation is clearly uncovered. It is a time-consuming process for establishing, maintaining, and mending a trusting relationship, but it is better to take action rather than do nothing.

Conclusion

The implementation of natural infrastructure is important for solving the flooding and nutrient pollution issues in the UMRB. Additionally, natural infrastructure implementation requires a combination of social and policy aspects. This study provides new insights into how natural infrastructure can be more effectively and efficiently implemented, and identifies key policy opportunities going forward. Primary findings are: (1) reduce administrative barriers for natural infrastructure implementation including using a wetland restoration proxy to increase implementation; (2) being conscious of environmental justice will increase equity by improving the distribution of environmental impacts and including diverse voices; (3) the change in administration and Democratic control of Congress provides good timing for capitalizing on Farm Bill opportunities. While issues related to flooding and pollution are pervasive, hope can be found in the work being done to reduce environmental risk. Together, researchers, farmers, community members, and policy makers can help create a future in which these issues can be addressed and solved, so that all communities can lead healthier, safer lives.

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APPENDIX A: CHAPTER II APPENDIXES

THE FOLLOWING APPENDIX INCLUDES 49 SUPPORTING MAPS FOR CHAPTER II.

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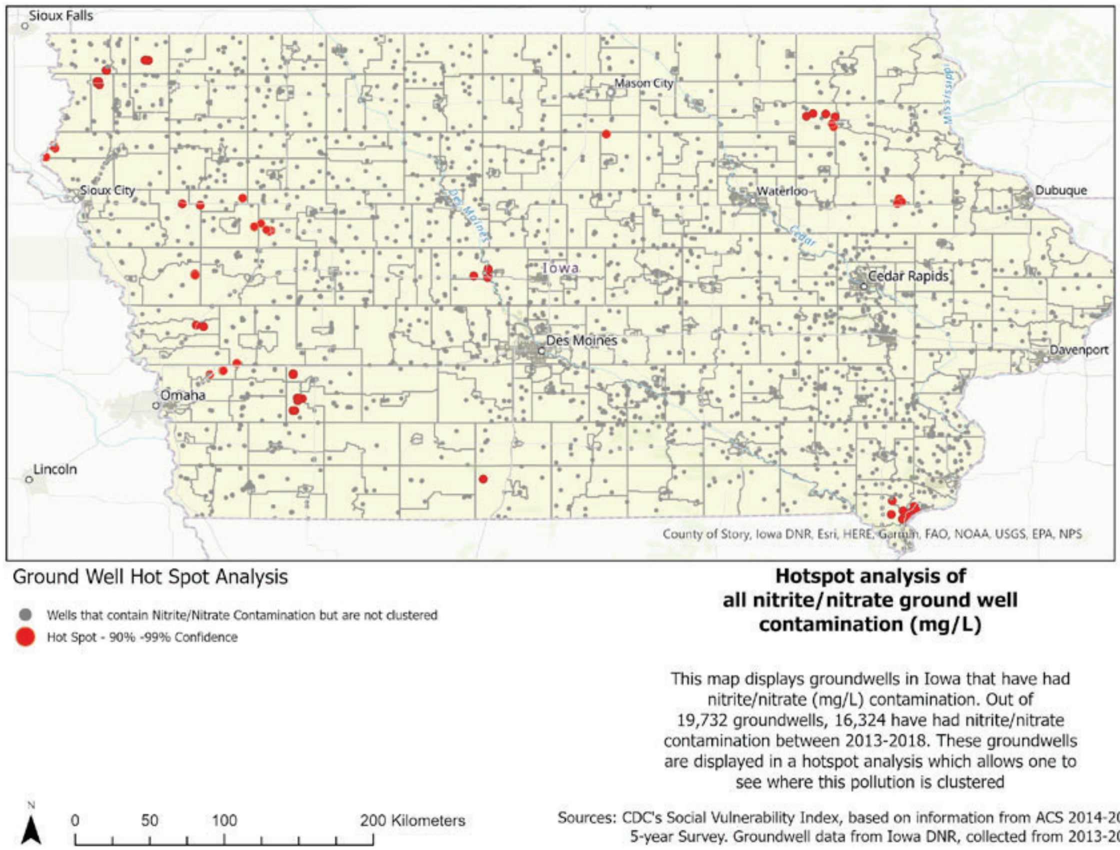
Hot spot Analysis: All Nitrite/Nitrate Contaminated Wells

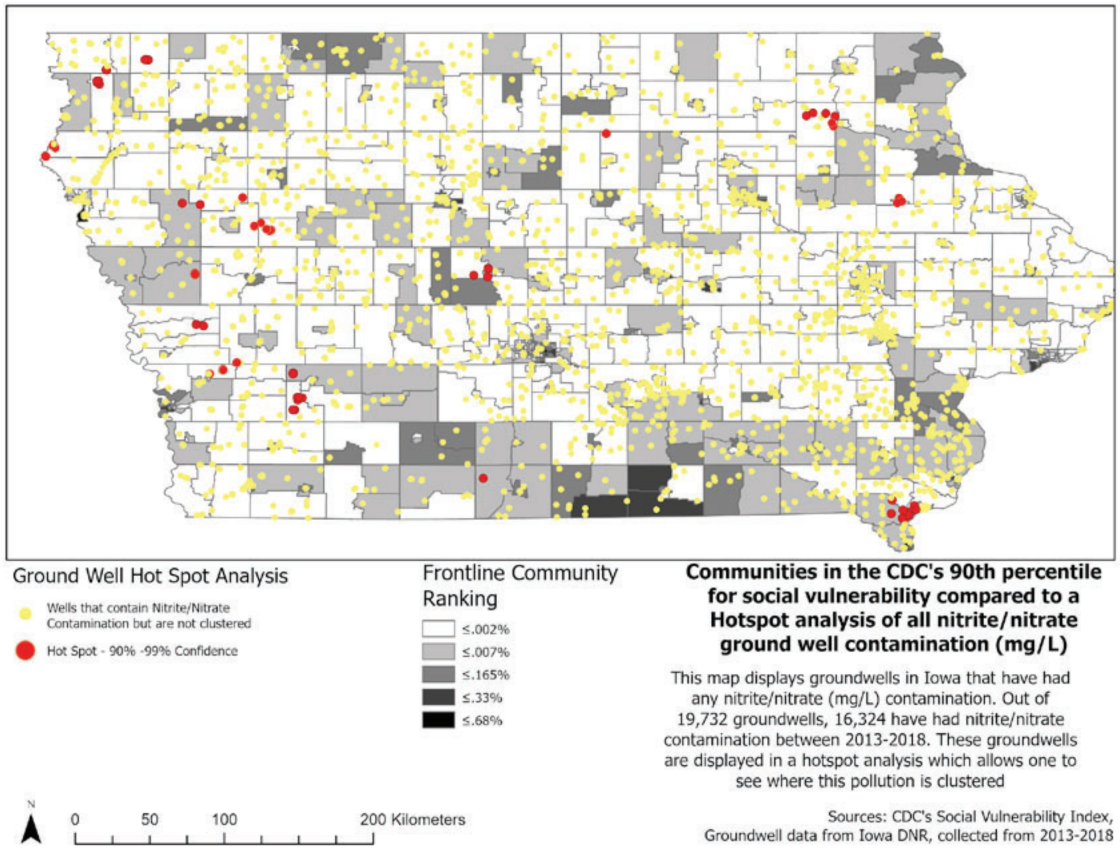


Hotspot analysis of all nitrite/nitrate ground well contamination (mg/L)

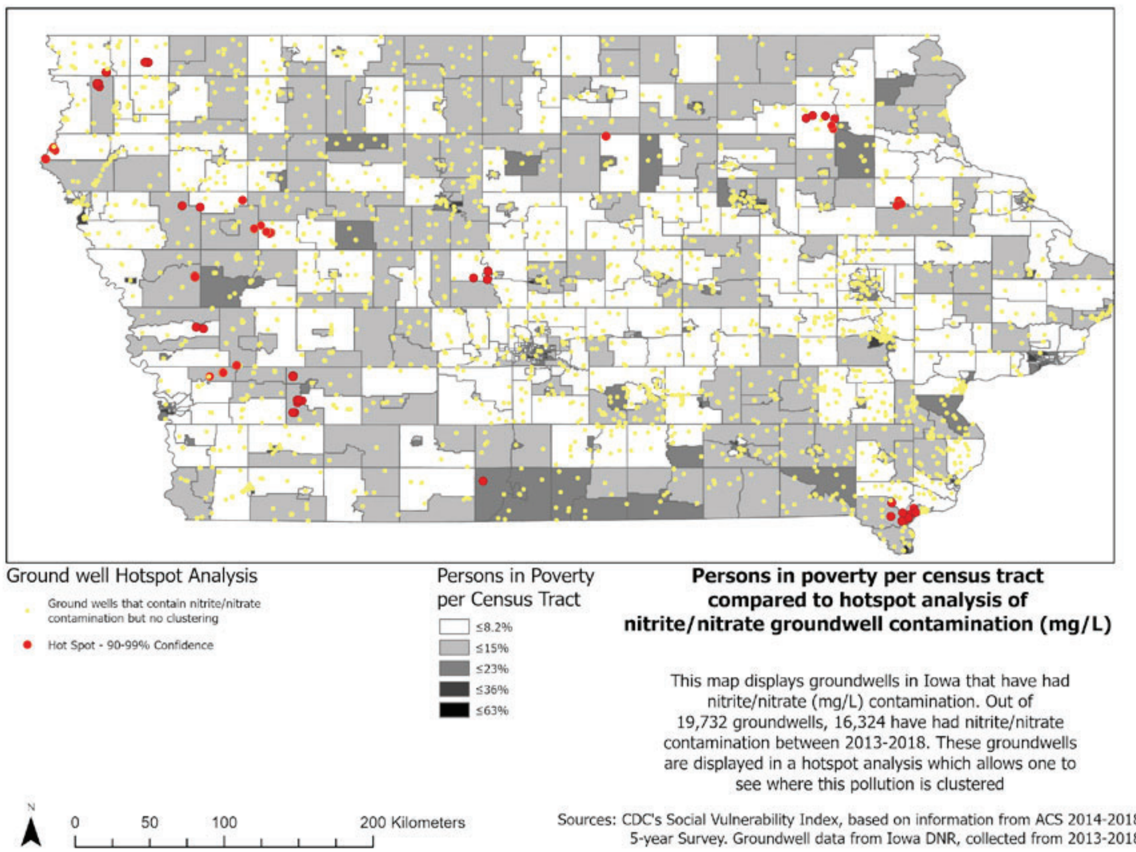
This map displays groundwells in Iowa that have had nitrite/nitrate (mg/L) contamination. Out of 19,732 groundwells, 16,324 have had nitrite/nitrate contamination between 2013-2018. These groundwells are displayed in a hotspot analysis which allows one to see where this pollution is clustered

Sources: CDC's Social Vulnerability Index, based on information from ACS 2014-2018 5-year Survey. Groundwell data from Iowa DNR, collected from 2013-2018

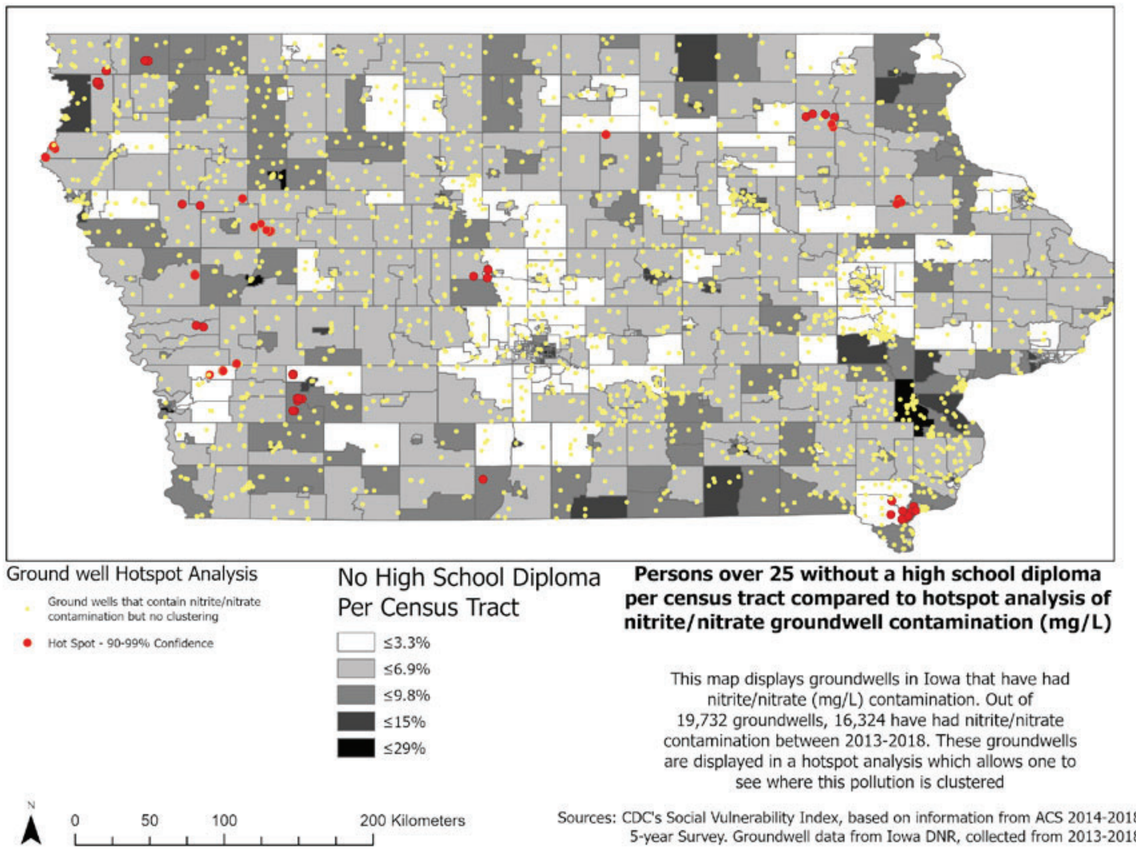
Total Communities in the 90th percentile of the CDC's SVI compared to all Nitrite/Nitrate contaminated Wells



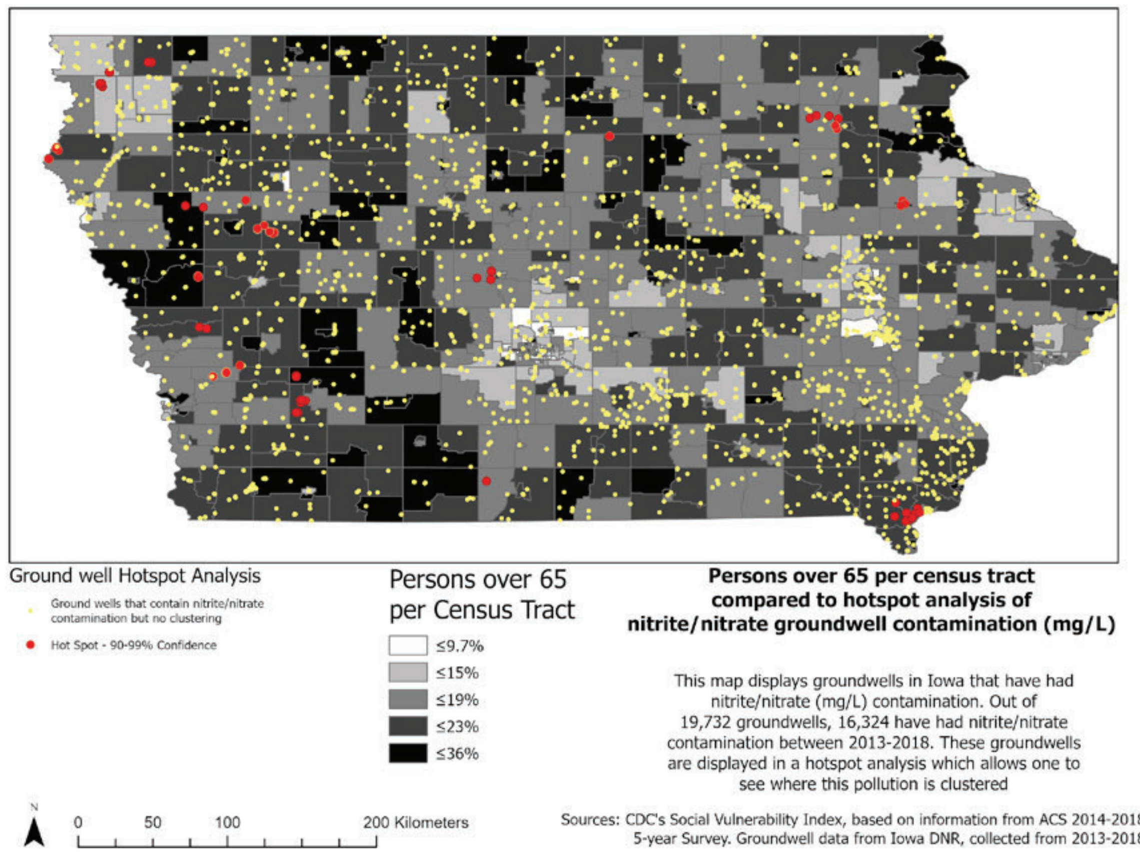
Poverty Rate per Census Tract compared to all Nitrite/Nitrate contaminated Wells



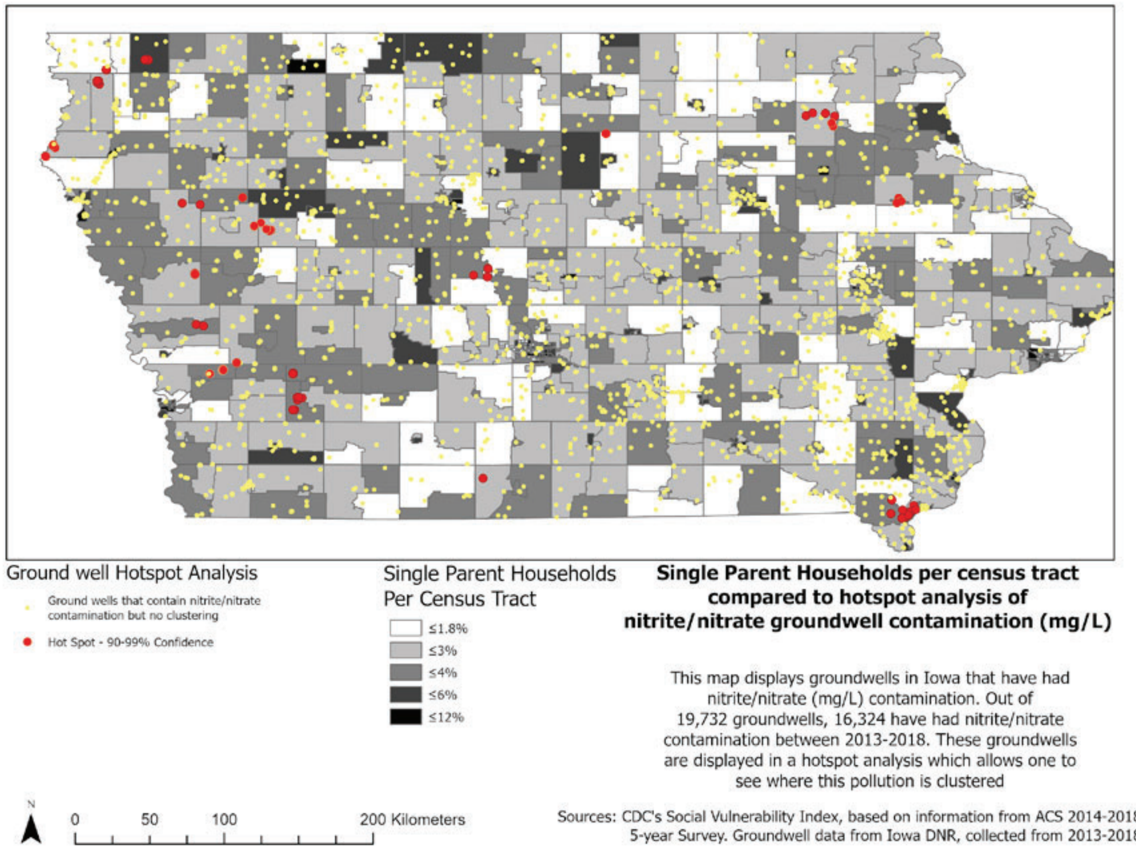
Persons over 25 without a High School Diploma per census tract compared to all Nitrite/Nitrate contaminated Wells:



