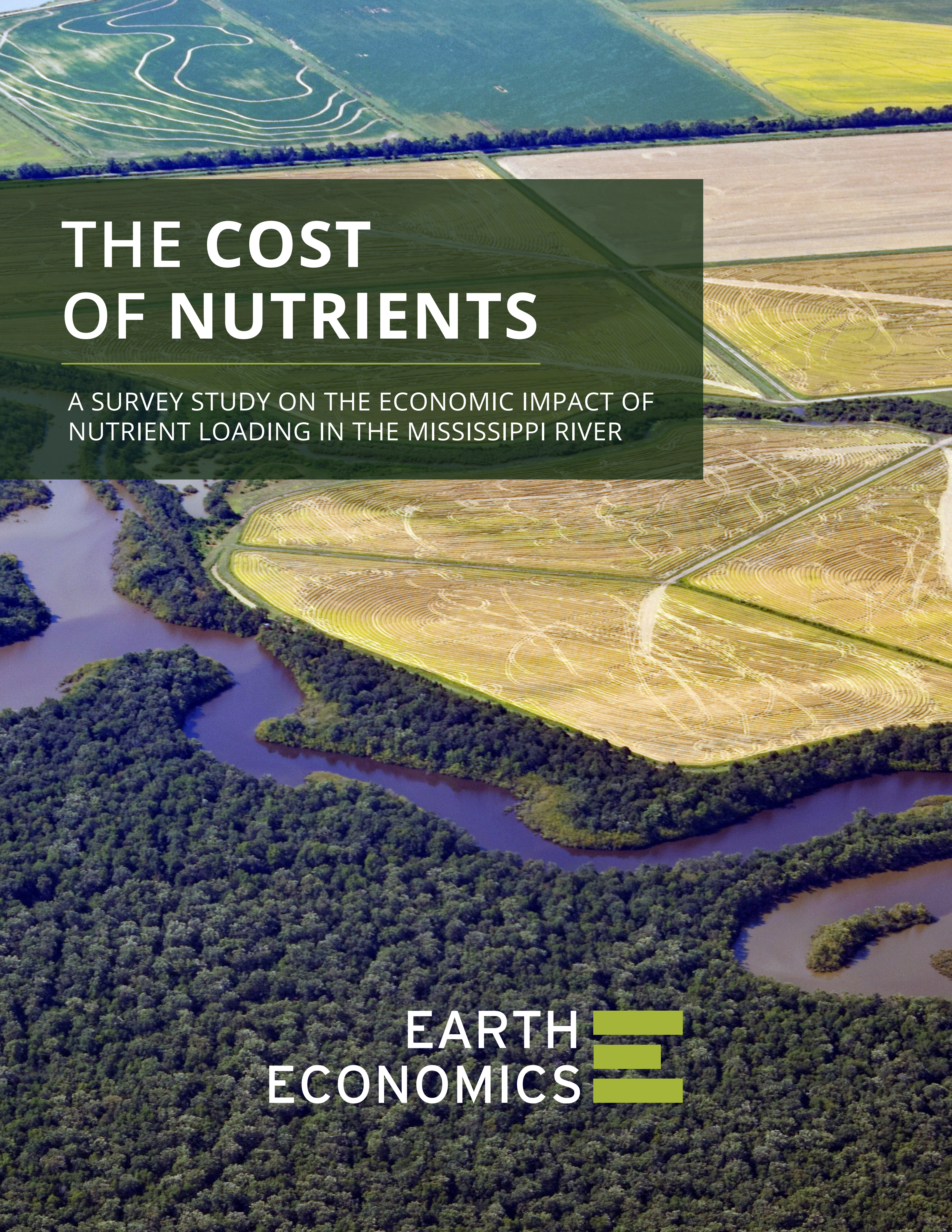

THE COST OF NUTRIENTS

A SURVEY STUDY ON THE ECONOMIC IMPACT OF NUTRIENT LOADING IN THE MISSISSIPPI RIVER

EARTH ECONOMICS

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EXECUTIVE SUMMARY

Water quality in the Mississippi River and Gulf of Mexico has been compromised by human activities that contribute nitrogen and phosphorus ("nutrients") to the watershed. Nutrient loading in the Mississippi River is costly to both the public and private sectors of cities, towns, and states through which the river flows. However, the total economic burden associated with nutrient loading in the Mississippi River has not been comprehensively studied.