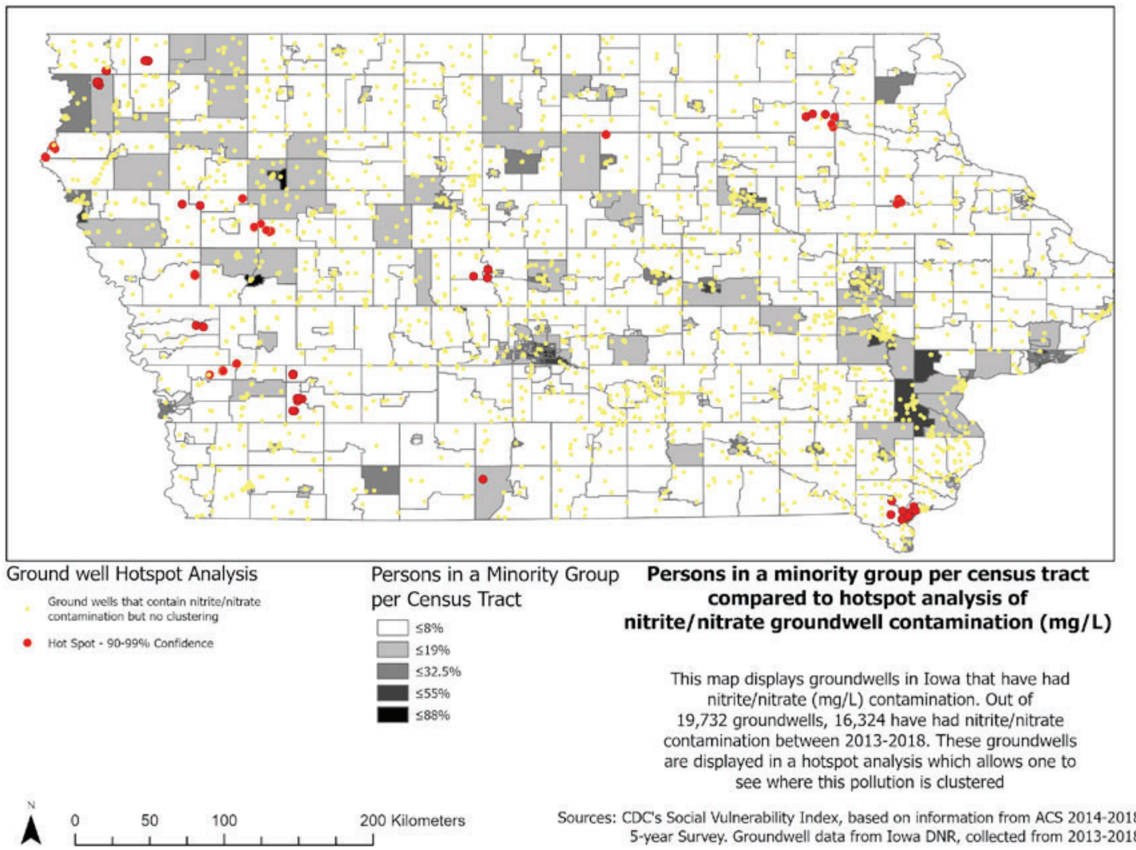
Persons over 65 per census tract compared to all Nitrite/Nitrate Contaminated Wells:



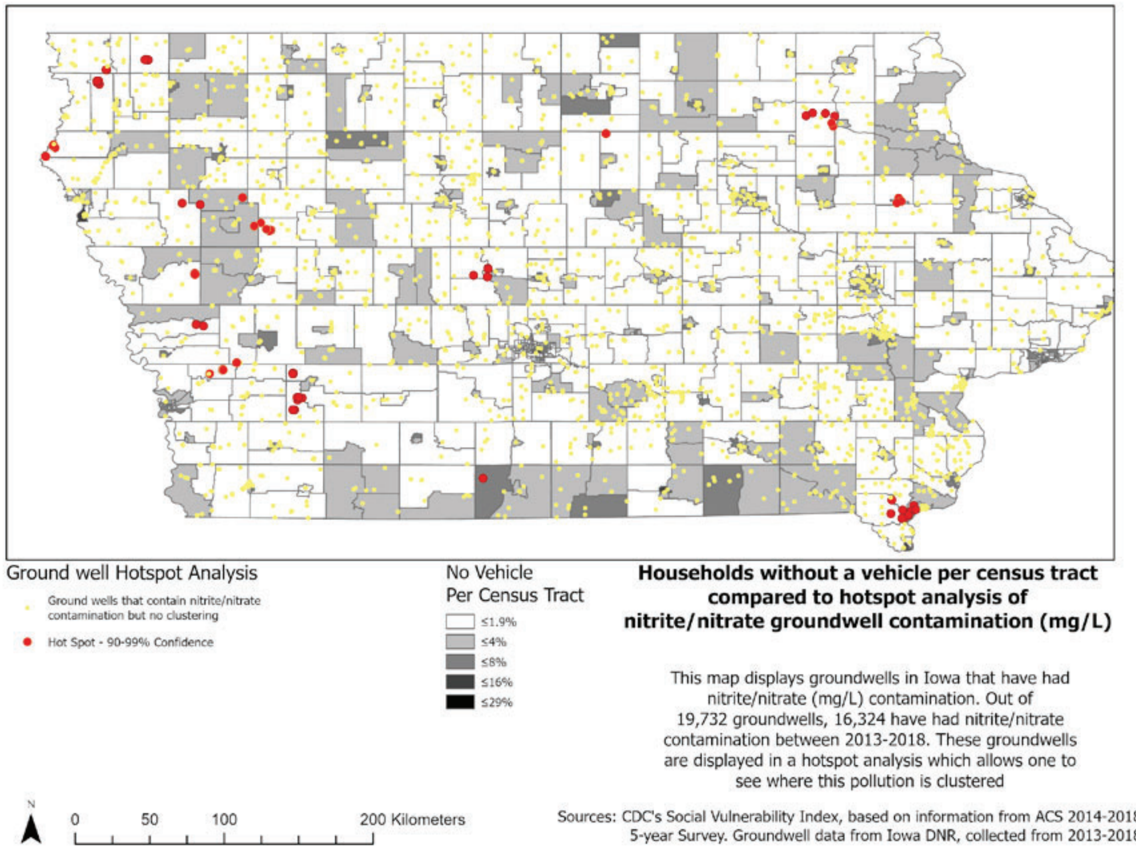
Single Parent Households per Census Tract compared to all Nitrite/Nitrate Contaminated Wells:



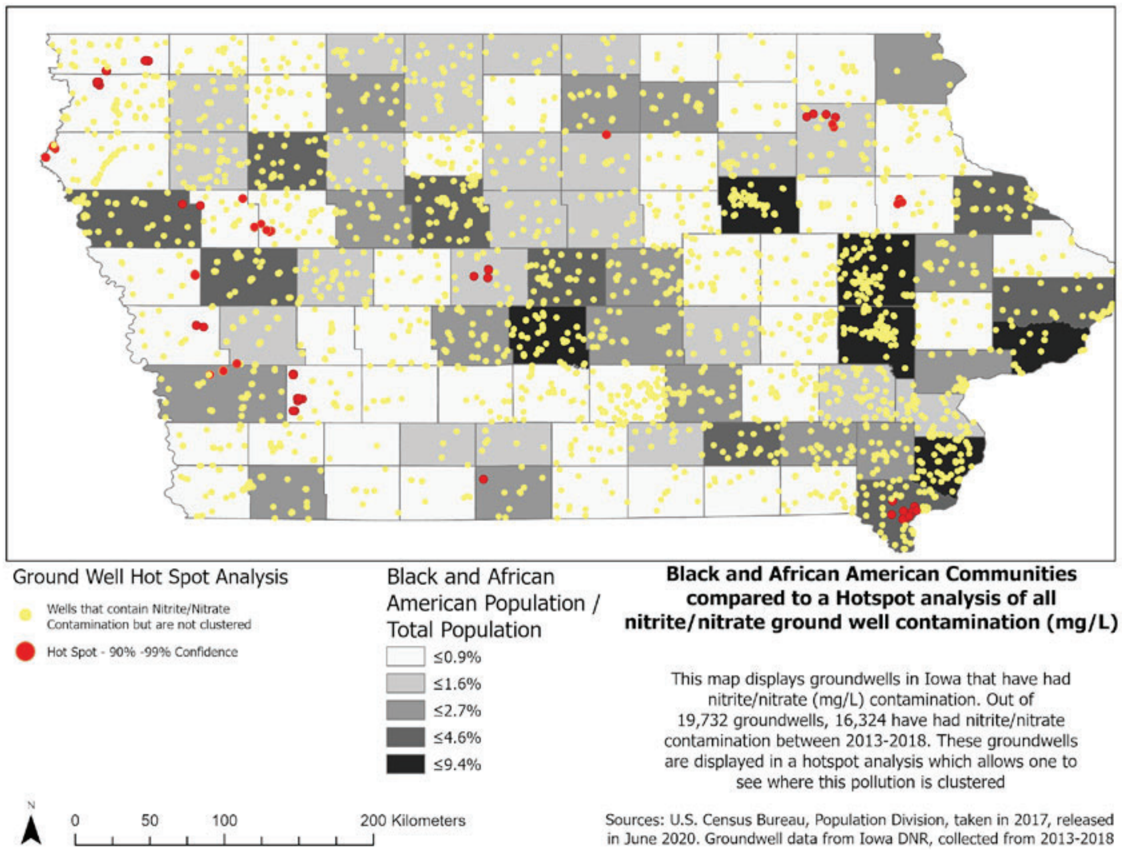
Persons in a Minority Group (non-white population) per Census Tract compared to all Nitrite/Nitrate Contaminated Wells:



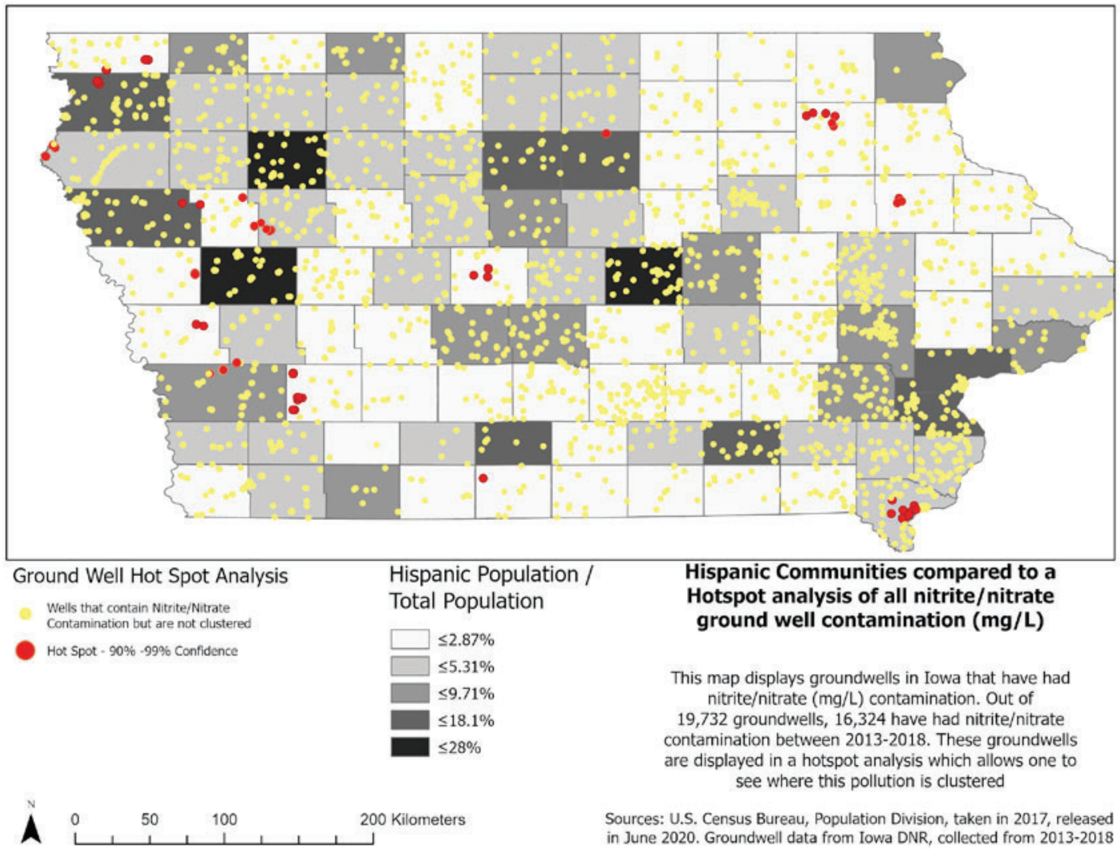
Households without a Vehicle per Census Tract compared to all Nitrite/Nitrate Contaminated Wells:



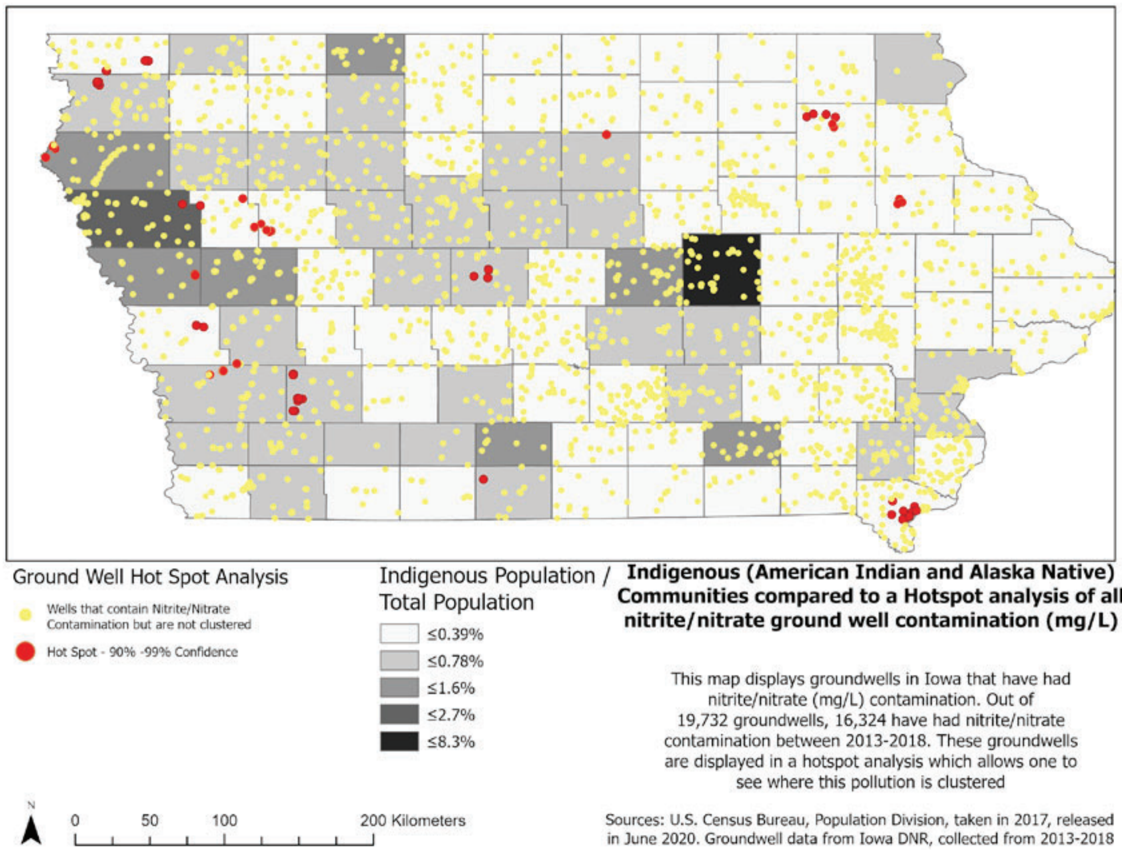
Black and African American Communities per County compared to all Nitrite/Nitrate Contaminated Wells:



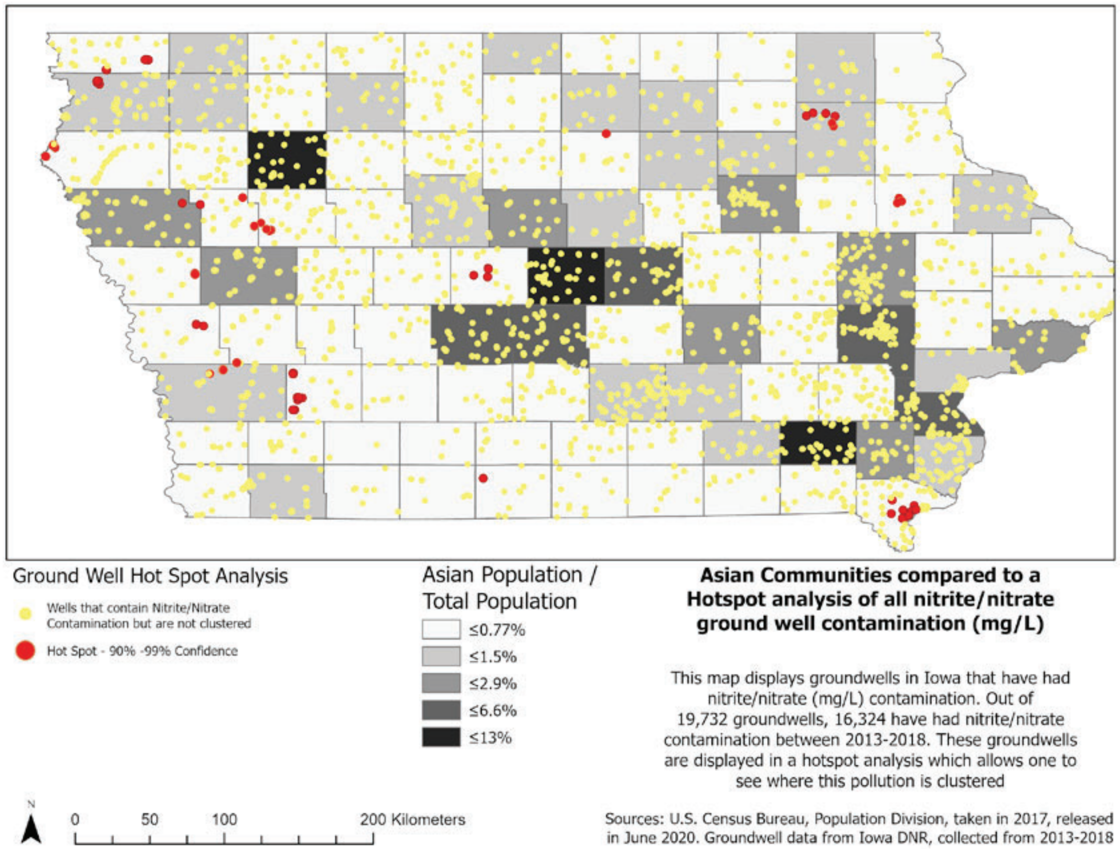
Hispanic Communities per County compared to all Nitrite/Nitrate Contaminated Wells:



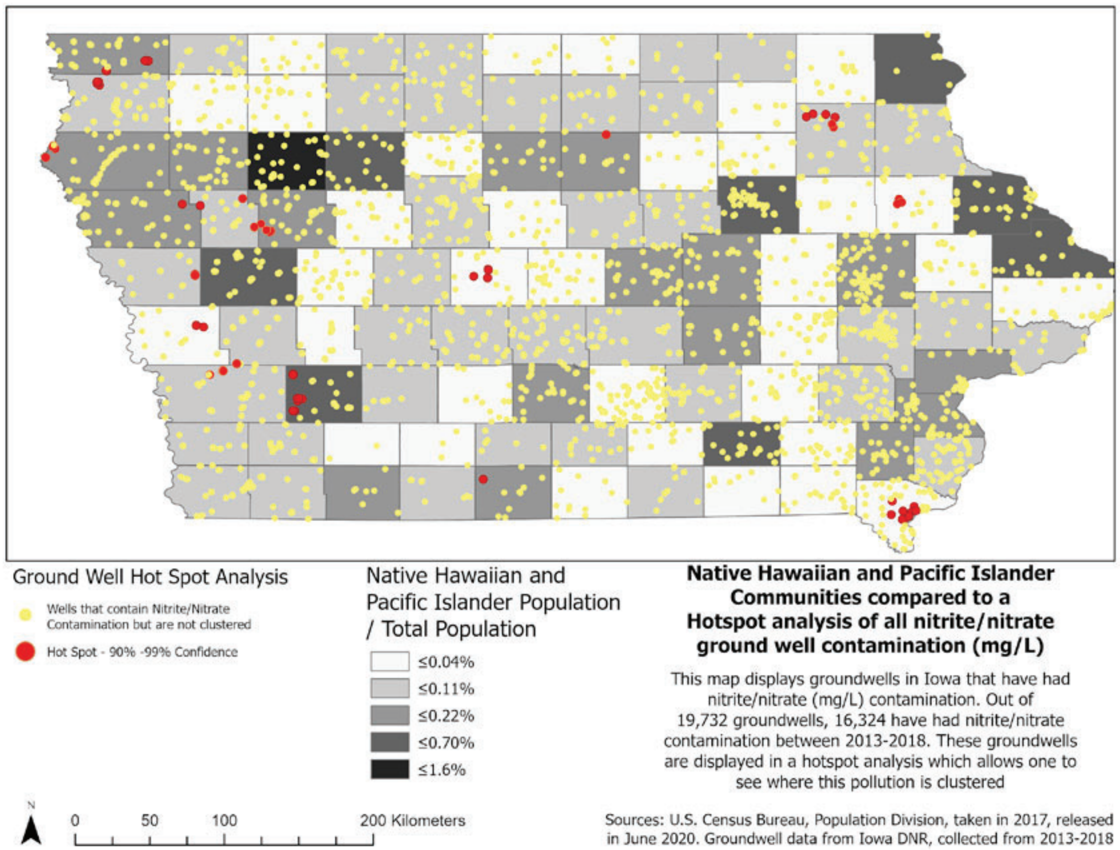
Indigenous Communities (American Indian and Native Alaskan) per County compared to all Nitrite/Nitrate Contaminated Wells:



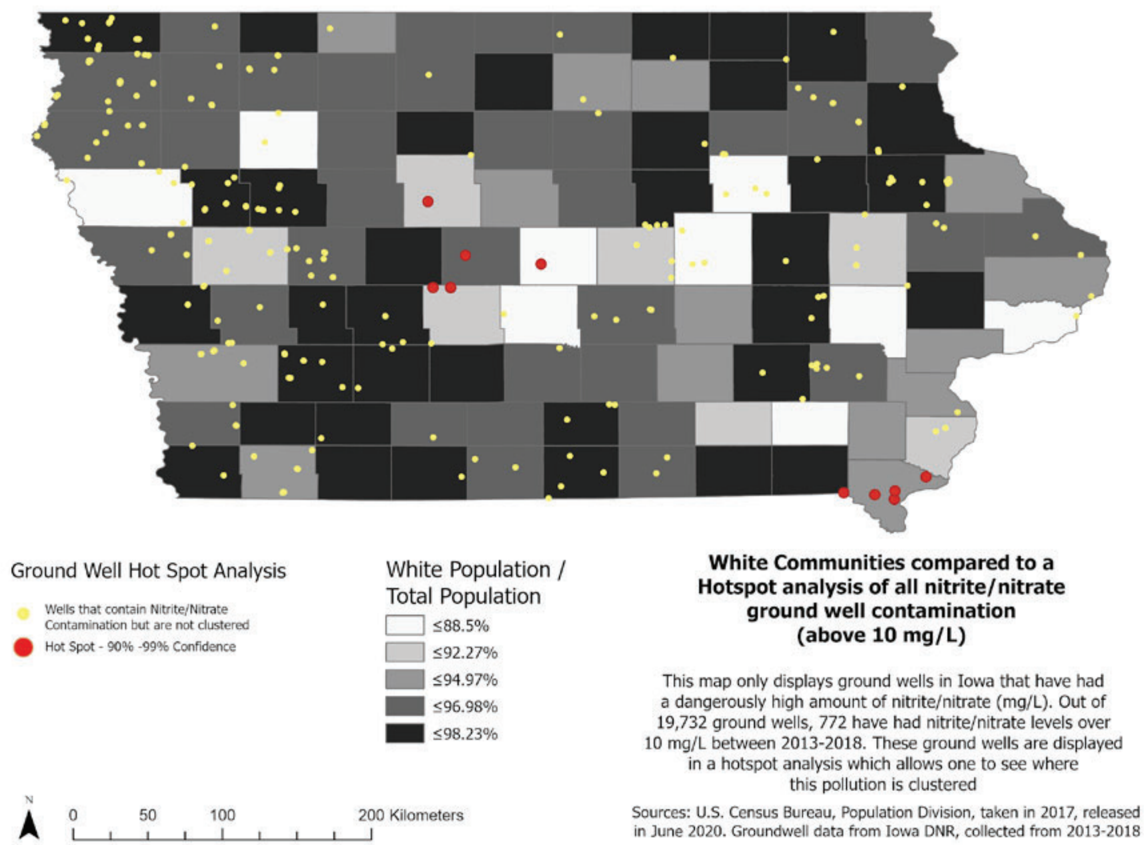
Asian Communities per County compared to all Nitrite/Nitrate Contaminated Wells:



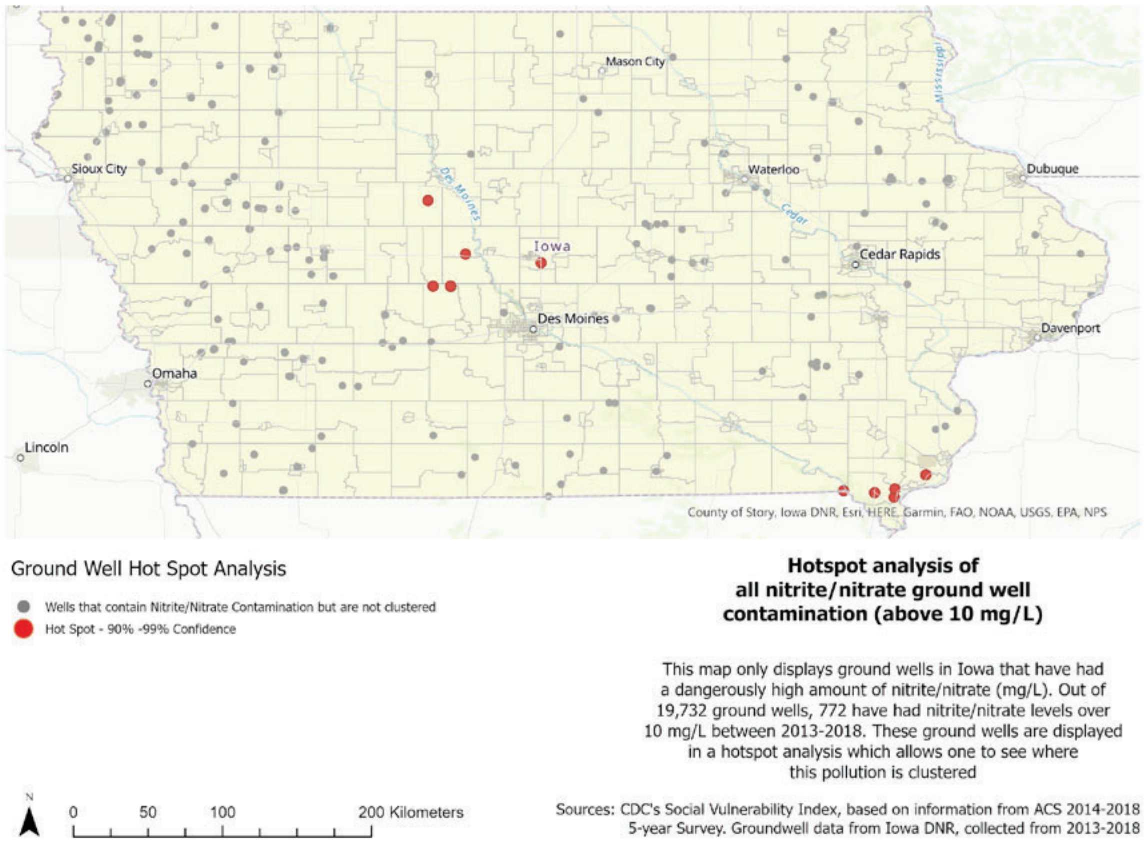
Native Hawaiian and Pacific Islander Communities per County compared to all Nitrite/Nitrate Contaminated Wells:



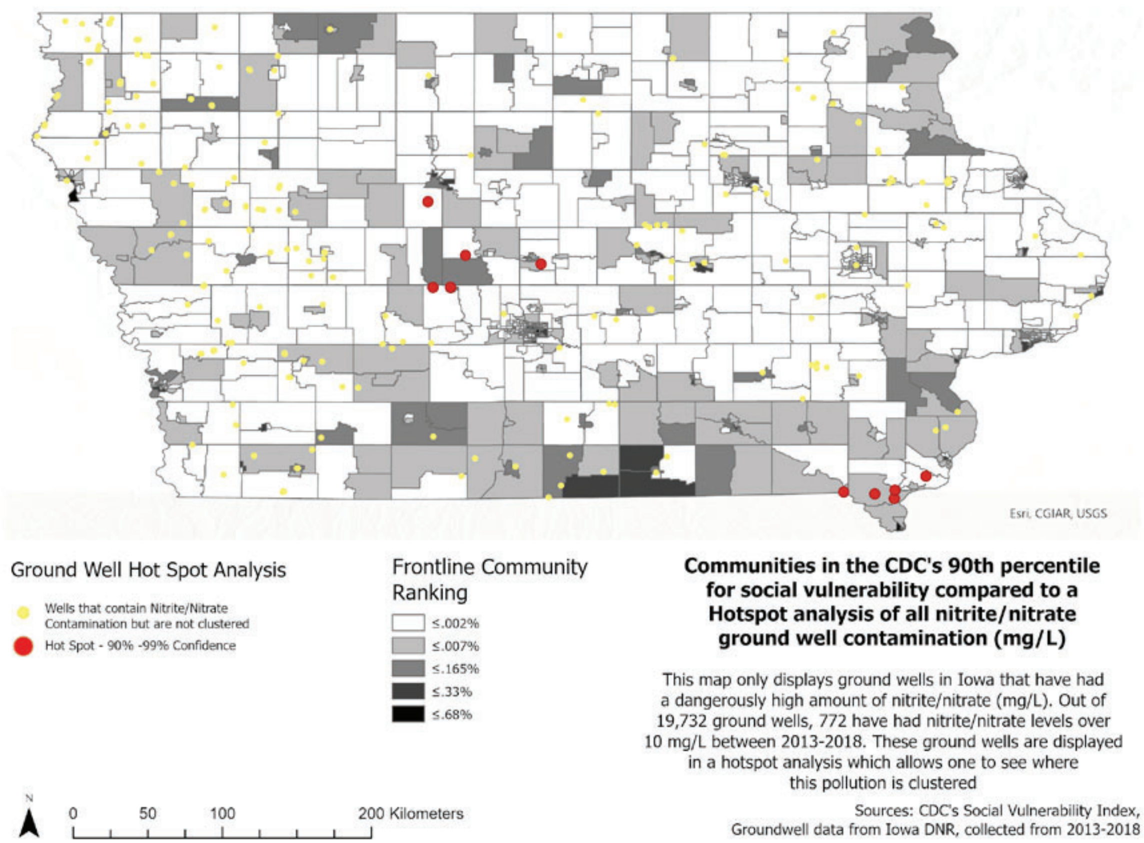
White Communities per County compared to all Nitrite/Nitrate Contaminated Wells:



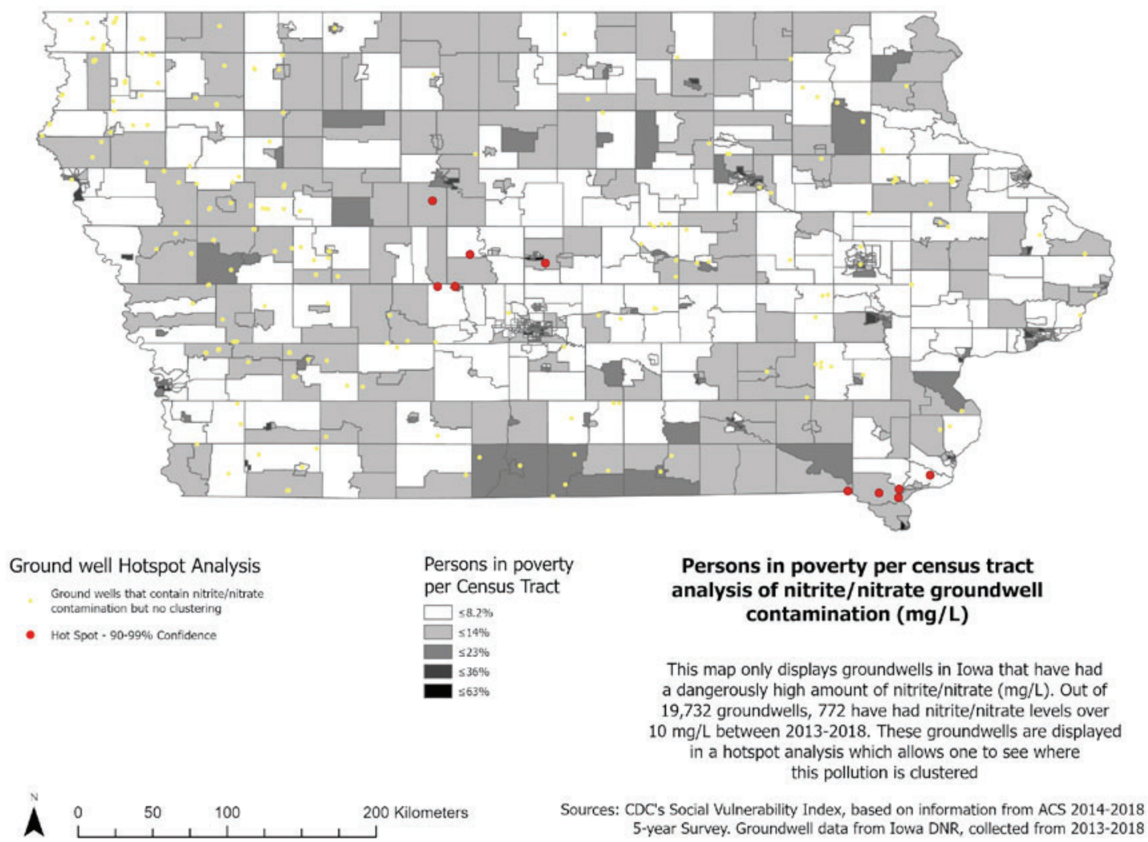
Hot spot Analysis of All Wells with a Nitrite/Nitrate contamination level above 10 mg/L:



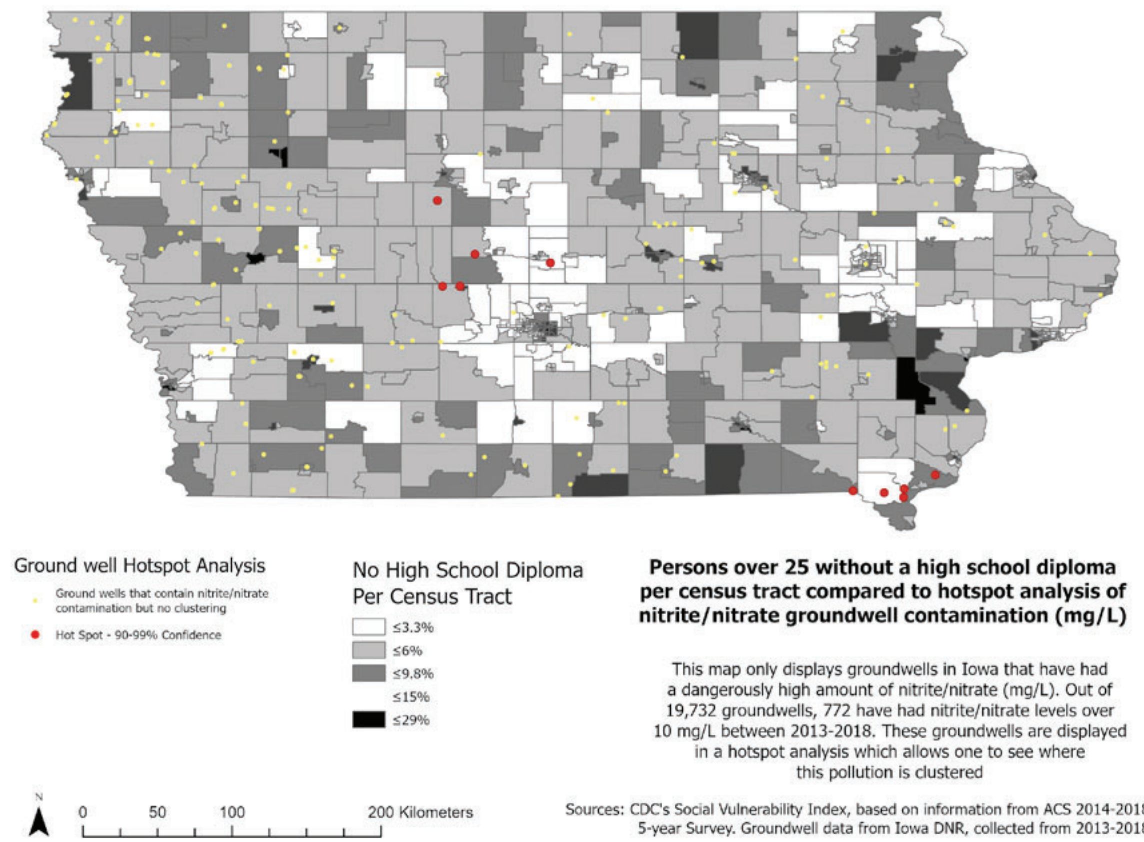
Total Communities in the 90th percentile of the CDC's SVI compared to All Wells with a Nitrite/Nitrate level above 10 mg/L:



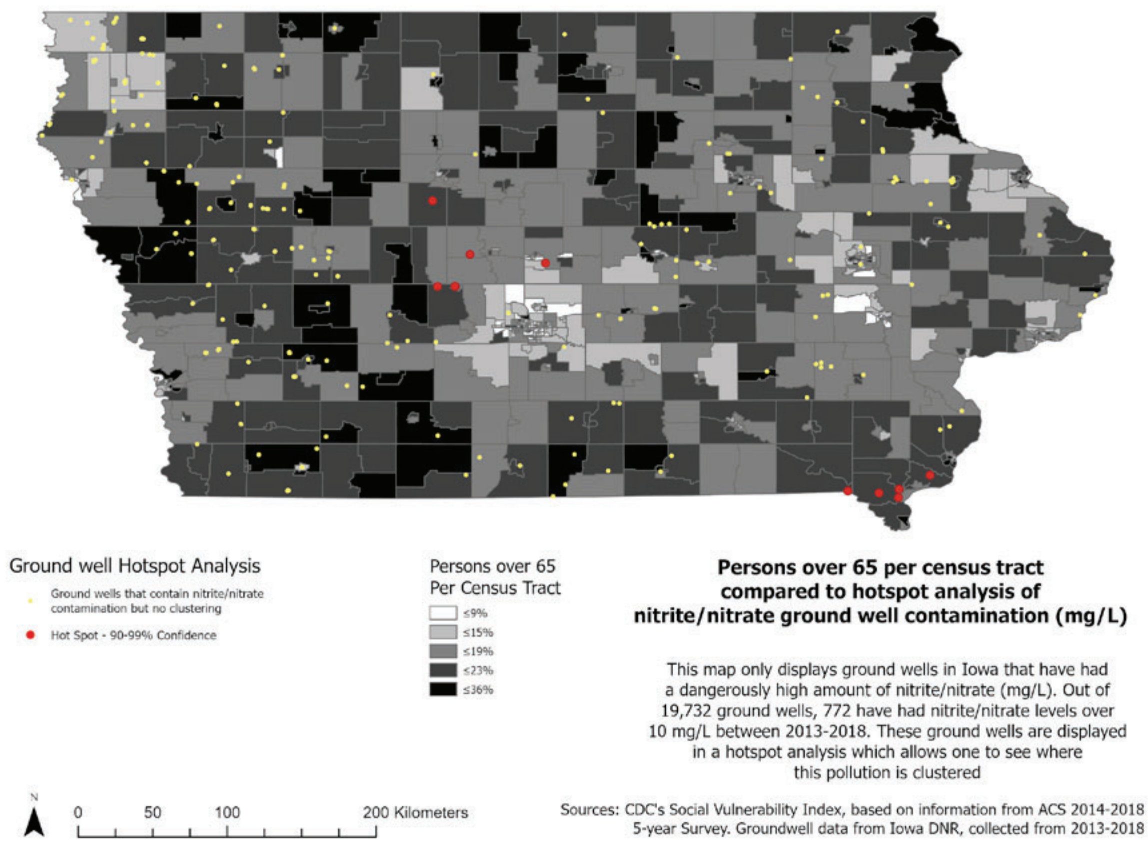
Poverty rate per Census Tract and All Wells with a Nitrite/Nitrate level over 10 mg/L:



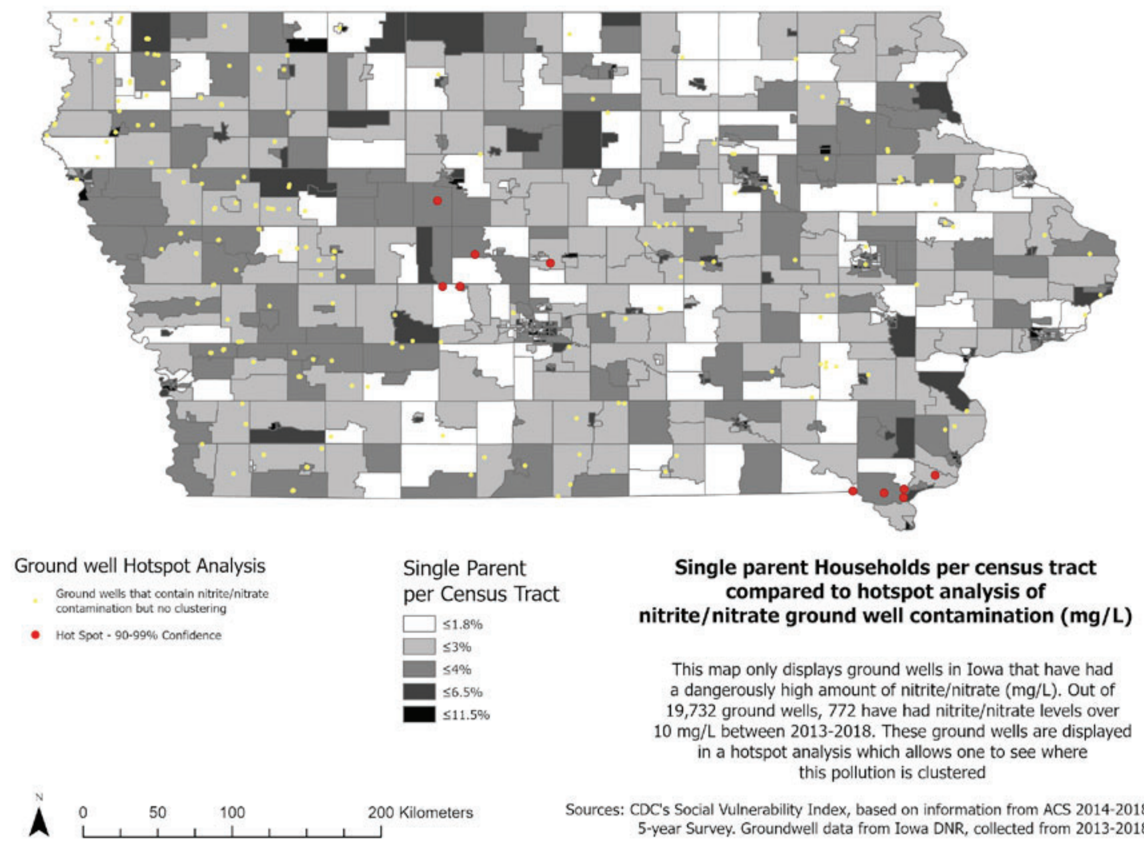
Persons over 25 without a High School Diploma per Census Tract compared to All Wells with a Nitrite/Nitrate level over 10 mg/L:



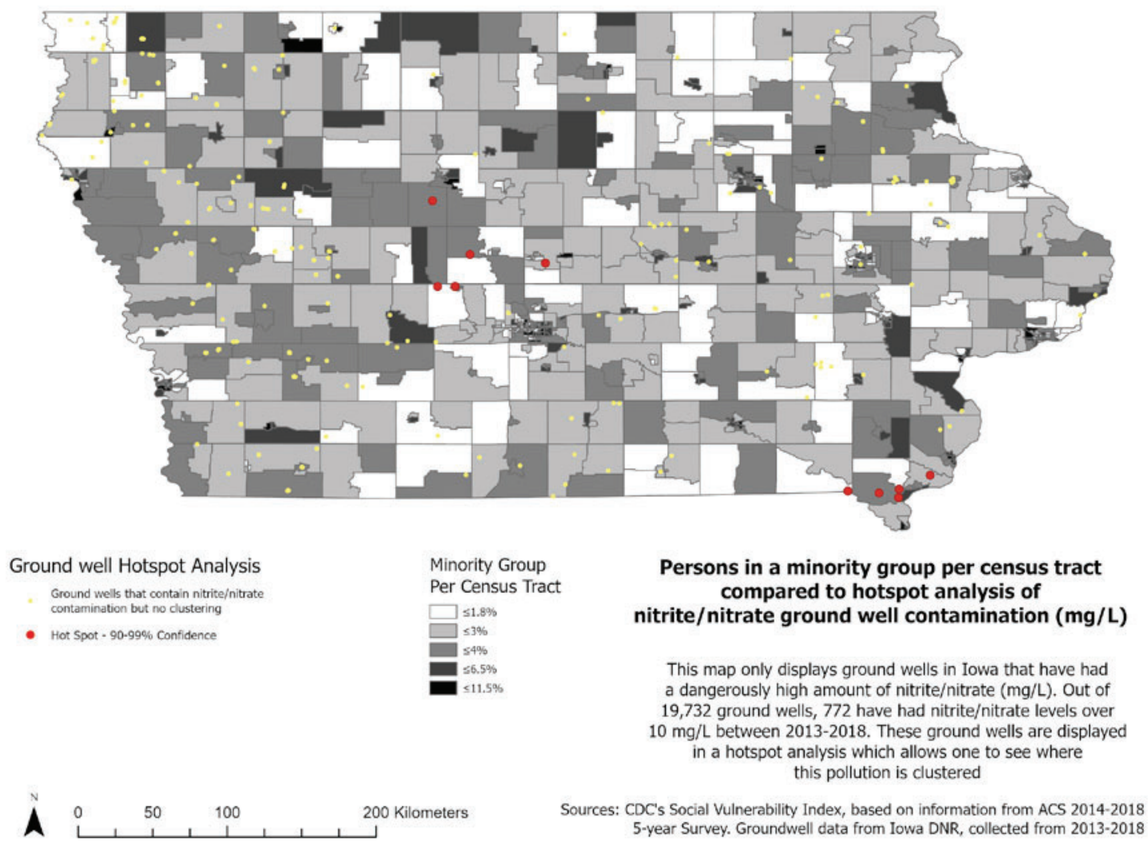
Persons over 65 per Census Tract compared to All Wells with a Nitrite/Nitrate level over 10 mg/L:



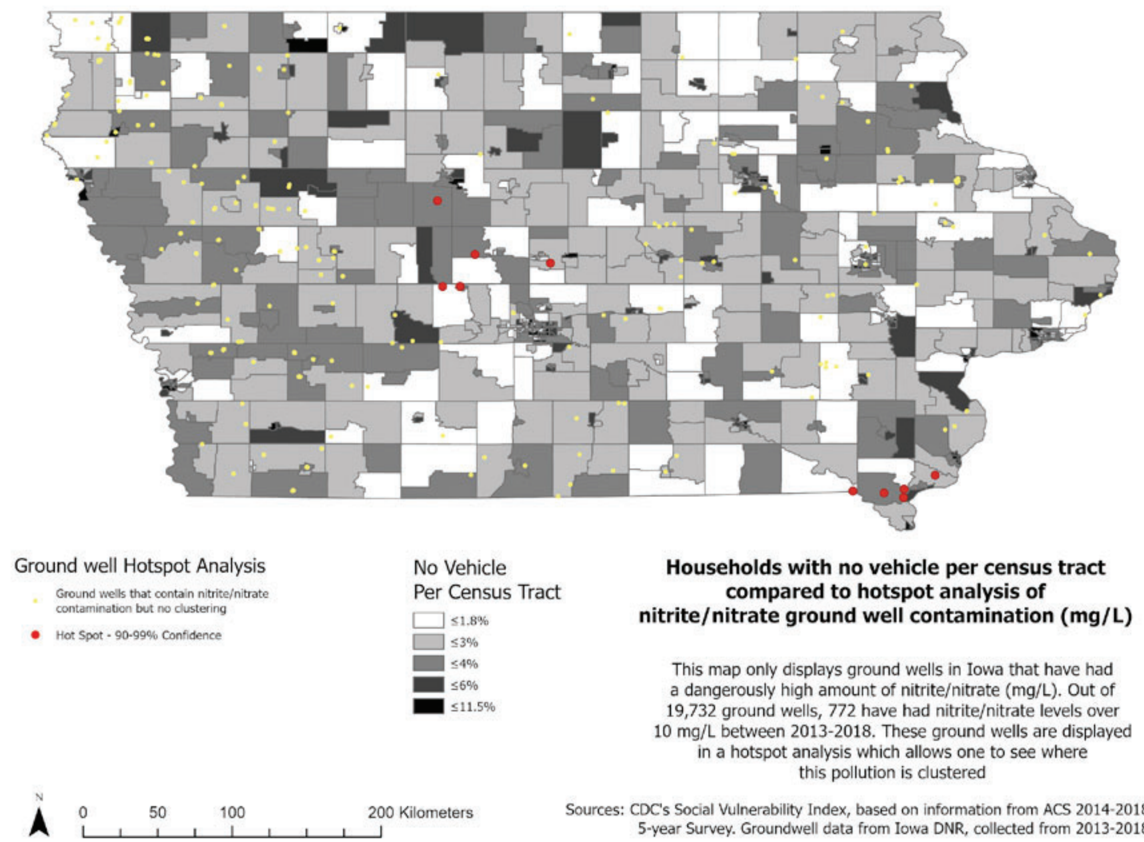
Single Parent Households per Census Tract compared to All Wells with a Nitrite/Nitrate level over 10 mg/L:



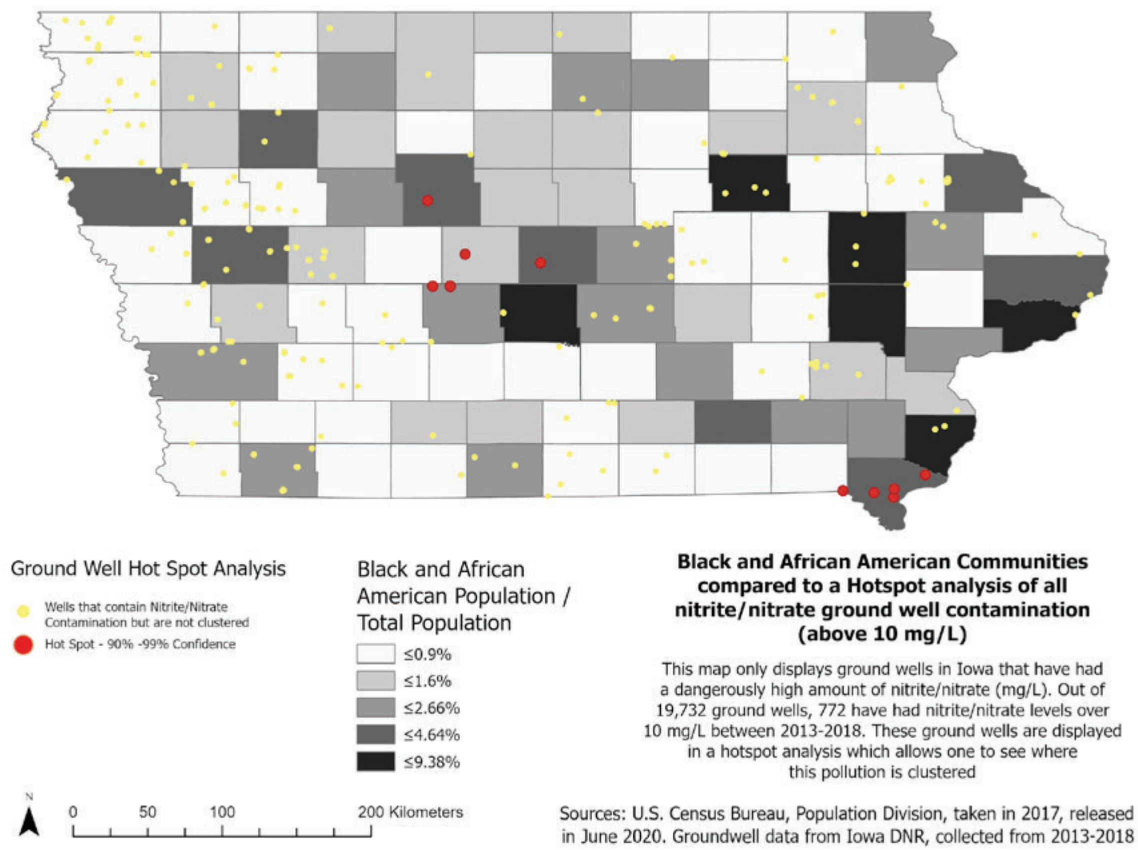
Persons in a Minority Group (non-white population) compared to All Wells with a Nitrite/Nitrate level over 10 mg/L:



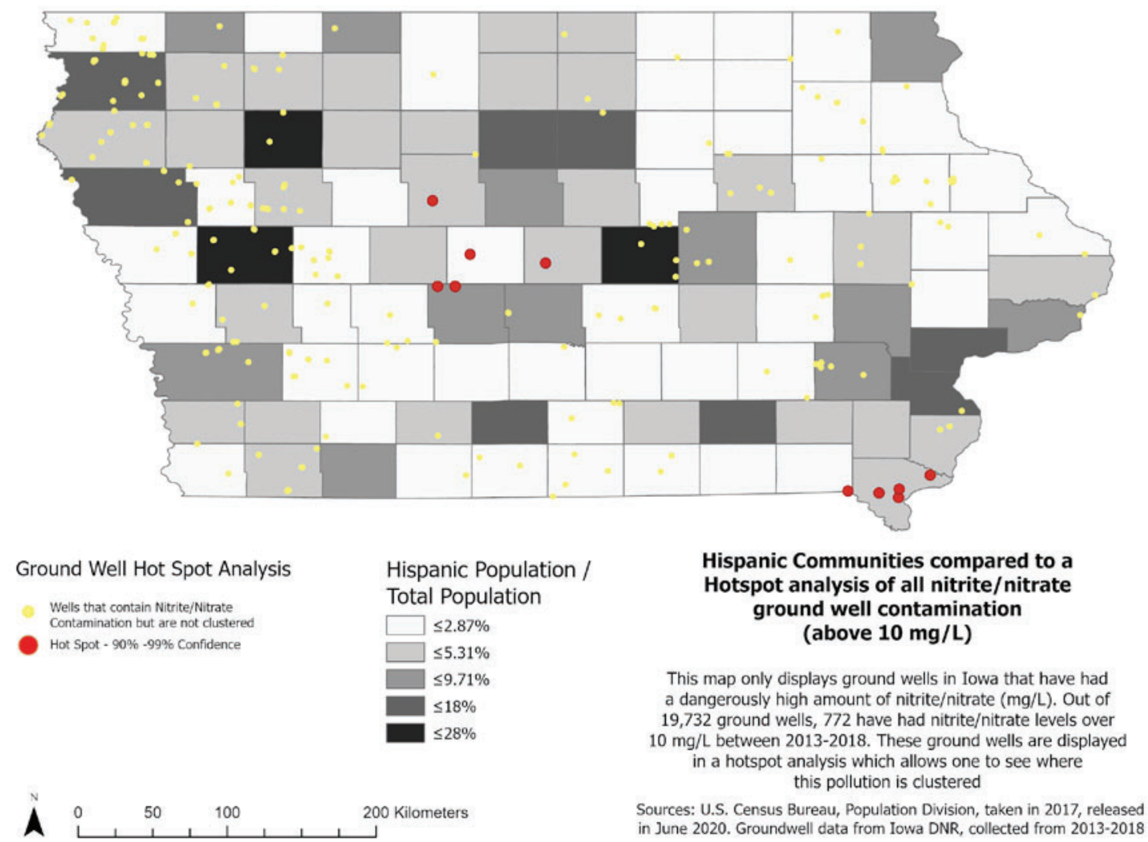
Households without a Vehicle per Census Tract compared to All Wells with a Nitrite/Nitrate level over 10 mg/L:



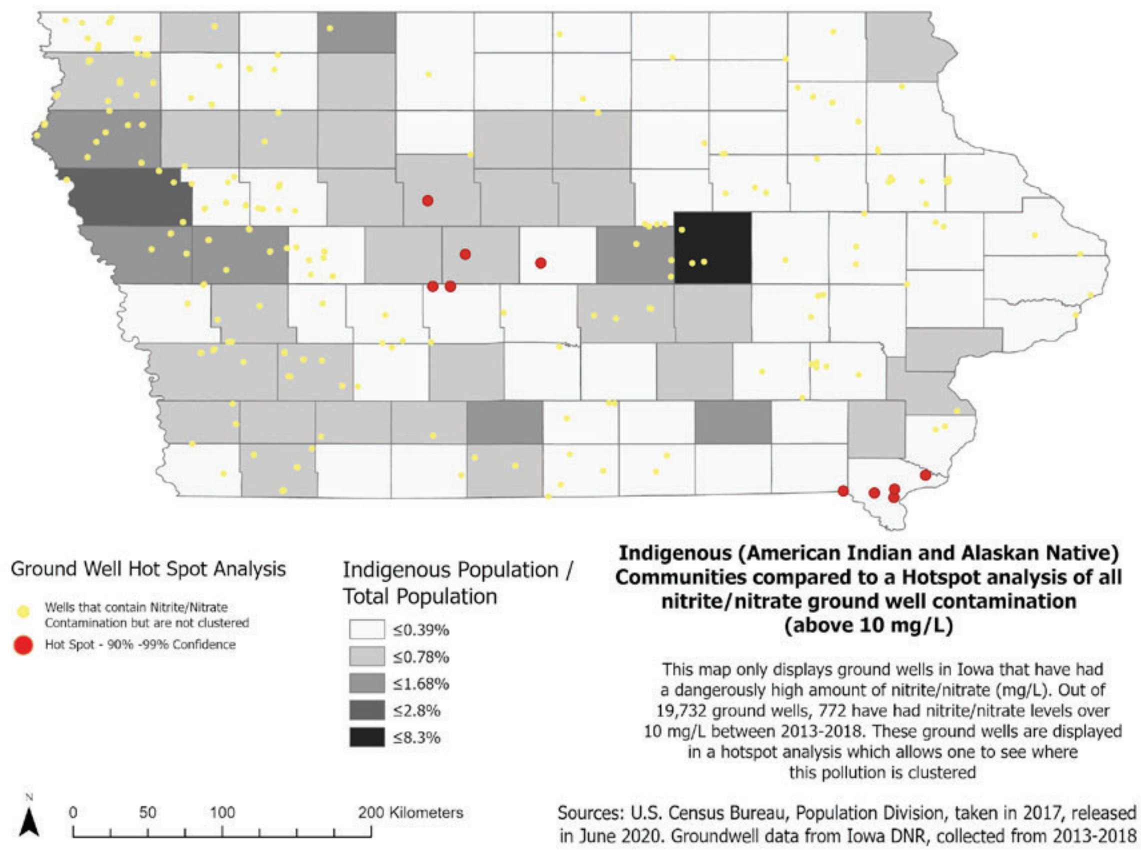
Black and African American Communities per County compared to all Nitrite/Nitrate Contaminated Wells above 10 mg/L:



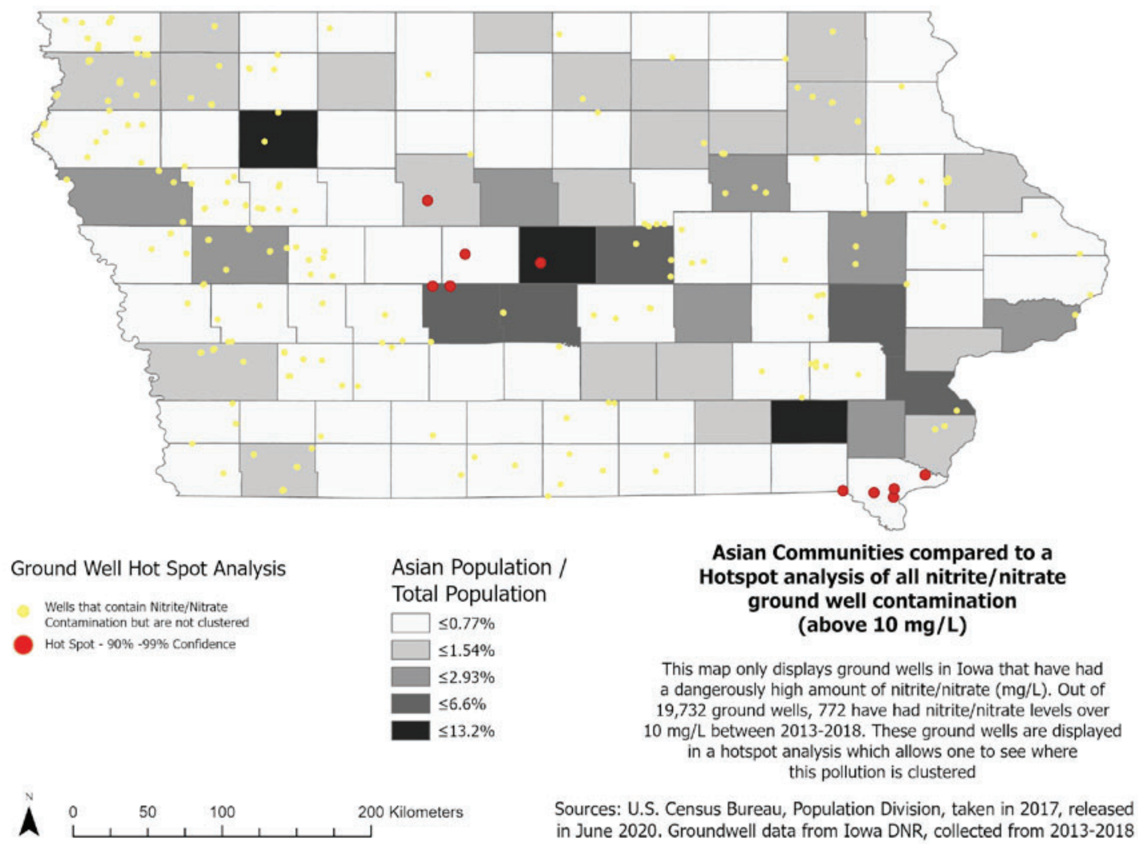
Hispanic Communities per County compared to all Nitrite/Nitrate Contaminated Wells above 10 mg/l:



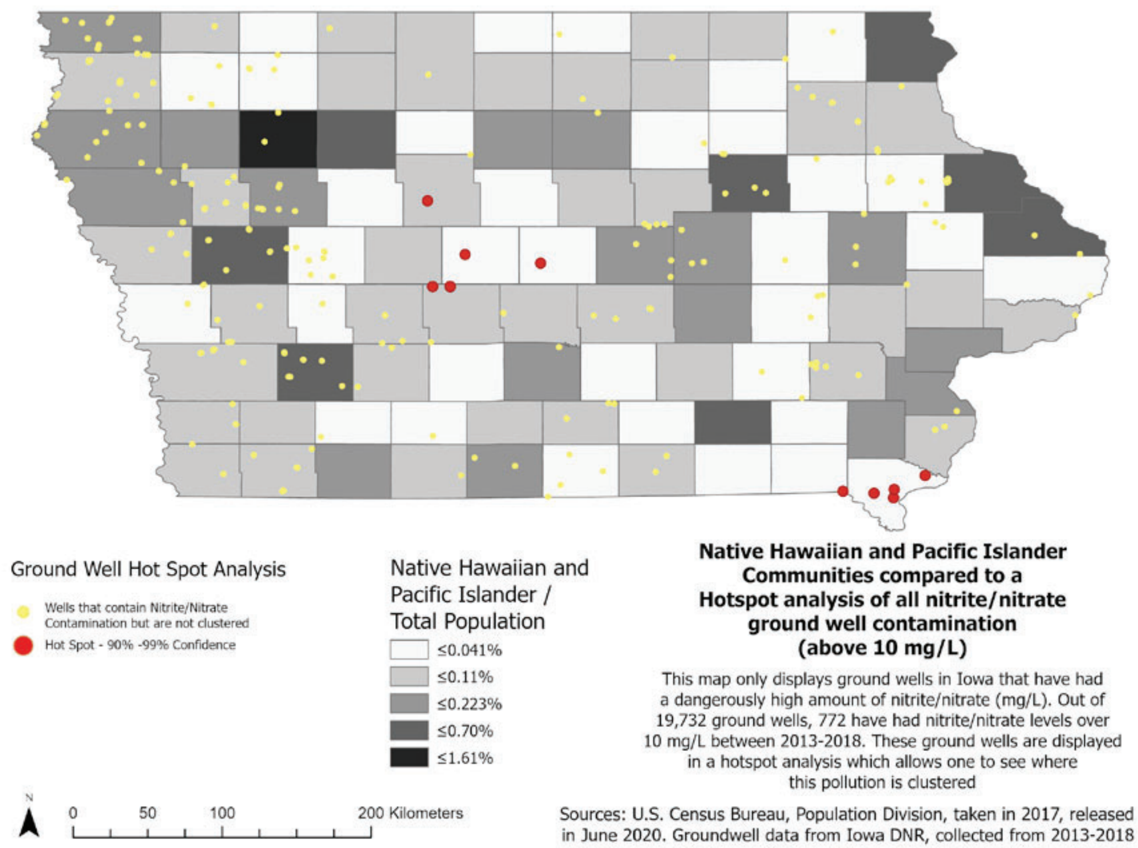
Indigenous Communities (American Indian and Native Alaskan) per County compared to all Nitrite/Nitrate Contaminated Wells above 10 mg/L:



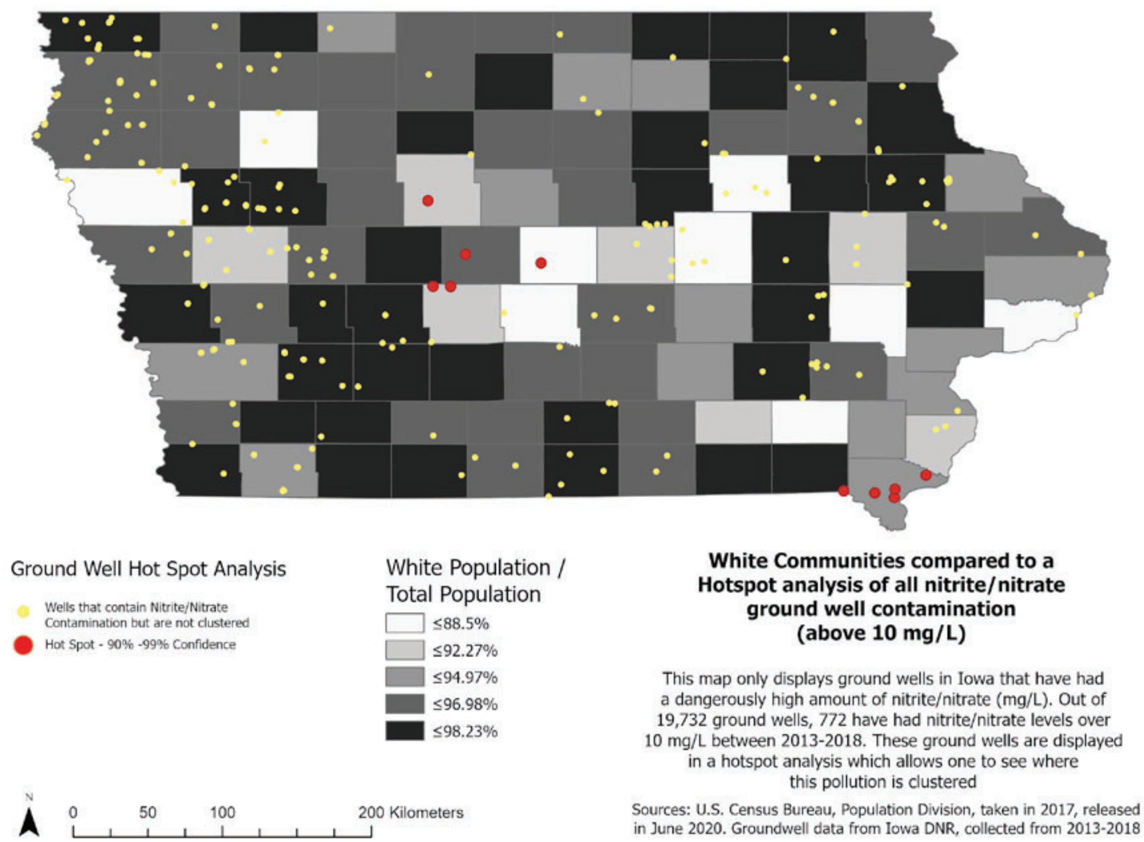
Asian Communities per County compared to all Nitrite/Nitrate Contaminated Wells above 10 mg/l:



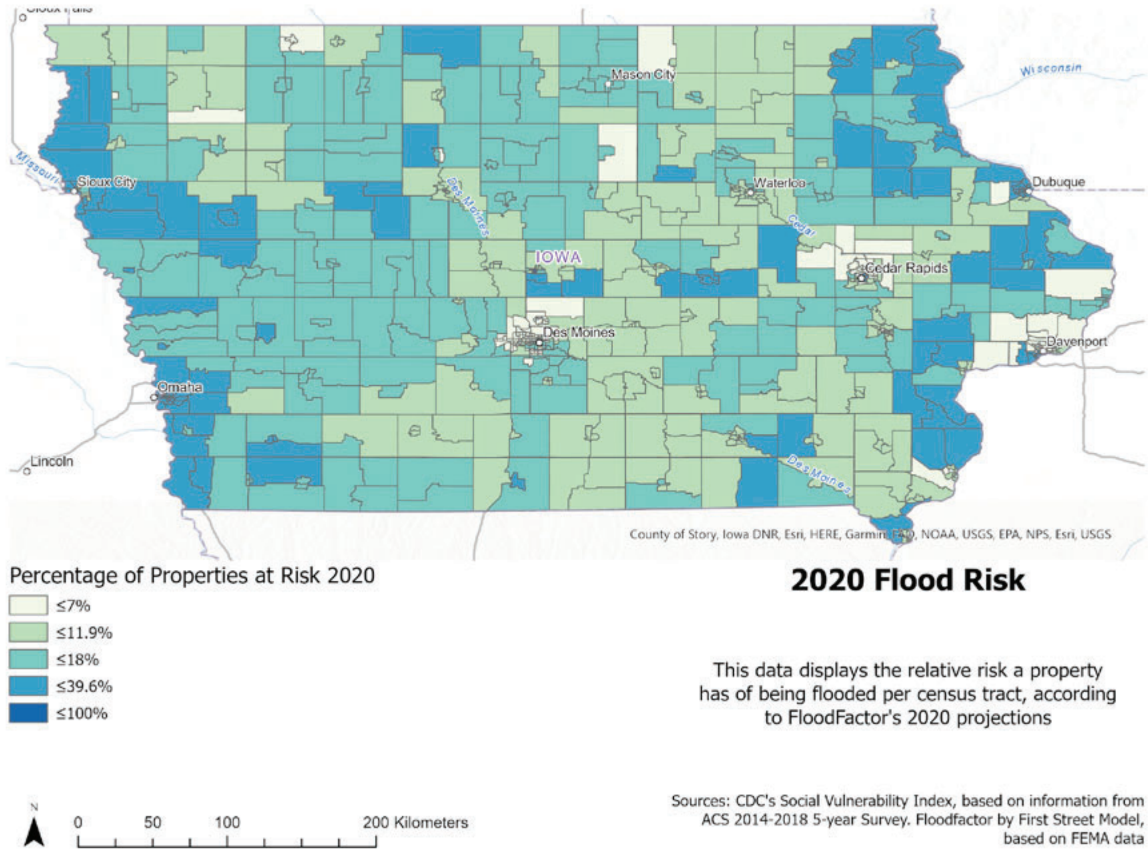
Native Hawaiian and Pacific Islander Communities per County compared to all Nitrite/Nitrate Contaminated Wells above 10 mg/L:



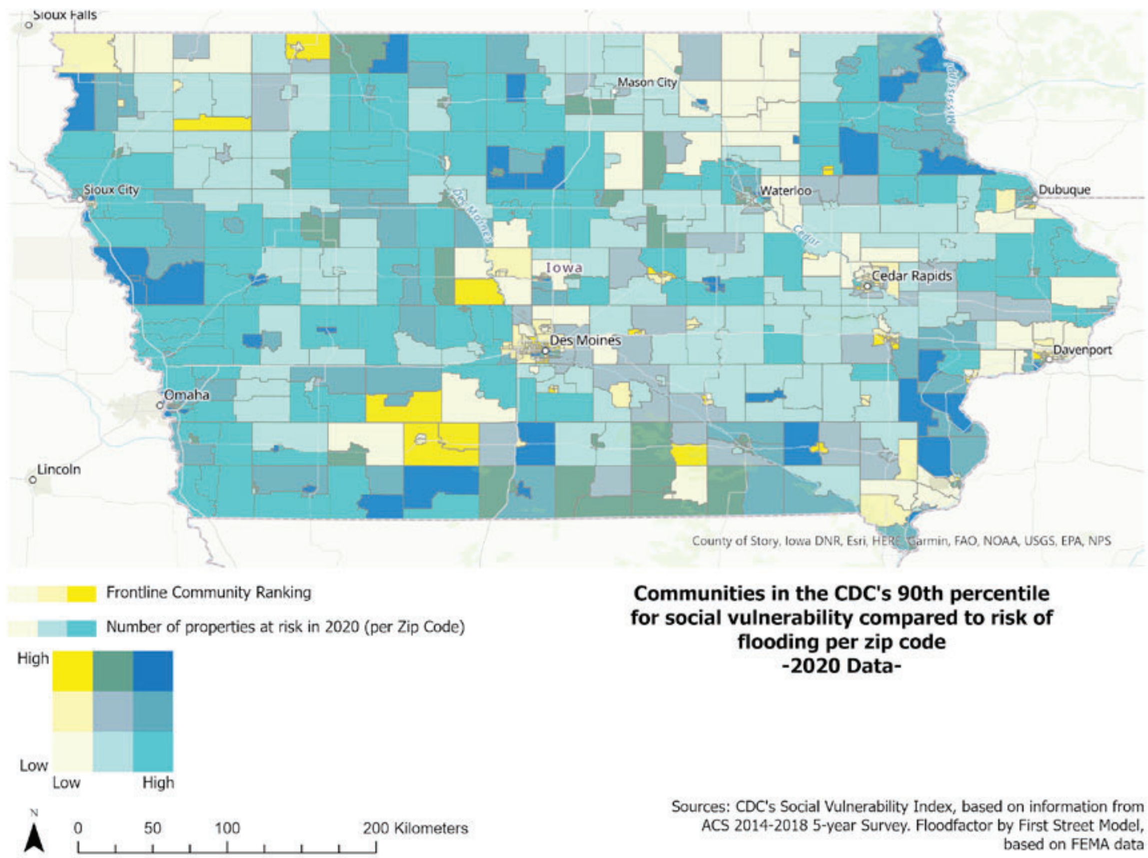
White Communities per County compared to all Nitrite/Nitrate Contaminated Wells above 10 mg/L:



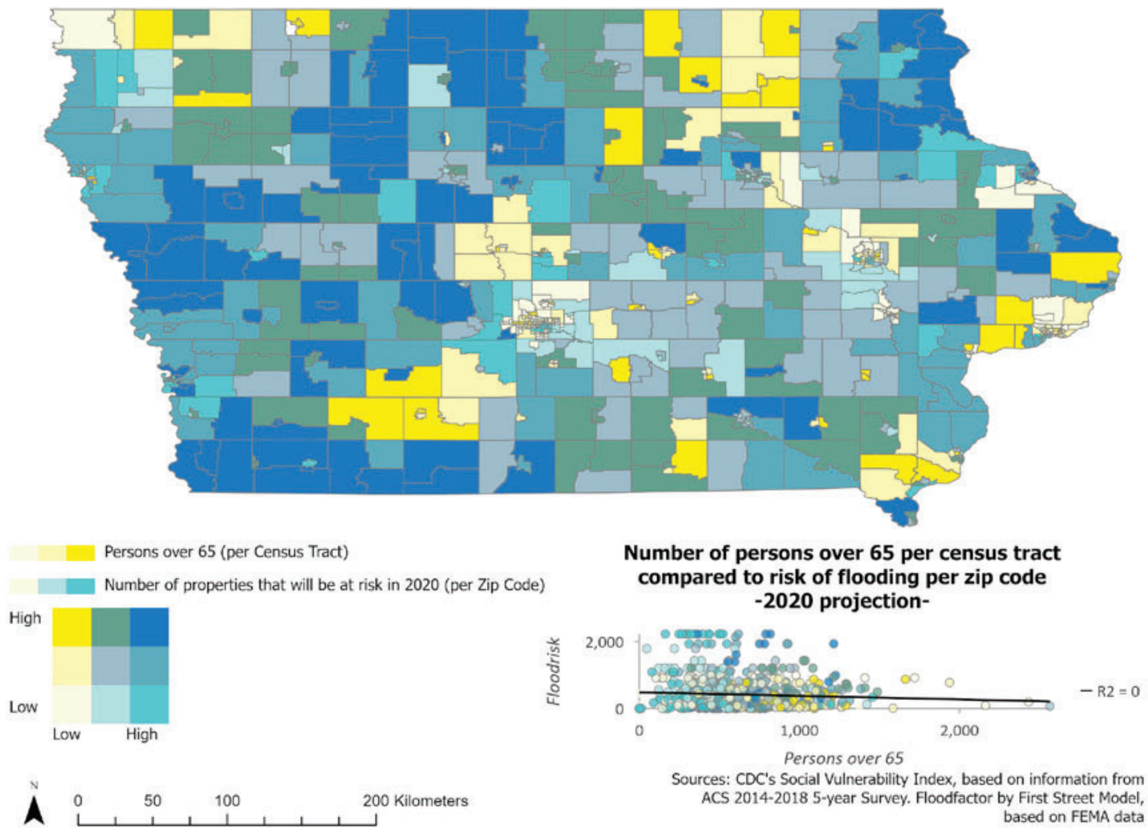
Flood Risk 2020:



Total Communities in the 90th percentile of CDC's SVI compared to 2020 Flood Risk:

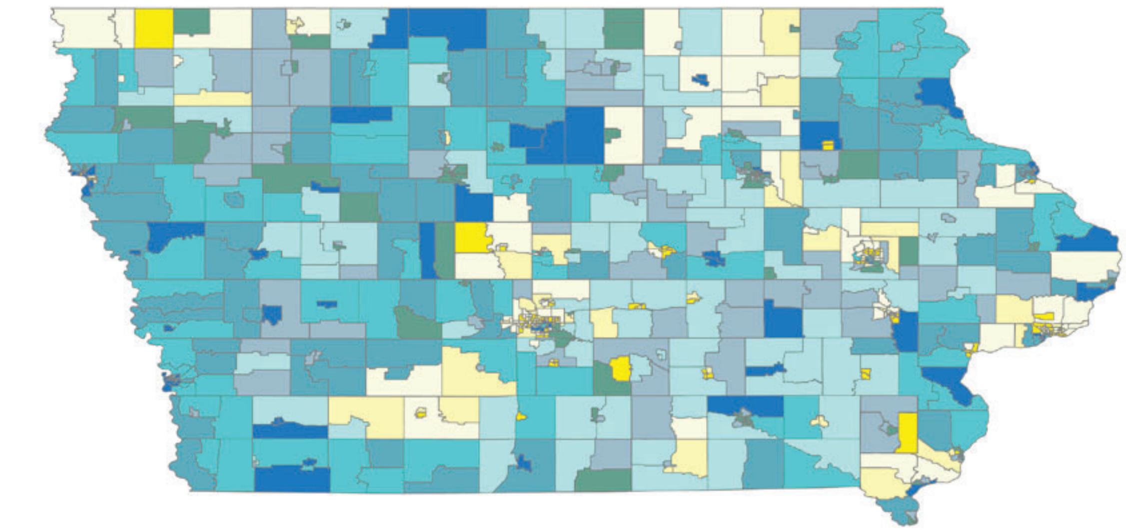


Persons over 65 compared to 2020 Flood Risk:

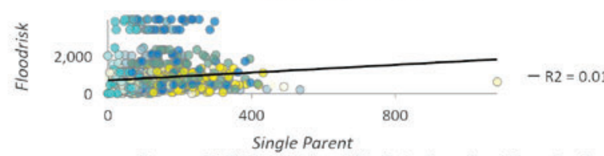


Sources: CDC's Social Vulnerability Index, based on information from ACS 2014-2018 5-year Survey. Floodfactor by First Street Model, based on FEMA data

Single Parent Households compared to 2020 Flood Risk:

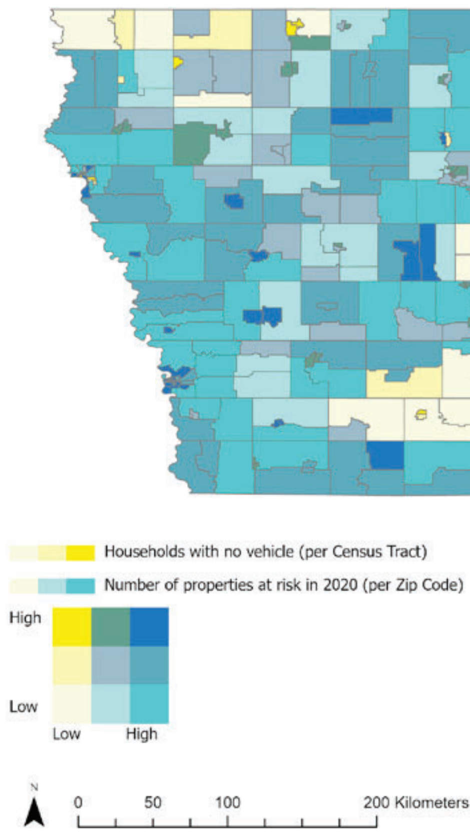


Number of single parent households per census tract compared to risk of flooding per zip code -2020 projection-

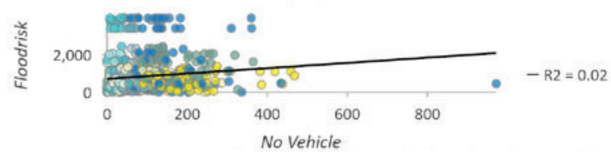


Sources: CDC's Social Vulnerability Index, based on information from ACS 2014-2018 5-year Survey. Floodfactor by First Street Model, based on FEMA data

Households without a Vehicle compared to 2020 Flood Risk:

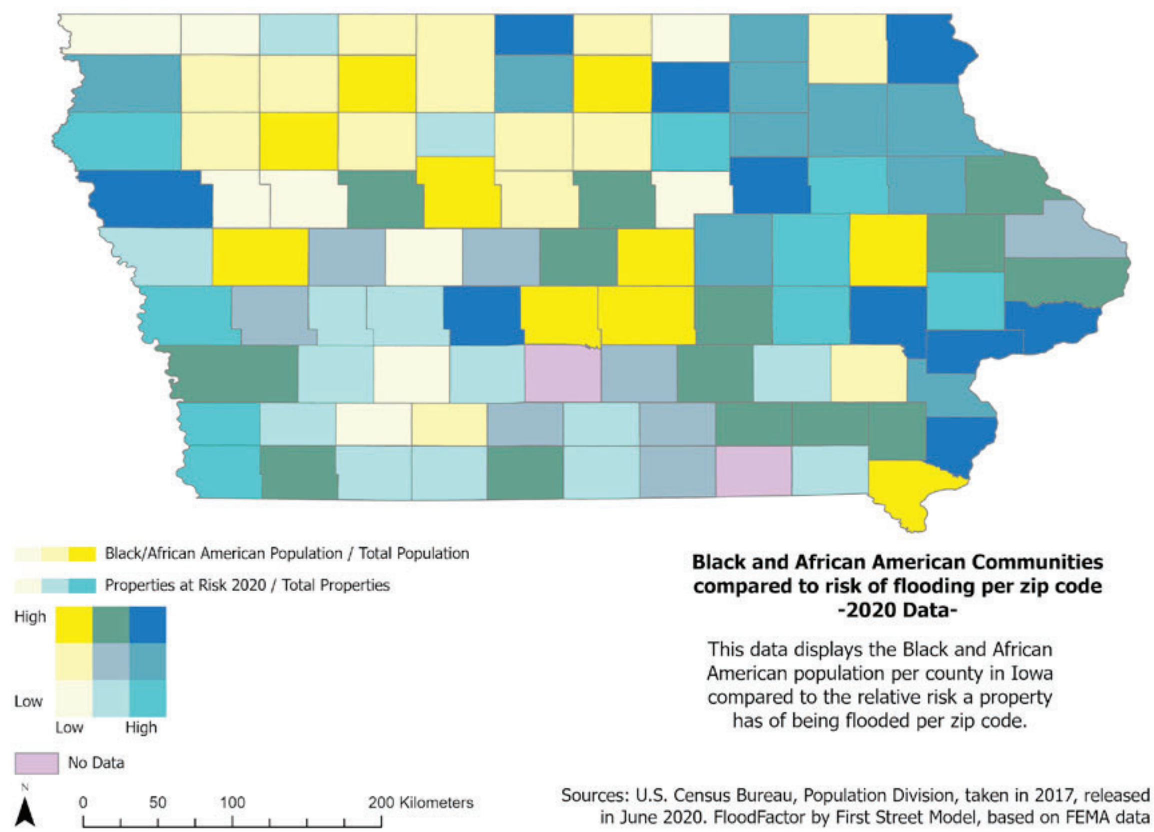


Number of households without a vehicle per census tract compared to risk of flooding per zip code -2020 projection-

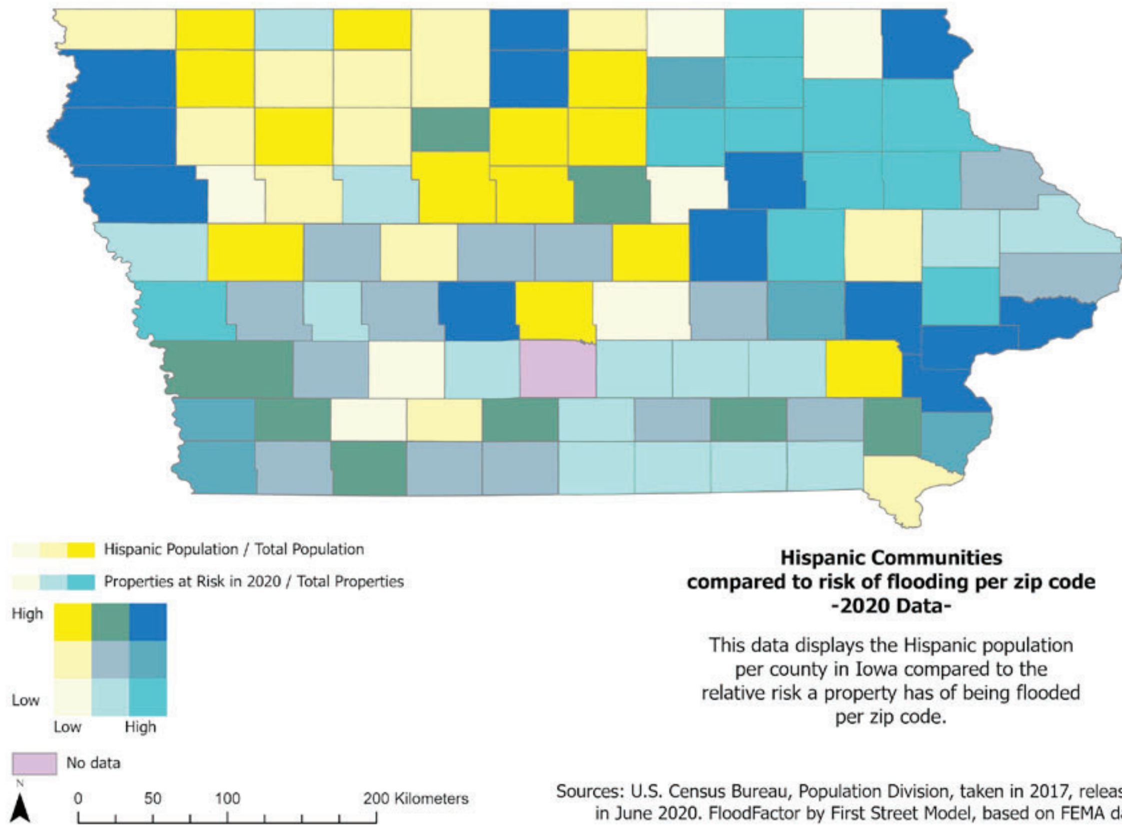


Sources: CDC's Social Vulnerability Index, based on information from ACS 2014-2018 5-year Survey. Floodfactor by First Street Model, based on FEMA data