Earth Economics, in partnership with the Mississippi River Cities and Towns Initiative (MRCTI), conducted a survey study of over 120 cities and towns along the main stem Mississippi River ("region") to identify potential sources of costs associated with nutrient-rich water. **A review of publicly available data on the costs of nutrients reveals evidence from in and around the Mississippi River Basin of economic and/or ecological impacts across seven sectors of the economy: water treatment, manufacturing, agriculture, recreation, and natural resource harvest.**

The most readily available cost data relates to nutrient removal technologies for treating drinking water and wastewater, as well as nutrient mitigation costs for on-farm technologies and practices. For example, Louisiana's aquifer is starting to dry up as groundwater levels have fallen over recent decades.[1,] A future deep dive study of New Orleans would detail the costs that their drinking water facilities incur from treating Mississippi River water so that it can provide estimates for better planning to nearby river cities and towns—like Baton Rouge—that may consider sourcing river water to supplement their drinking water supply as groundwater depletes.

After identifying these cost data, this report looked for key variables within the communities of the region that will influence how communities incur costs from nutrient-laden water. Highlights include:

- There are at least 35 drinking water treatment facilities across 27 cities and towns treat water from the Mississippi River for community drinking water, serving no less than 67 percent of the total population in the region.
- There are at least 54 effluent discharge facilities across 48 cities or towns in Illinois, Iowa, Louisiana, Minnesota, Wisconsin, and Tennessee that: 1) discharged nitrogen and/or phosphorus directly to the Upper or Lower Mississippi River watersheds in 2020; 2) are located within 2 km of the River; and 3) are classified as "likely contributing to impairments" by the EPA.
- There are 371 food and beverage manufacturers located within 1 mile of the main stem Mississippi River. Food and beverage manufacturers would most likely require nutrient removal treatment if using river water for use in the facility, but also for their nutrient-rich wastewater. Focusing on facilities within 1 mile of the river is intended to increase the likelihood of finding private facilities bearing these costs.
- Cropland and forests make up about 35% and 24%, respectively, of all land in the region's counties. This includes over 5.5 million acres of corn and 6.8 million acres of soybeans—the two dominant crops in the region.
- There are nearly 19,000 livestock operations in the counties of the region as of 2017.

Earth Economics used these findings to develop a set of criteria to choose two sites for a future deep dive study that would detail the costs associated with nutrient loading to individuals, as well as the public and private sectors. **The chosen sites are New Orleans, LA and "Quad Cities" in IA and IL (includes Davenport and Bettendorf, IA and Rock Island, Moline, and East Moline, IL).** The sites are defined as the region of economic dependence on the central city (or the statistical areas defined by the census)—for example, Metairie and Kenner would be included for New Orleans.

These sites were chosen because they collectively represent:

1. Cities that get their drinking water from the Mississippi River; likely among the most significant

cost drivers;

2. Evidence of impaired waters and nearby industry likely to bear costs of nutrient loading (e.g., agriculture, recreation, manufacturing, etc.);
3. Different populations and densities, as well as diverse geographies and watersheds;
4. Areas with greater social vulnerability and climate risk.

Additional research in the selected deep-dive communities based on this study will be a unique and important effort that brings together data from multiple sources to focus on how nutrient-loaded water imposes additional costs to communities large and small across the Mississippi River Basin. Ultimately, this study has identified important data on the costs of nutrient loading to different sectors of the economy. Some of these data are local, others are not; these in turn will need to be scaled, normalized, and augmented with targeted primary data collection, and paired with a clear understanding of the ecological process by which nutrients impose costs on communities.

Using this report as its foundation, a future deep dive could provide important estimates of returns on investment for nutrient reduction strategies that would help coordinate efforts between the public and private sectors and aid policy development to improve water quality for stakeholders across the Mississippi River Basin.

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1. INTRODUCTION

1.1. Background & Objectives

Nitrogen and phosphorous ("nutrients") from both industrial point sources and agricultural nonpoint sources flow into the Mississippi River (MSR) and its tributaries, compromising water quality. Contaminated water is costly water, and this report outlines Earth Economics' approach for identifying relevant data, selecting a representative sample of two river communities for focused case studies, estimating the market and nonmarket costs of nonpoint nutrient loading, and identifying the populations who bear the burden of such costs.

In this phase of the project, Earth Economics conducted a survey of costs for nutrient loading at a regional scale in order to determine those cities best suited for a deeper-dive investigation in the next phase. Earth Economics has identified data sources and formulated a detailed plan for how to study such costs and the likely form costs may take (e.g., opportunity costs, replacement costs, electricity costs, and whether such costs are relatively stable, or increase over time). This report outlines how case study communities were selected and provides a roadmap for identifying and reporting the costs those communities incur as they contend with the effects of nutrient loading.

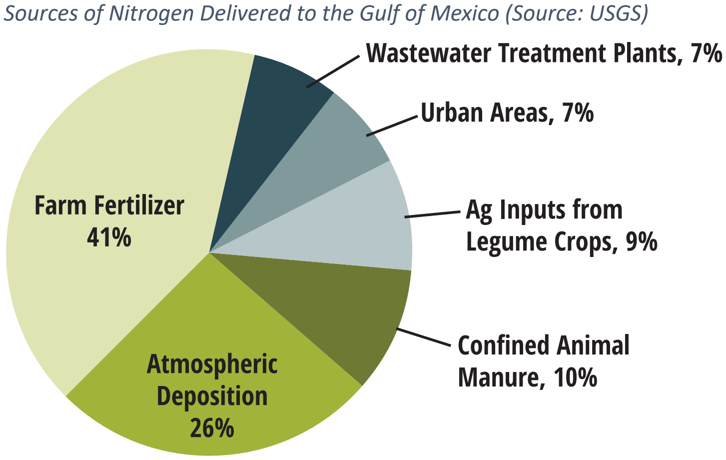
For the purpose of this report, "region" refers to all cities, towns, and counties directly adjacent to the Mississippi River (Appendix A).

1.2. Nutrient Loading in the Mississippi River

Nitrogen (N) and phosphorus (P) are essential nutrients for plant and animal growth, but agricultural and urban runoff can create an overabundance of nutrients in waterways (Figure 1). For example, when farmers fertilize their crops or homeowners fertilize their lawns and gardens, a portion of that fertilizer containing N and P can wash into storm drains or nearby streams that drain to the MSR and ultimately the Gulf of Mexico. The process of loading a water body with nutrients is called "eutrophication."

Once nutrients reach the Gulf, a convergence of conditions including warm temperatures and low turbidity often provided by summer months can produce harmful agal blooms (HABs) that release toxins and use up oxygen in the water. This produces a "dead zone" where oxygen levels drop below the threshold to support aquatic life. Harmful toxins produced by algal blooms can also enter the food supply via shellfish. The reason HAB formation is a consequence of nutrient runoff is because nitrogen is considered the "limiting nutrient," which means that algae growth is limited when N is in short supply. As N loading in the MSR has increased over time, so has the frequency and size of algal blooms in the Gulf of Mexico.

Figure 1. Sources of Nitrogen Delivered to the Gulf of Mexico (Source: USGS)



Nitrogen and phosphorus have different chemical properties, which influences how they enter and move through the MSR. One key difference is that N is more water soluble than P: N is dissolved by and moves with water, whereas P most commonly binds to sediments and reaches the MSR via erosion. These nutrients assume different chemical forms as they enter and cycle through water systems, and some forms pose greater risk than others.

Of the common forms, nitrate (NO_3^-) poses the greatest health risk to humans when it gets into the drinking water supply, because it reduces the ability of blood cells to carry oxygen. Infants are especially susceptible to nitrate: consuming water or food prepared with water that contains high levels of nitrates can cause "blue baby syndrome." From 1980–2010, the upper MSR—north of Clinton, IA—nitrate concentration increased by 70%, and the MSR south of Clinton, IA increased by 17%–19%.

Whereas N is the limiting nutrient for HABs in the Gulf, P is the limiting nutrient for HABs in freshwater. Lakes and reservoirs are often recreational areas where humans and animals can be exposed to the toxins released by HABs.

Because of the risk these nutrients pose to human and animal health, the U.S. Clean Water Act and EPA established regulatory standards for discharging wastewater and Total Maximum Daily Load (TMDL) limits for impaired waters. A TMDL is the maximum amount of a pollutant the water body can take and still meet water quality standards, and each is determined individually for pollutants and water bodies. However, even when the MSR meets EPA water quality standards, river water still needs to be treated substantially before certain uses, like municipal drinking water or food and beverage manufacturing. Water treatment plants need to turn on nutrient treatment systems when nutrient loads increase and remain elevated, often at significant cost. Beyond the cost to turn on nutrient removal systems, increased nutrient loading in the MSR has prompted expensive upgrades to water treatment plants and more stringent regulations for wastewater discharge.

2. THE COST OF NUTRIENTS

The different chemical properties of N and P are important to consider because they influence the pathways by which they impose costs upon MSR communities. These pathways, and the data that support them, are mapped in the following section.