Black and African American Communities per County compared to 2020 Flood Risk:



Hispanic Communities per County compared to 2020 Flood Risk:

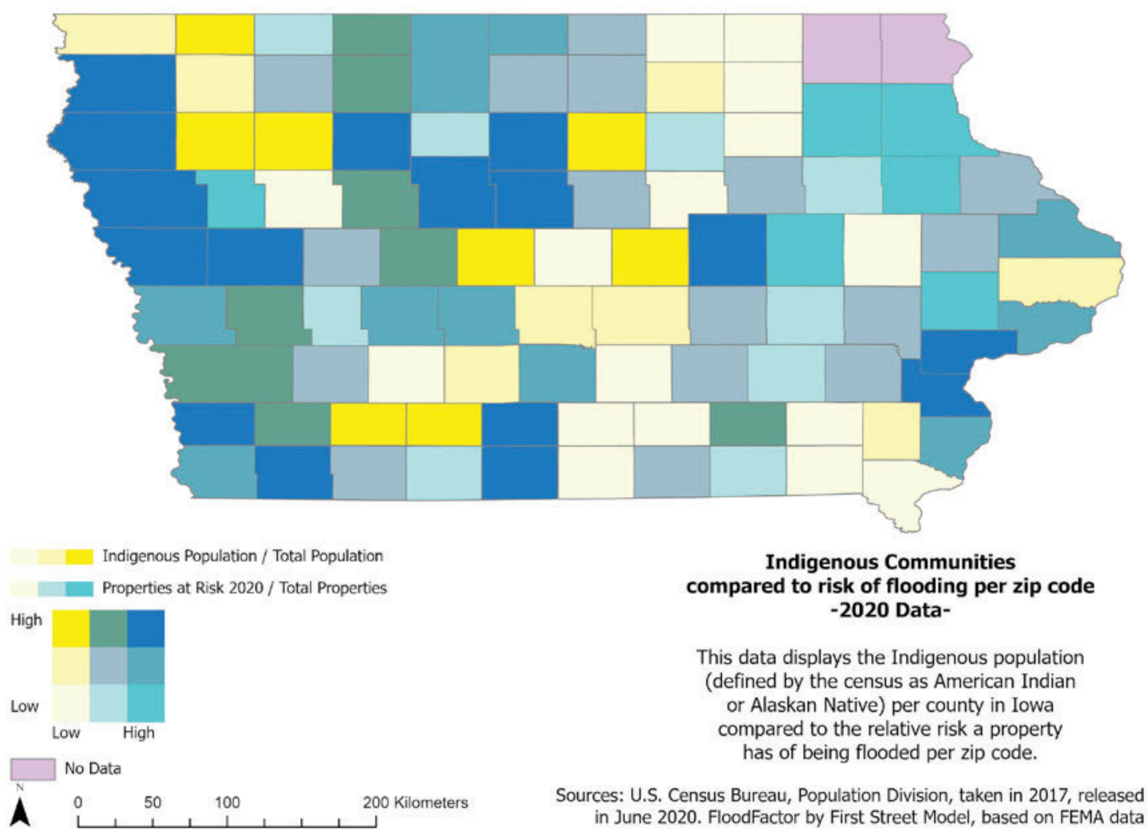


Hispanic Communities compared to risk of flooding per zip code -2020 Data-

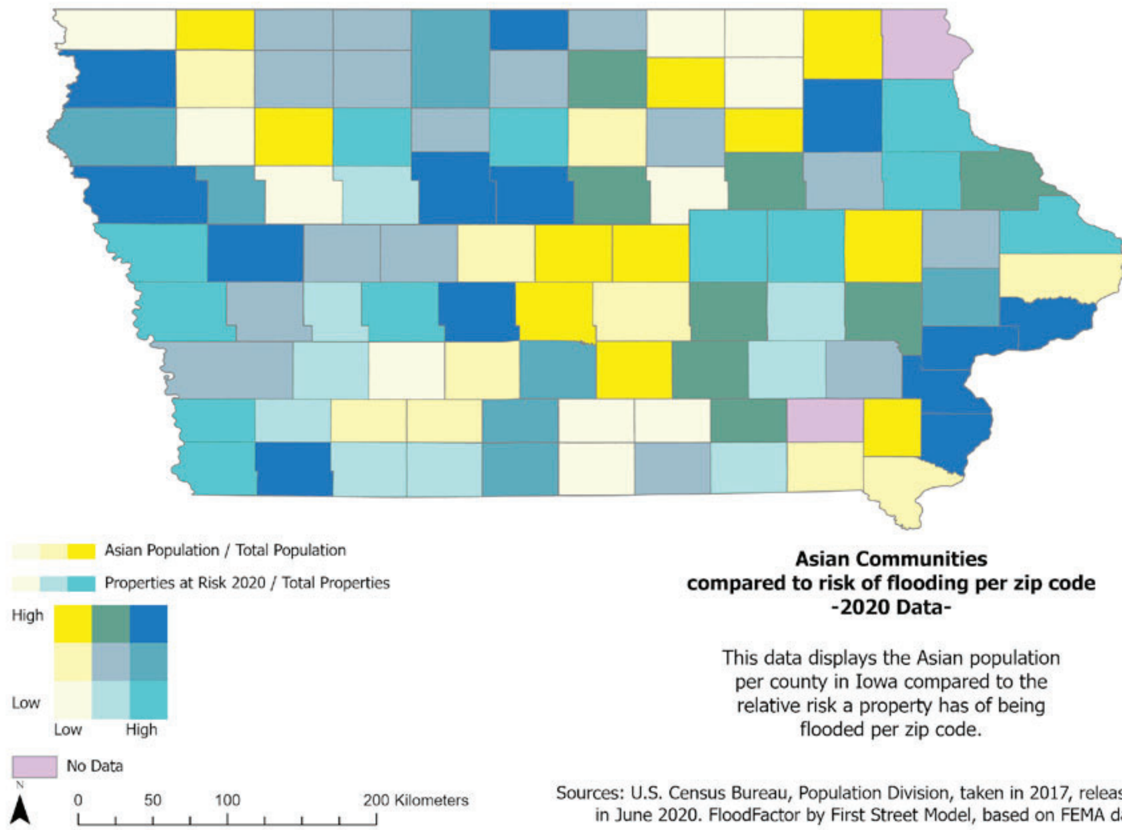
This data displays the Hispanic population per county in Iowa compared to the relative risk a property has of being flooded per zip code.

Sources: U.S. Census Bureau, Population Division, taken in 2017, released in June 2020. FloodFactor by First Street Model, based on FEMA data

Indigenous Communities (American Indian and Native Alaskan) Communities per County compared to 2020 Flood Risk:



Asian Communities per County compared to 2020 Flood Risk:

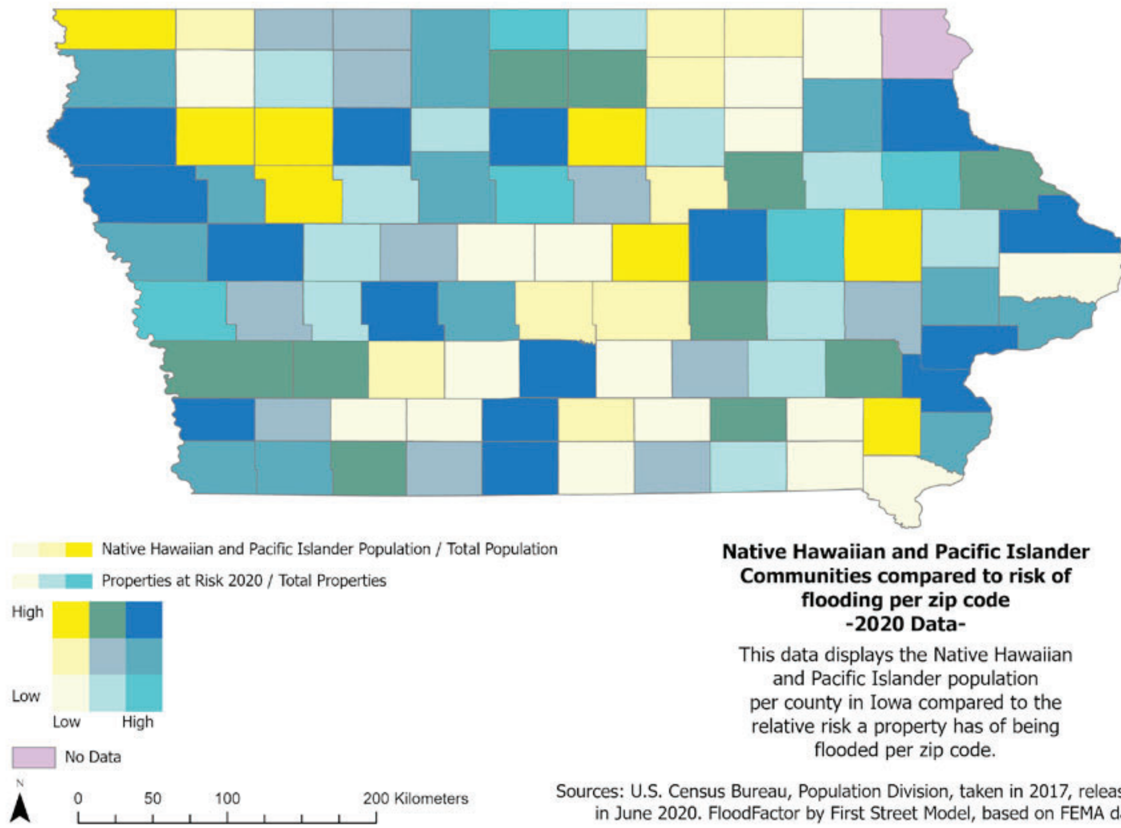


Asian Communities compared to risk of flooding per zip code -2020 Data-

This data displays the Asian population per county in Iowa compared to the relative risk a property has of being flooded per zip code.

Sources: U.S. Census Bureau, Population Division, taken in 2017, released in June 2020. FloodFactor by First Street Model, based on FEMA data

Native Hawaiian and Pacific Islander Communities per County compared to 2020 Flood Risk:

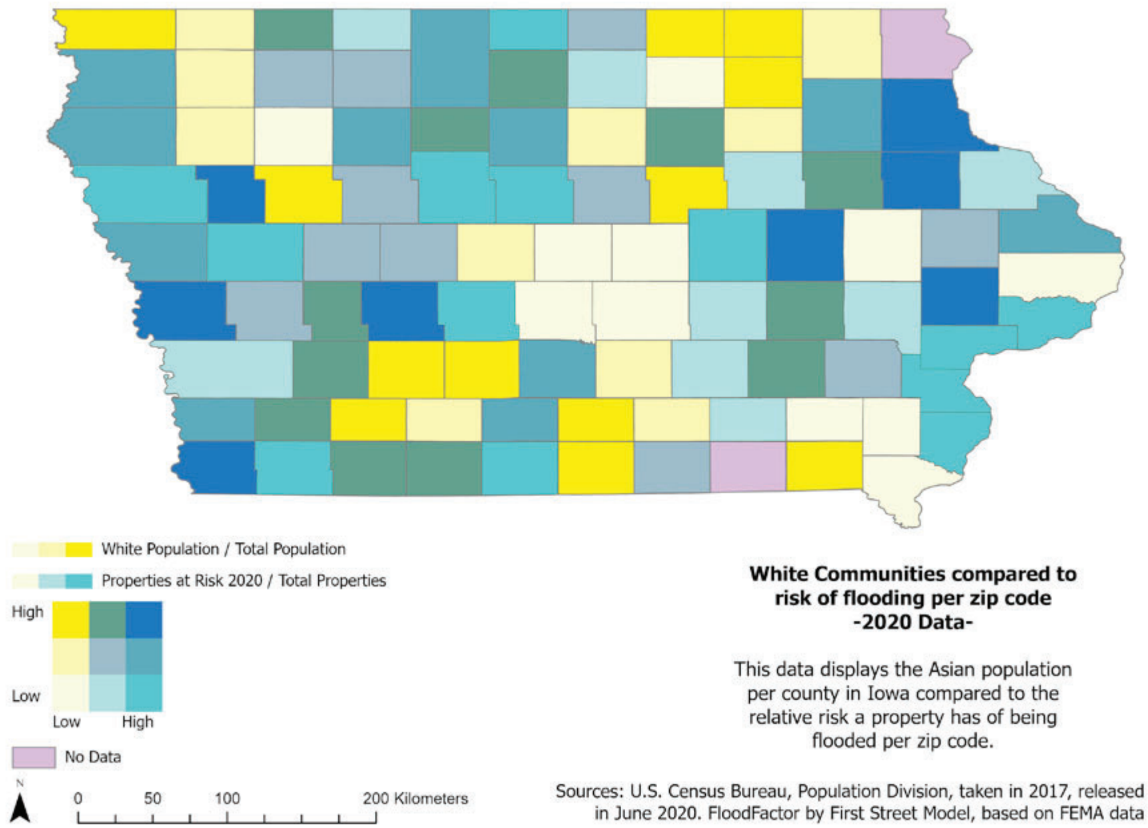


Native Hawaiian and Pacific Islander Communities compared to risk of flooding per zip code -2020 Data-

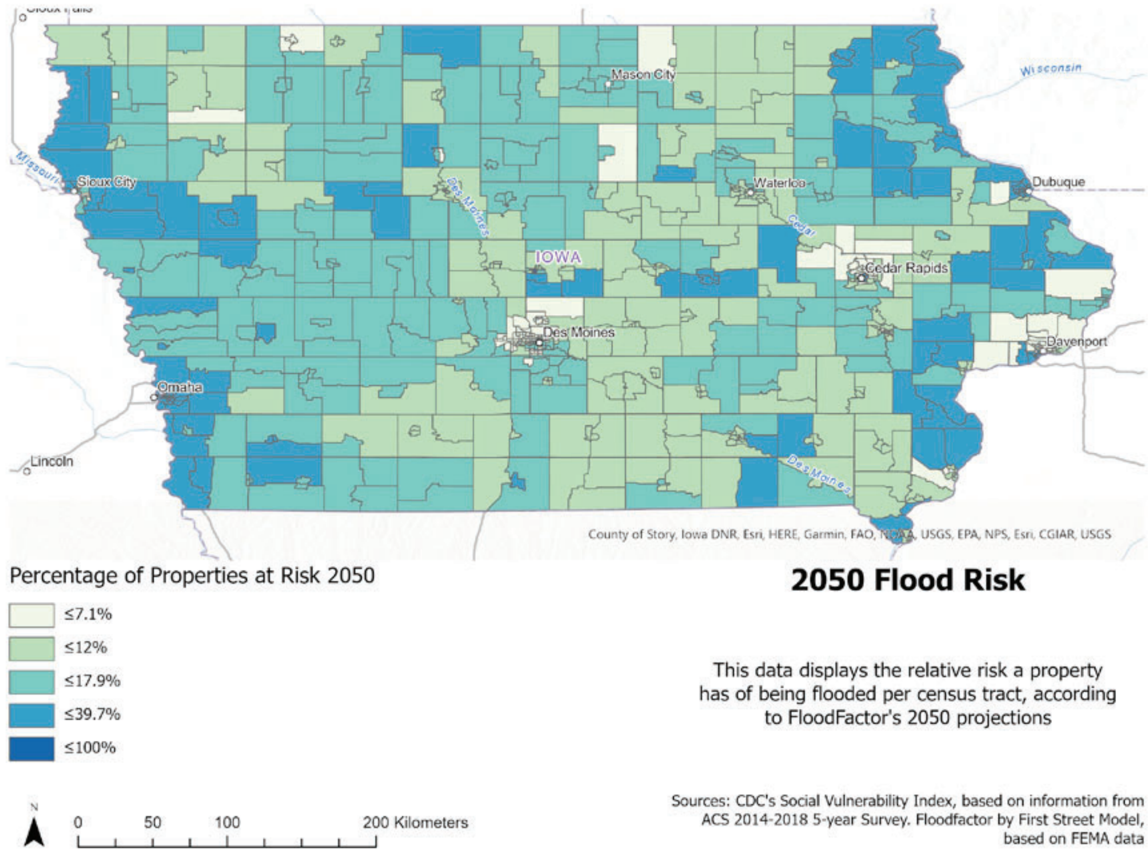
This data displays the Native Hawaiian and Pacific Islander population per county in Iowa compared to the relative risk a property has of being flooded per zip code.

Sources: U.S. Census Bureau, Population Division, taken in 2017, released in June 2020. FloodFactor by First Street Model, based on FEMA data

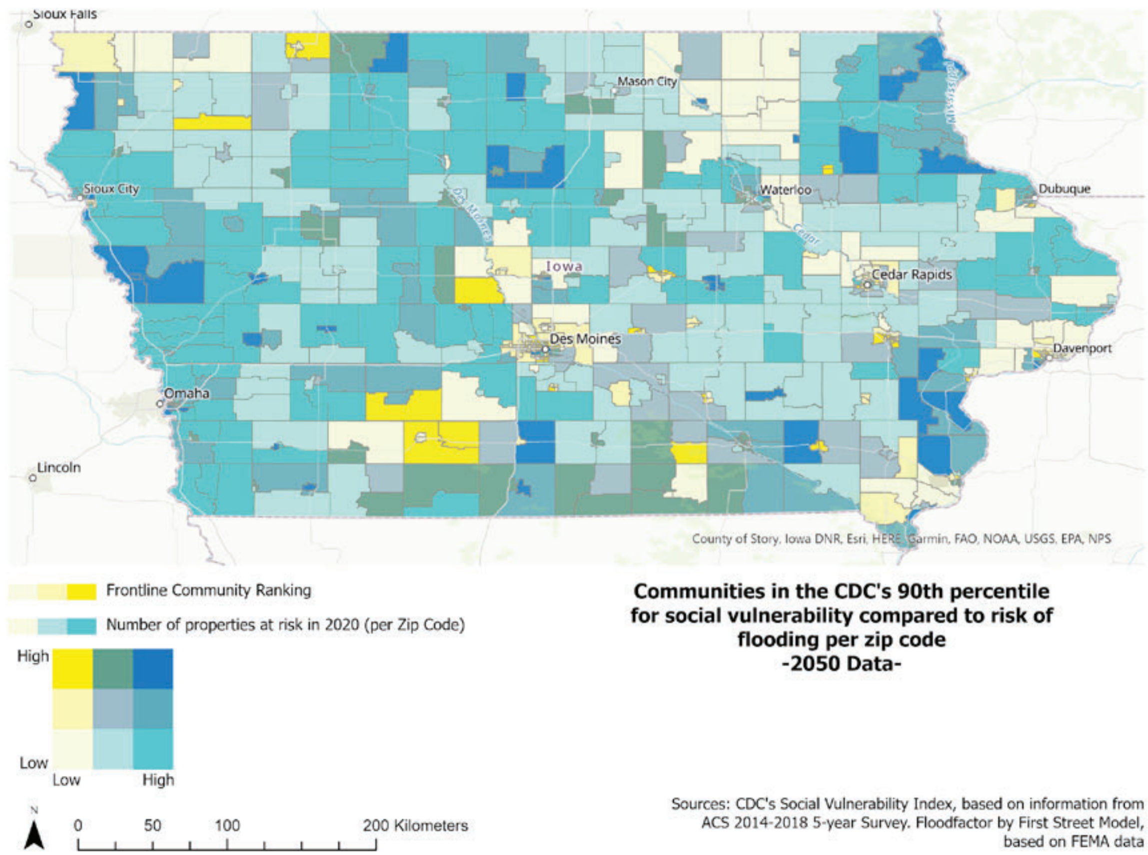
White Population per County compared to 2020 Flood Risk:



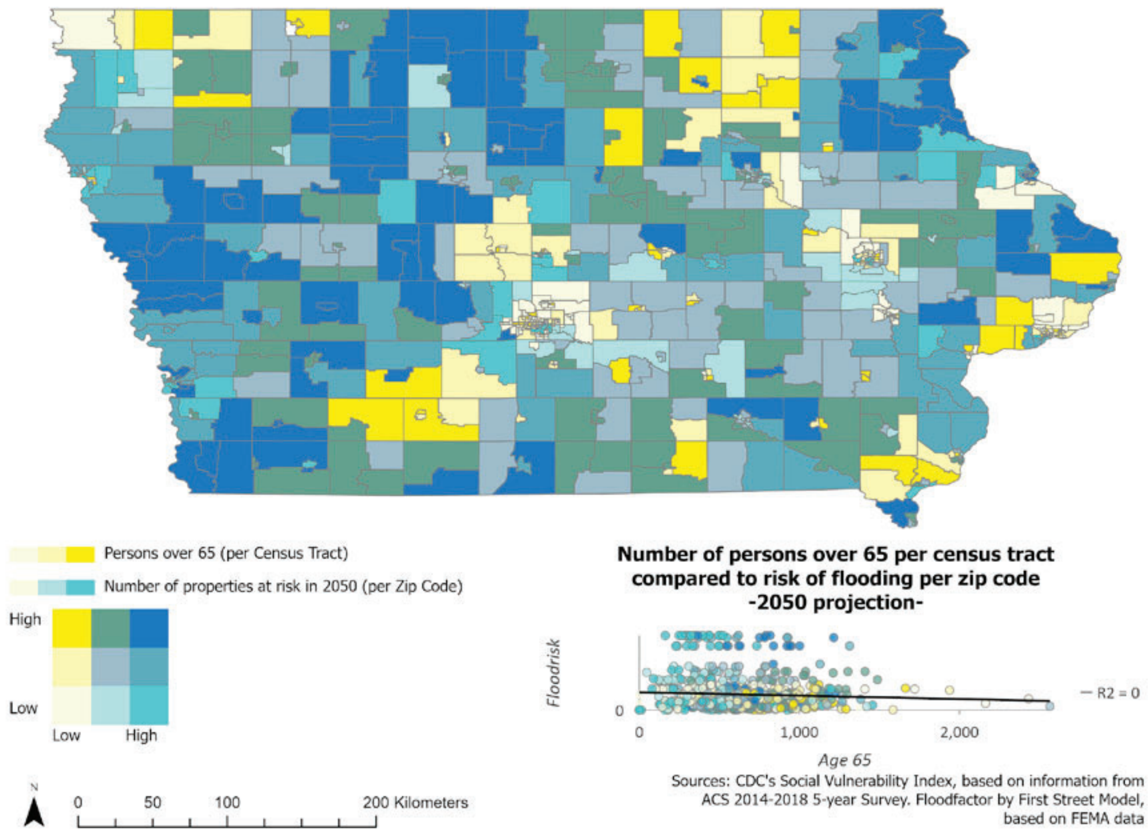
Flood Risk 2050 projection:



Total Communities in the 90th percentile of CDC's SVI compared to 2050 Flood Risk Projection:

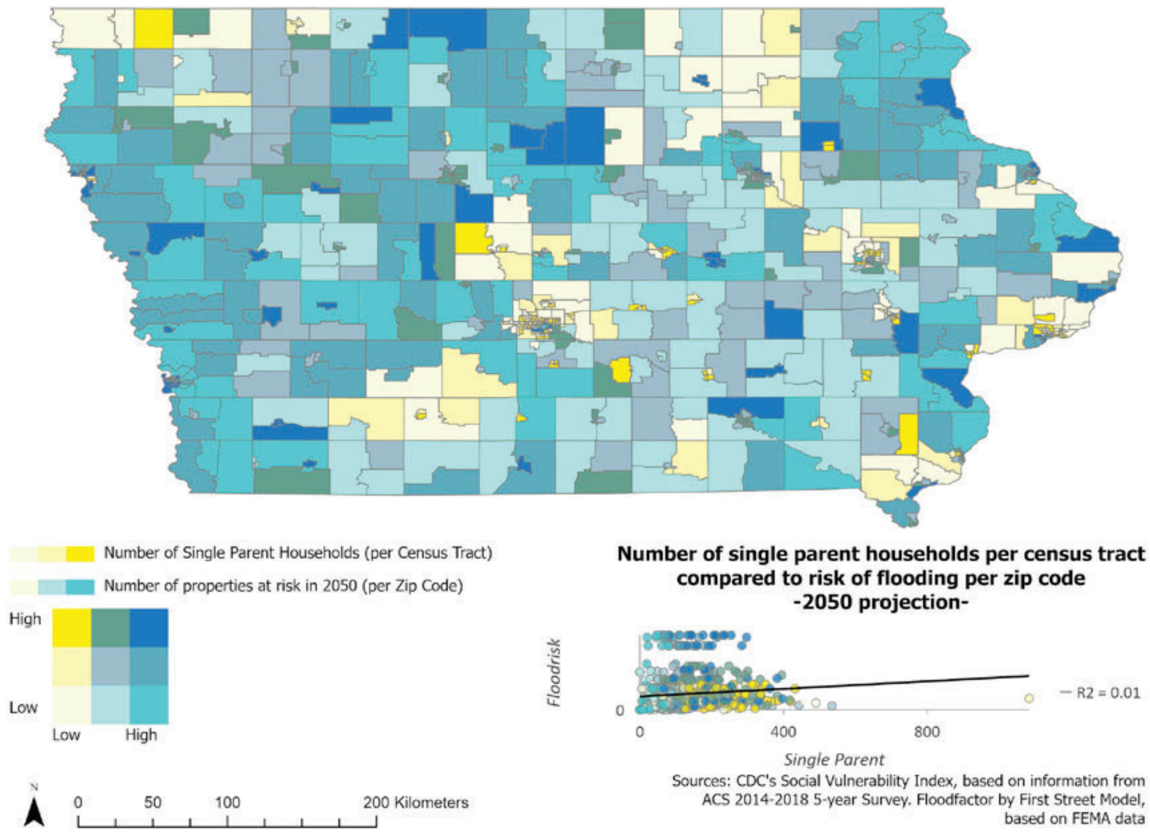


Persons over the age of 65 per Census Tract compared to 2050 Projected Flood Risk:



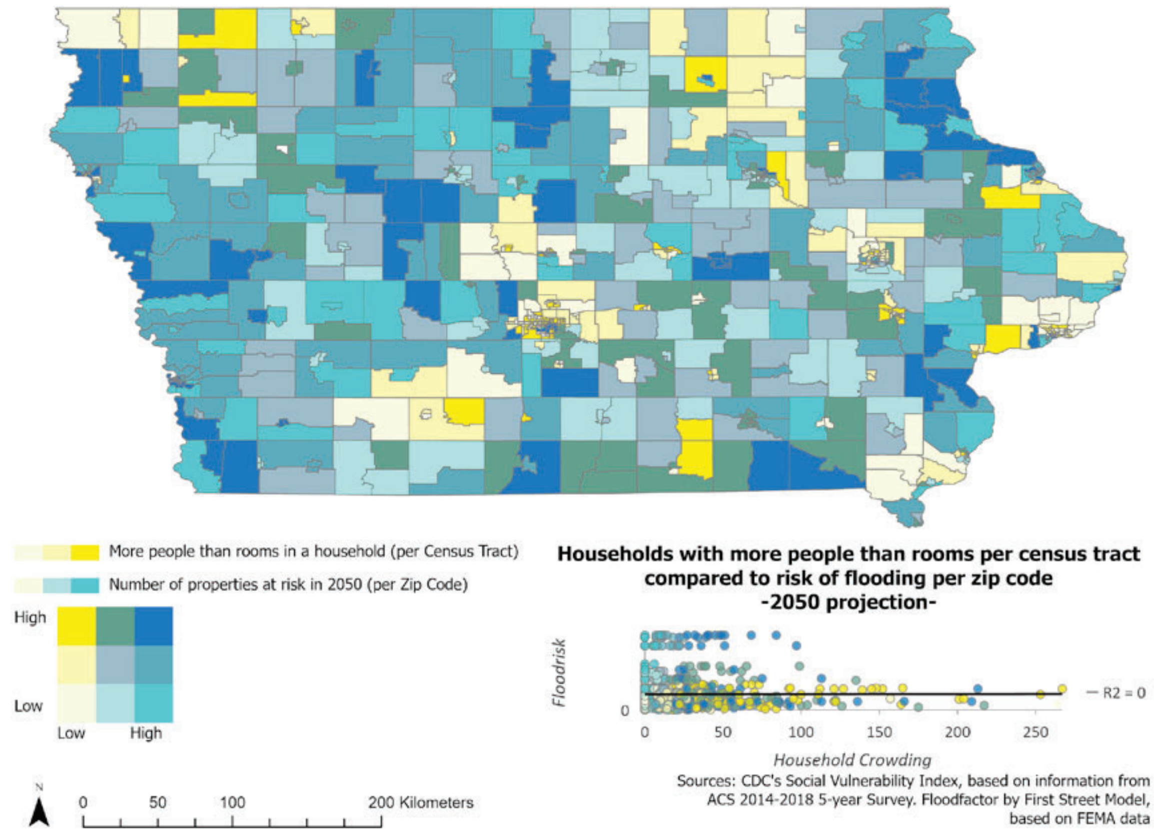
Sources: CDC's Social Vulnerability Index, based on information from ACS 2014-2018 5-year Survey. Floodfactor by First Street Model, based on FEMA data

Single Parent Households per Census Tract Compared to 2050 Projected Flood Risk:



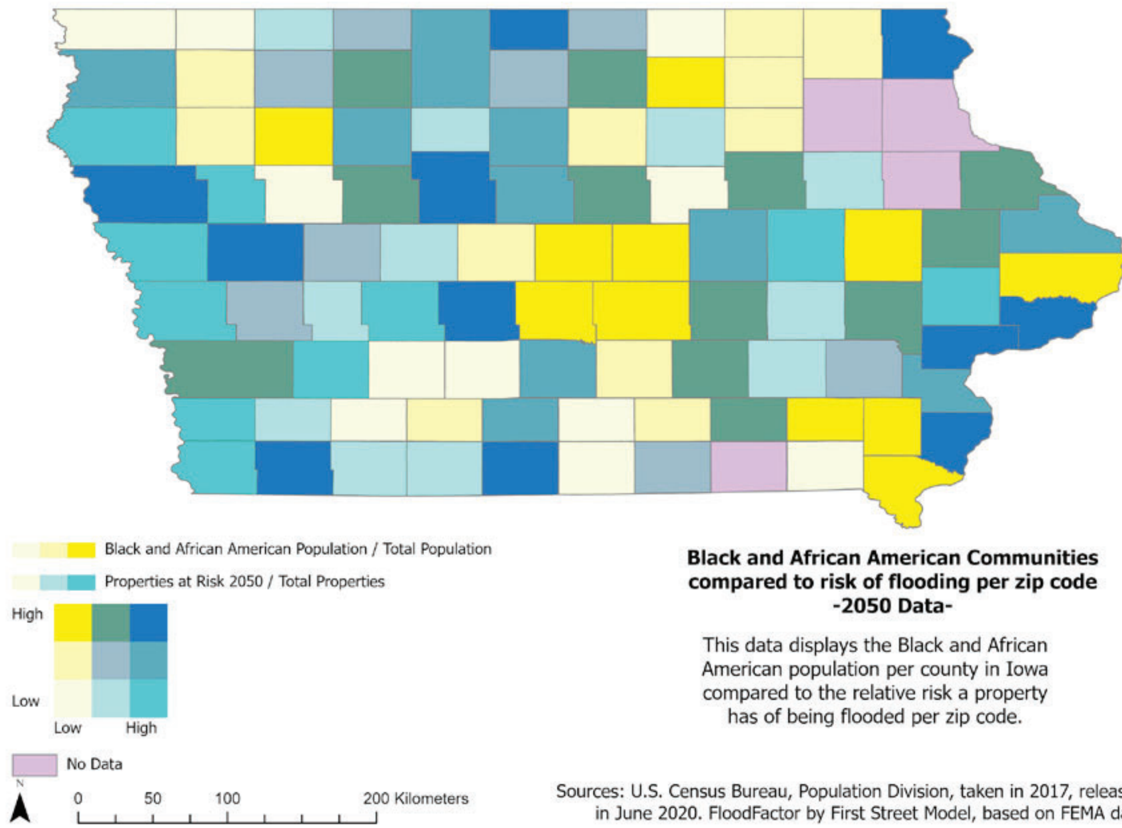
Sources: CDC's Social Vulnerability Index, based on information from ACS 2014-2018 5-year Survey. Floodfactor by First Street Model, based on FEMA data

Household Crowding per Census Tract Compared to 2050 Projected Flood Risk:



Sources: CDC's Social Vulnerability Index, based on information from ACS 2014-2018 5-year Survey. Floodfactor by First Street Model, based on FEMA data

Black and African American Communities per County compared to 2050 Projected Flood Risk:

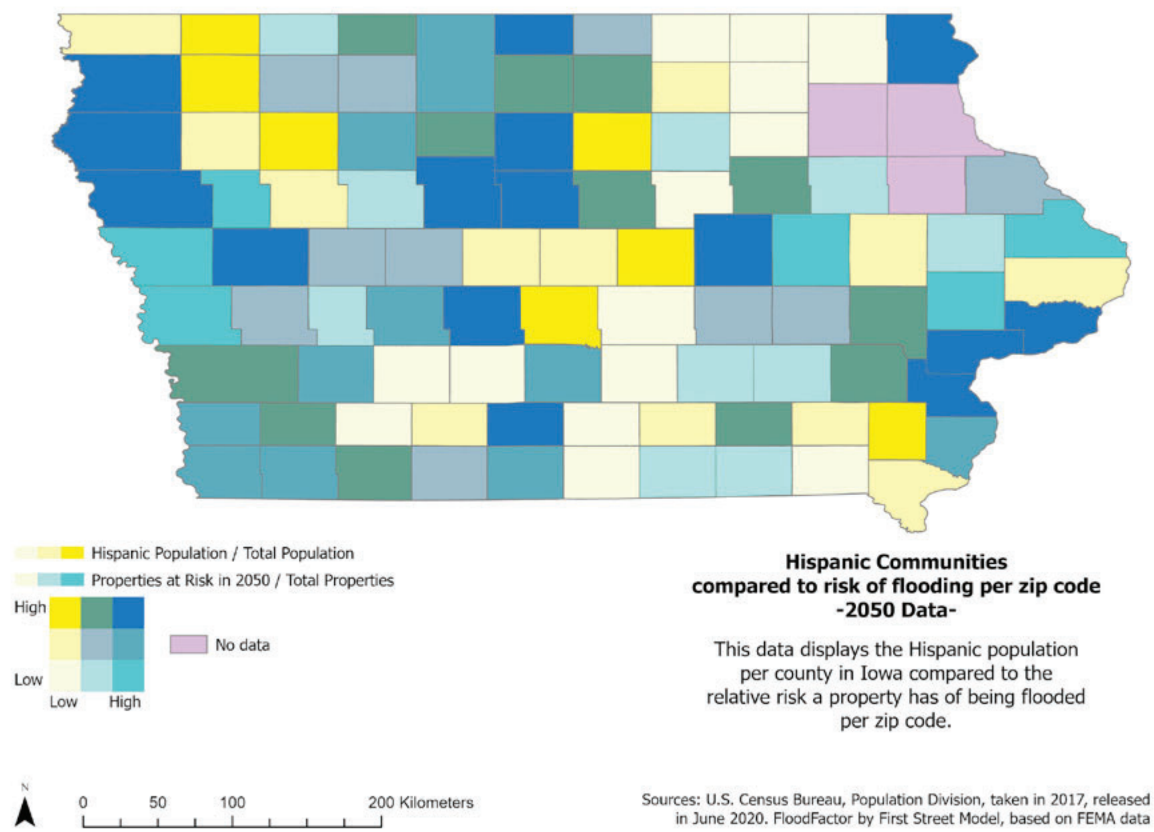


Black and African American Communities compared to risk of flooding per zip code -2050 Data-

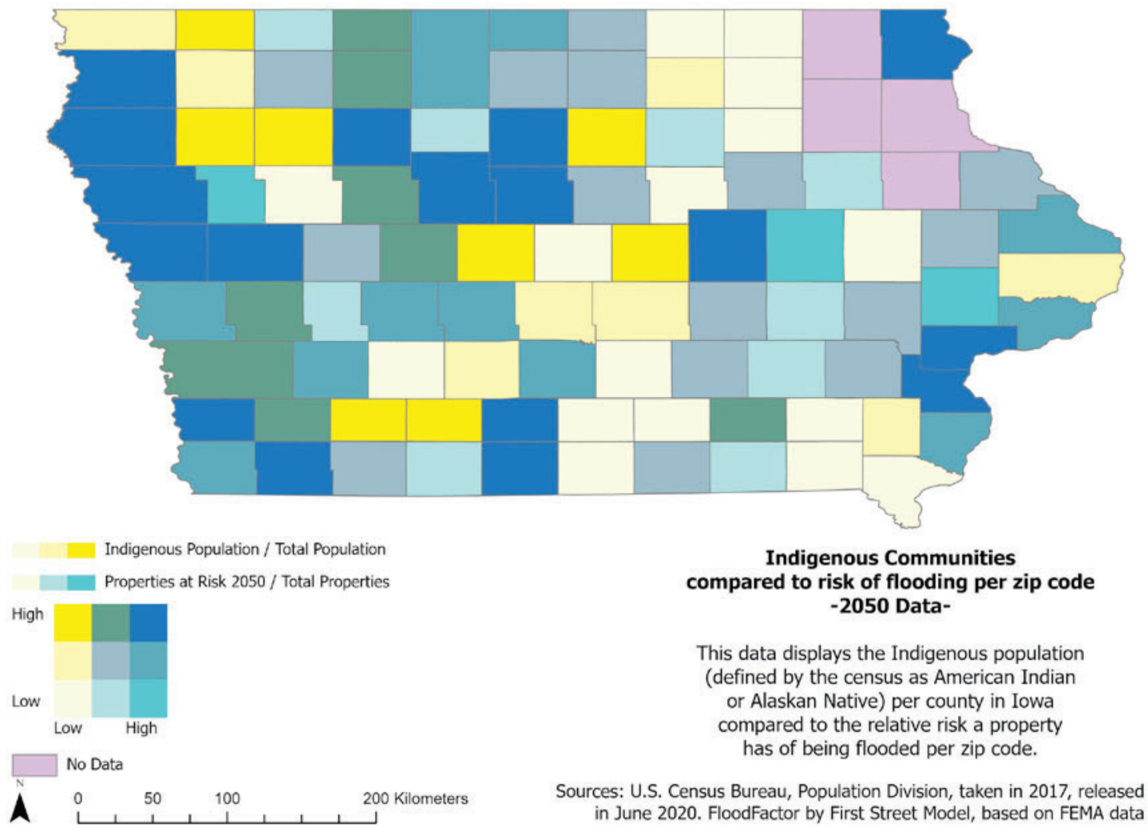
This data displays the Black and African American population per county in Iowa compared to the relative risk a property has of being flooded per zip code.

Sources: U.S. Census Bureau, Population Division, taken in 2017, released in June 2020. FloodFactor by First Street Model, based on FEMA data

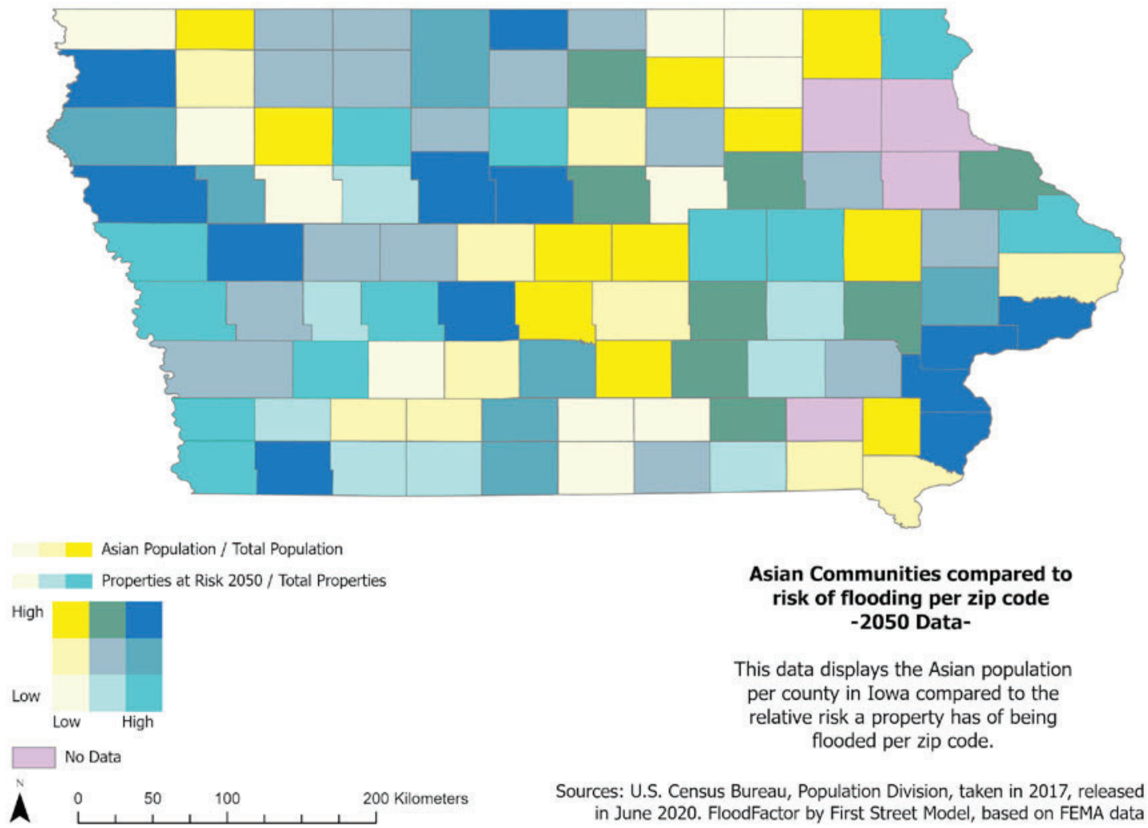
Hispanic Communities per County compared to 2050 Projected Flood Risk:



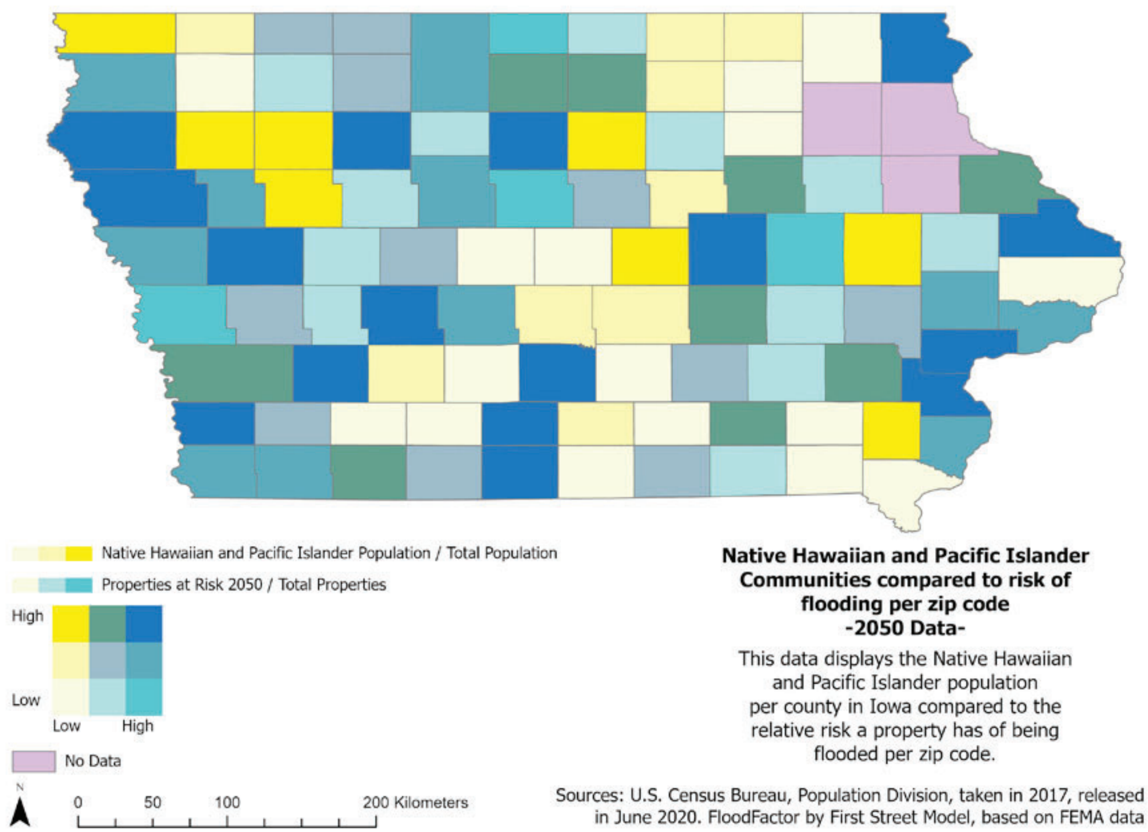
Indigenous Communities (American Indian and Native Alaskan) Communities per County compared to 2050 Projected Flood Risk:



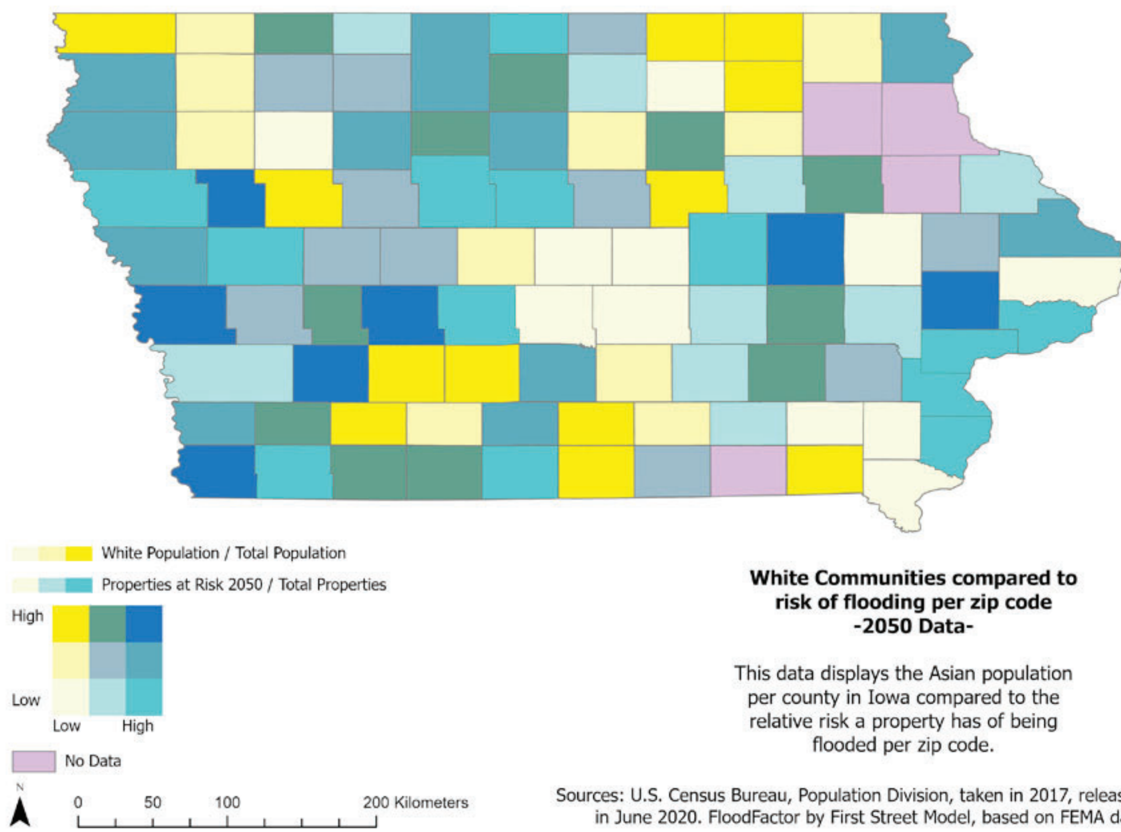
Asian Communities per County compared to 2050 Projected Flood Risk:



Native Hawaiian and Pacific Islander Communities per County compared to 2050 Projected Flood Risk:



White Population per County compared to 2050 Projected Flood Risk:



White Communities compared to risk of flooding per zip code -2050 Data-

This data displays the Asian population per county in Iowa compared to the relative risk a property has of being flooded per zip code.

Sources: U.S. Census Bureau, Population Division, taken in 2017, released in June 2020. FloodFactor by First Street Model, based on FEMA data

APPENDIX B: CHAPTER III APPENDIXES

THE FOLLOWING APPENDIX INCLUDES INTERVIEW GUIDES FROM CHAPTER III

SCHOOL FOR
ENVIRONMENT & SUSTAINABILITY
UNIVERSITY OF MICHIGAN

Appendix B1: Recruitment Email of DMWW case

Dear [interviewee],

My name is [UofM student], and I am a Master's student at the School for the Environment and Sustainability at the University of Michigan. I am currently doing a Capstone project with my teammates to investigate how natural infrastructure can mitigate flood risk and reduce nutrient pollution in the Upper Mississippi River Basin. We hope that our work will increase natural infrastructure implementation and benefit communities that are at high risk of flooding and nutrient pollution, especially low-income communities.

By natural infrastructure, we are referring to land management processes that use, restore, or emulate natural ecological processes by utilizing natural features to achieve water management purposes based on natural physical, geological, biological, and chemical processes over time. These natural infrastructure projects could include two-stage ditches, buffer strips in working lands, restored wetlands, or even reconnecting floodplains in rivers.

We are contacting you because we are interested in better understanding experiences in Des Moines with implementing natural infrastructure projects. As a [interviewee's position], your perspective would be very valuable.

The interview will be recorded for analysis, but will remain completely confidential. The interview will take about an hour to finish. However, you would be free to end it at any time.

Is there a time in the next two weeks that you would be available to meet with us virtually through Zoom? If you'd like, we can also send you a few questions ahead so you can have some time to think about them before we meet.

If you have any questions feel free to respond to this email or contact the team at UMRBnaturalinfrastructure@umich.edu.

Have a great day!

Sincerely,

[UofM Master project team]
M.S. Class of 2021
University of Michigan
UMRBnaturalinfrastructure@umich.edu

Appendix B2: Recruitment Email of MCPP case

Dear [Interviewee],

My name is [UofM student], a Master's student at the School for the Environment and Sustainability at the University of Michigan. I am currently doing a Capstone project with my teammates to investigate how natural infrastructure can mitigate flood risk and reduce nutrient pollution in the Upper Mississippi River Basin. We hope that our work will increase natural infrastructure implementation and will benefit communities that are at high risk of flooding and nutrient pollution, especially low-income communities

By natural infrastructure, we are referring to land management processes that use, restore, or emulate natural ecological processes by utilizing natural features to achieve water management purposes based on natural physical, geological, biological, and chemical processes over time. These natural infrastructure projects could include two-stage ditches, buffer strips in working lands, restored wetlands, or even reconnecting floodplains in rivers.

We are contacting you because we are interested in better understanding experiences in Cedar Rapids with implementing natural infrastructure projects, and specifically the MCPP. As a [Interviewee's position], your perspective would be very valuable.

We understand that the weeks following the derecho storm have been difficult for many families within your community, but our hope is that through understanding barriers and opportunities for natural infrastructure implementation in the region, the worst effects of natural disasters, such as flooding, can be mitigated in the future. The interview will be recorded for analysis, but will remain completely confidential. The interview will take about an hour to finish. However, you would be free to end it at any time.

Is there a time in the next two weeks that you would be available to meet with us virtually through Zoom? Acknowledging that there is still some uncertainty around power and internet connectivity in your area, we would like to be as flexible as possible in scheduling your interview as we value your perspective for this project. If you'd like, we can send you a few questions ahead so you can have some time to think about them before we meet.

If you have any questions feel free to respond to this email or contact the team at UMRBnaturalinfrastructure@umich.edu.

Have a great day!

Sincerely,

[UofM Master project team]
M.S. Class of 2021
University of Michigan
UMRBnaturalinfrastructure@umich.edu

Appendix B3: Des Moines, IA Interview Guide

Thank you for participating in this research project. The purpose of this interview is to get a better understanding of the experiences in Des Moines with implementing natural infrastructure projects, and specifically the Des Moines Water Works lawsuit. We hope to use the results of this project to further the adoption of natural infrastructure in the Upper Mississippi River Basin.

By natural infrastructure[4], I am referring to land management processes that use, restore, or emulate natural ecological processes by utilizing natural features to achieve water management purposes based on natural physical, geological, biological, and chemical processes over time. For example, two-stage ditches, buffer strips in working lands, restored wetlands and reconnected floodplains in rivers and flood plains are considered natural infrastructure.

As a reminder, your personal information and responses will be kept completely confidential. Your participation in this research is voluntary and you are free to stop the interview at any time or to choose to skip questions. The interview should take about **60 minutes**. Before we begin, do you have any questions about the project's purpose or your confidentiality?

With your consent, I will start to record our conversation.

<u>Background Questions</u>

1. What is your title and position?
    a. How long have you been in this position?
    b. Can you briefly describe your work and how it relates to natural infrastructure?
    c. What projects that you participated in or were involved in are you most proud of?
    d. Where did you work previously?

<u>Des Moines Water Works Lawsuit</u>

2. In your mind, what led to the Des Moines Water Works lawsuit?
    a. What was the timeline of events?
    b. What went wrong?
    c. Who were the important actors and players?
3. Take me back to before the Water Works lawsuit, when the results first came

4 .https://www.epw.senate.gov/public/_cache/files/2/f/2f412342-ca2b-440f-8053-a3c25c303db3/F0CE190B720489058518305C-1D359AC4.america-s-transporation-infrastructure-act-edw19827-.pdf

out that the nitrate levels in Des Moines water were high, what efforts were made to reconcile the issue?
   a. What groups were involved?
   b. How would you describe the interactions between these groups?
4. Were there existing tensions between these groups?
5. In your opinion, were the groups interested in collaborating?
6. Retrospectively, what strategies would you have used for things to have turned out differently?

Ending Questions

7. Is there anything that we haven't discussed yet that you would like to share?
8. Do you have suggestions for other groups or individuals you think I should speak with?

Thank you for your time!

Appendix B4: Cedar Rapids, IA Interview Guide

Thank you for participating in this research project. The purpose of this interview is to get a better understanding of the experiences in Cedar Rapids with implementing natural infrastructure projects, and specifically the Middle Cedar Partnership Project. We hope to use the results of this project to further the adoption of natural infrastructure in the Upper Mississippi River Basin.

By natural infrastructure[5], I am referring to land management processes that use, restore, or emulate natural ecological processes by utilizing natural features to achieve water management purposes based on natural physical, geological, biological, and chemical processes over time. For example, two-stage ditches, buffer strips in working lands, restored wetlands and reconnected floodplains in rivers and flood plains are considered natural infrastructure.

As a reminder, your personal information and responses will be kept completely confidential. Your participation in this research is voluntary and you are free to stop the interview at any time or to choose to skip questions. The interview should take about **60 minutes**. Before we begin, do you have any questions about the project's purpose or your confidentiality?

With your consent, I will start to record our conversation.

Background Questions

1. What is your title and position?
    a. How long have you been in this position?
    b. Can you briefly describe your work and how it relates to natural infrastructure?
    c. What projects that you participated in or were involved in are you most proud of?
    d. Where did you work previously?

Middle Cedar Partnership Project

2. What led to the creation of the Middle Cedar Partnership Project?
    a. Who were important actors and players?
    b. How was funding secured?
    c. Why were people motivated to participate?
3. In your mind, what have been the major accomplishments of the Middle Cedar

5 .https://www.epw.senate.gov/public/_cache/files/2/f/2f412342-ca2b-440f-8053-a3c25c303db3/F0CE190B720489058518305C-1D359AC4.america-s-transporation-infrastructure-act-edw19827-.pdf

Partnership Project?

4. What barriers did the partnership face?
5. What helped stakeholders overcome these barriers?
6. Do you see ongoing barriers or obstacles to the success of the Middle Cedar Partnership Project?

Replicating the Success

7. What opportunities do you see for replicating the success of the Middle Cedar Partnership Project in other parts of Iowa?
8. What would facilitate greater uptake of these kinds of approaches in Iowa?

Ending Questions

9. Is there anything that we haven't discussed yet that you would like to share?
10. Do you have suggestions for other groups or individuals you think I should speak with?

Thank you for your time!

Appendix B5: The analysis codebook of comparative case study

Descriptive Code - Level 1	Descriptive Code - Level 2	Description
Actor Motivation	Health concern	Description of the cause of Des Moines Lawsuit and Cedar Partnership project
	Property concern	
Barriers to collaboration	Funding crisis	Barriers identified as inhibiting collaboration in either case
	Opponents to NI	
Case Impact	--	Description of state-wide ramifications of the lawsuit or the Middle Cedar Partnership Project
Case Outcome	Biophysical outcomes	Participants described the outcomes of the Des Moines Lawsuit and Middle Cedar Partnership Program
	Social outcomes	
CR Timeline	--	Timeline of events for the Middle Cedar Partnership Project
DM Timeline	--	Timeline of events for the Des Moines lawsuit
Event driver	--	Participant described a catalyst for the formation of the Middle Cedar Partnership Project or the Des Moines lawsuit
Group interactions	Breach of trust	Description of the interactions between groups in either case
	Existing tension	
	Lack of trust between stakeholders	
	Mutually beneficial relationship	
	Presence of trust between stakeholders	
Important actors	--	Individuals or groups identified by the participant as playing a large role in either case
Land Practice	Between-Field NI	Participant described the NI practice has done during partnership project
	In-Field NI	
	Out-of-field NI	
Opportunities for collaboration	--	Opportunities identified as facilitating collaboration in either case

Strategies for future collaboration	--	Description of how to improve inter-group relations for future collaboration

APPENDIX C: CHAPTER IV APPENDIXES

THE FOLLOWING APPENDIX INCLUDES INTERVIEW GUIDES FROM CHAPTER IV

SCHOOL FOR
ENVIRONMENT & SUSTAINABILITY
UNIVERSITY OF MICHIGAN

Appendix C1: Recruitment Email for Policy Interviewees

Dear [Interviewee],

My name is [UofM student], a Master's student at the School for the Environment and Sustainability at the University of Michigan. I am currently doing a Capstone project with my teammates to investigate how natural infrastructure can mitigate flood risk and reduce nutrient pollution in the Upper Mississippi River Basin. We hope that our work will increase natural infrastructure implementation and will benefit communities that are at high risk of flooding and nutrient pollution, especially low-income communities.

By natural infrastructure, we are referring to land management processes that use, restore, or emulate natural ecological processes by utilizing natural features to achieve water management purposes based on natural physical, geological, biological, and chemical processes over time. These natural infrastructure projects could include two-stage ditches, buffer strips in working lands, restored wetlands, or even reconnecting floodplains in rivers.

We are contacting you because we are interested in better understanding existing policy barriers and opportunities for natural infrastructure implementation in Iowa. As a [interviewee's position], your viewpoint would be very valuable. The interview will be recorded for analysis, but will remain completely confidential. The interview will take about an hour to finish. However, you would be free to end it at any time.

Is there a time in the next two weeks that you would be available to meet with us virtually through Zoom? If you'd like, we can send you a few questions ahead so you can have some time to think about them before we meet.

If you have any questions feel free to respond to this email or contact the team at UMRBnaturalinfrastructure@umich.edu.

Have a great day!

Sincerely,

Madison Goff, Wanying Wu, Dana VanHuis, and Joey Dierdorf
M.S. Class of 2021
University of Michigan
UMRBnaturalinfrastructure@umich.edu

Appendix C2: Policy Interview Guide

Thank you for participating in this research project. The purpose of this interview is to get a better understanding of the existing policy barriers and opportunities for natural infrastructure implementation in Iowa. We hope to use the results of this project to further the adoption of natural infrastructure in the Upper Mississippi River Basin.

By natural infrastructure[6], I am referring to land management processes that use, restore, or emulate natural ecological processes by utilizing natural features to achieve water management purposes based on natural physical, geological, biological, and chemical processes over time. For example, two-stage ditches, buffer strips in working lands, restored wetlands and reconnected floodplains in rivers and flood plains are considered natural infrastructure.

As a reminder, your personal information and responses will be kept completely confidential. Your participation in this research is voluntary and you are free to stop the interview at any time or to choose to skip questions. The interview should take about **60 minutes**. Before we begin, do you have any questions about the project's purpose or your confidentiality?

With your consent, I will start to record our conversation.

Background Questions

1. What is your title and position?
    a. How long have you been in this position?
    b. Can you briefly describe your work and how it relates to natural infrastructure?
    c. What projects that you participated in or were involved in are you most proud of?
    d. Where did you work previously?

Water Issue Questions

2. What do you feel are the most important water issues in Iowa?
3. How has your work related to water issues such as nutrient pollution or flooding in Iowa?/How has your work related to agricultural practices in Iowa?/How has your work related to [water issue stated in response to Q2] in Iowa?
4. What would you say are your biggest considerations when making decisions about flood management in Iowa? About nutrient control?

6 .https://www.epw.senate.gov/public/_cache/files/2/f/2f412342-ca2b-440f-8053-a3c25c303db3/F0CE190B720489058518305C-1D359AC4.america-s-transporation-infrastructure-act-edw19827-.pdf

5. How prominent are questions of racial and economic justice in water policy discussions in Iowa?

Natural Infrastructure Policy Opportunities and Barriers

6. What do you view as being the main obstacle or set of obstacles to natural infrastructure adoption in Iowa?
    a. Are there any policies or programs that you feel have particularly impeded the adoption of natural infrastructure in Iowa?
7. What do you view as best facilitating natural infrastructure adoption in Iowa?
    a. Are there any policies or programs that you feel have been particularly enabling for the adoption of natural infrastructure?
    b. Are there strategies that you have found useful in your work?
8. Who do you see as key actors in promoting the adoption of natural infrastructure in Iowa?
    a. Alternatively, who do you see as the biggest opponents to natural infrastructure in Iowa?
9. Are there stakeholder groups that aren't being included in decision making processes related to natural infrastructure that you feel should be included?
10. What level of government (federal, state, local) has the most impact on the adoption of natural infrastructure in Iowa?
11. Based on your experience, who do you think most benefits from natural infrastructure policies?

Ending Questions

12. Is there anything that we haven't discussed yet that you would like to share?
13. Do you have suggestions for other groups or individuals you think I should speak with?

Thank you for your time!

Appendix C3. Policy Analysis Codebook

Descriptive Code - Level 1	Descriptive Code - Level 2	Description
Adoption Strategies	Coalition building	Strategies utilized by the participant in their work to promote the adoption on natural infrastructure
	Community engagement	
	Message framing	
	Technical support	
Beneficial programs and policies	Federal beneficial programs and policies	Programs and policies (sorted by level of government) identified by the participant as being beneficial to the adoption of natural infrastructure
	State beneficial programs and policies	
	Local beneficial programs and policies	
Beneficiaries	--	Groups identified by the participant as most benefiting from the implementation of natural infrastructure
Decision-making considerations	--	Biggest considerations the participant makes about water issue decision-making in Iowa
Exclusion	--	Groups or actors that are being excluded from the decision-making processes related to natural infrastructure in Iowa
Facilitative actors	--	Actors identified by the participant as being facilitative to the adoption of natural infrastructure

Level of Intervention	Federal intervention	Level of government that the participant identified as having the greatest impact on the implementation of natural infrastructure in Iowa
	State intervention	
	Local intervention	
Obstacles and Barriers	Federal obstacles and barriers	Obstacles and barriers to the implementation of natural infrastructure in Iowa (sorted by level of government)
	State obstacles and barriers	
	Local obstacles and barriers	
Justice	--	Participants acknowledgement of racial and economic justice in relation to water issues in Iowa
Needed Resources	--	Resources or capacity that are needed to the successful implementation of natural infrastructure
Obstructionist actors	--	Participant identified the biggest opponent(s) to natural infrastructure
Obstructionist programs and policies	Federal obstructionist programs and policies	Programs and policies identified by the participant as being barriers or actively working against the adoption of natural infrastructure (sorted by level of government)
	State obstructionist programs and policies	
	Local obstructionist programs and policies	
Pivotal Resources	--	Resources or capacity that was essential to the implementation of natural infrastructure