2.1. Approach

All data used in this survey study had to meet specific criteria for inclusion:

Publicly available data

Data included in this study are sourced from publicly available government reports and databases or peer-reviewed scientific literature. While it is possible to fill in data gaps through targeted primary research (e.g., survey development), describing possible survey methods is beyond the scope of this survey study.

Locally relevant data

Data supporting costs of nutrient loading must either be collected in or related directly to the region of interest. This can mean within a justifiable distance of a community; that is, in the same watershed, or county, or within a fixed buffer width from the river. However, due to gaps in the cost data in the region, we have outlined how data from outside the region could be transferable from elsewhere, and describe how such transfers can produce defensible cost estimates. For key data gaps, the relative merits of collecting data directly from a study site are discussed.

Recent data

Cost data collected prior to 2000 is considered on a case-by-case basis. For example, water treatment technology costs have significantly changed since the 1990s, thus evidence from these studies may be referenced but not considered for future valuation work. Where there are gaps in publicly available data, a plan is provided for how and where data may be collected for future work.

There are two ways of characterizing costs associated with nutrient loading in the MSR: treatment costs and regulatory/mitigation costs. Treatment costs are associated with removing nutrients from nutrient-loaded river water, whereas regulatory/mitigation costs are related to additional preventative measures that must be undertaken because of existing problems with nutrient loading.

Based on the RFP and confirmed by a targeted review of the literature, this study identified seven sectors likely to experience economic impacts from nutrient loading in the MSR:

- Public Water (e.g., drinking water, wastewater)
- Manufacturing
- Agriculture
- Recreation and Tourism
- Fisheries
- Forestry
- Commercial Navigation

2.2. Nutrient-Associated Cost Drivers in River Communities

This section details the relationship between each sector and the ways that each is subject to additional costs due to nutrient loading, and provides supporting evidence from the literature and existing cost data or potential data sources.

2.2.1. Drinking Water & Wastewater Treatment Costs

2.2.1.1. Drinking Water Treatment Costs

Hypothesis: Increased nutrient loading in the MSR will result in greater capital costs and operational and maintenance (O&M) costs to water treatment facilities.

Pathway: Communities that depend on surface water incur costs to remove nutrients and make their water safe and enjoyable to drink. While different technologies with differing treatment costs are used to remove N and P, in general, the more nutrients in the water, the more expensive it is to treat.

After reviewing community water systems in the region, this study identified 35 facilities across 27 cities and towns that treat surface water from the main stem MSR for community drinking water. Based on 2019 population estimates from the U.S. Census Bureau, these facilities combined serve no less than 67 percent of the total population across the region.

Research focused on collecting data based on system size (e.g., volume of water treated, number of households served) and the nature of the specific treatment technologies that will be necessary to estimate treatment costs per person. It is more expensive to provide clean water to fewer households, because of the economies of scale that exist for water treatment. Other variables tracked during this research included sources of nutrient loading, service area characteristics (e.g., urban, suburban, rural), and water source types (ground or surface).

In addition to community water systems, the EPA also regulates transient (e.g., motels, parks) and non-transient water systems (e.g., schools, factories). As with community water systems, these may also draw from nitrate-laden surface water, requiring expensive cleaning treatments. Data are likely easiest to collect from publicly owned municipal facilities, which was a factor in narrowing down the list of MRCTI communities to the two selected for deeper dive case studies.

Cost Calculation: This study focused specifically on studies that investigated the costs directly associated with nutrient removal from influent for the purpose of public drinking water supply. Not included in this study are the multiple studies that have focused on the costs of eutrophication based on odor and taste in drinking water resulting from algal blooms.[,] Because algal blooms are less common on the mainstem MSR (though not unheard of), this research focused on data that measures the cost of nutrient removal, because such studies will be more widely applicable to communities up and down the MSR. However, future analysis could incorporate these eutrophication cost studies if data emerges that demonstrate recurring a reoccurring pattern of algal blooms in the MSR upstream of a city or town of interest.

Nutrient loading affects both capital and O&M costs for drinking water treatment. An example of a capital cost is when a water utility needs to upgrade its nutrient removal technology in response to additional water treatment need; examples of O&M cost include the additional labor associated with operating, maintaining, and cleaning nutrient treatment systems, and purchasing necessary chemical inputs (e.g., NaCl).

Cost data that is reported by facility size/capacity (e.g., by gallons of water treated per day or by millions of gallons supplied annually) and/or by nutrient removal technology can be transferred across geographies to estimate treatment costs. While this is defensible for capital costs, transferring cost data between treatment systems in this way becomes difficult with O&M costs. Interviews with water treatment facilities to validate cost estimates for both labor and chemical inputs will be necessary, as different sites will have different nutrient concentrations in their influent and different thresholds that trigger turning on the nutrient removal system.

Cost Data: Several sources referred to increased costs associated with greater nutrient concentrations in surface water influent, though these were not specifically for the MSR. Most studies were not in the region, including those from Waco, TX and Tulare Lake Basin, CA. However, several studies did document costs by treatment capacity (millions of gallons of water supplied annually) and treatment technology; these per-unit treatment costs are more transferrable to the MSR.[12,,] For example, a study by Jensen et al. (2012)[12] provided a comprehensive dataset of nitrate treatment cost data from 26 different utilities across California. Understanding how the studied systems operate across key variables—thresholds for use, technologies used—allows these studies to be useful for estimating treatment costs in the MSR.

Several studies did measure treatment costs in the region. The first was by the University of Minnesota Department of Soil Water and Climate (2007)[13] that investigated the costs of nitrate removal from drinking water by several Minnesota community water suppliers—including Clear Lake, MN. Although this study looked specifically at groundwater sources and collected data via interviews with water suppliers, the authors reported their findings based on treatment technology and size of treatment plant in terms of millions of gallons of water supplied annually. The second study was conducted by Vedachalam et al. at the Northeast-Midwest Institute in 2018. It reported nitrate treatment costs from two facilities in Illinois (City of Decatur and Aqua Illinois Vermillion County) and one in Iowa (Des Moines Water Works). The authors also provided additional data (from sources that are no longer appear available: Dakota County, 2018; The Nature Conservancy, 2012) on capital and O&M costs from facilities in Bloomington, IL and Hastings, MN. Treatment technology cost to remove nitrates is unlikely to differ greatly by location, which could make these studies applicable to other areas in the region.

Additional Costs: While this study focused on communities that source their public drinking water directly from the river, future studies could also include communities that source their drinking water from tributaries (which deposit nutrients into the MSR and may be more vulnerable to HABs than the mainstem MSR) and vulnerable aquifers adjacent to the MSR that could be infiltrated by surface nutrients.

Though groundwater is typically less prone to nutrient pollution, it can be a problem for vulnerable, shallow aquifers—those that are less than 100 feet deep. Vulnerable aquifers are often found in areas with high nitrogen inputs, including agricultural regions with significant nutrient application, and stormwater runoff in high-density areas that contribute nitrogen via lawn fertilizers, septic systems, and pet waste. Finally, land cover and soil type matter: less forested and well-drained soils often mean that underlying aquifers tend to be more vulnerable to anthropogenic nitrogen contamination. Of the 66 MRCTI member community water systems that rely on groundwater, some portion likely draw from vulnerable aquifers, and the same is likely true for transient and non-transient water systems.

Finally, because private wells are not federally regulated, recent, comprehensive water quality data are unavailable. However, a 2009 USGS survey of 2,100 wells found that, "… nitrate is the only contaminant derived primarily from man-made sources that [is] found at concentrations greater than a human-health benchmark in more than 1 percent of wells." Because that study sampled wells throughout the lower-48 states, wells in agricultural areas of the MSR basin with known contributors of N are also likely to be impaired by nitrates more than 1 percent of the time. A study of wells in southeast Minnesota conducted by the Minnesota Department of Agriculture between 2008 and 2019 found that in any given year, between 7.5 and 14.6 percent of those wells exceeded the EPA nitrogen threshold for safe drinking water.

A final cost to cities and towns is that of regulatory monitoring and testing, which is the result of persistent nutrient loading issues. The 2007 University of Minnesota study estimated regular nitrate testing cost an estimated $450–$900 (2006 USD) annually.[13] Additional costs to facilities that fall into this category but are not measured in the literature include expenditures related to developing nutrient limit levels and the maintaining monitoring equipment that is used to identify when nutrient removal systems should be turned on.

2.2.1.2. Wastewater Treatment Costs

Hypothesis: Water already rich in nutrients imposes additional costs on public and private wastewater facilities, because effluent must be treated to a higher standard prior to discharge than would be required if nutrient loading was not a persistent problem.

Pathway: Because the MSR is already overloaded with nutrients from multiple sources, point sources that discharge to the river must receive permits and spend money on wastewater treatment prior to discharge in order to comply with government regulations and avoid further exacerbating the nutrient costs for downstream users.

Using the EPA Water Pollution Loading Tool, this study identified 54 facilities—across 39 communities—that likely discharged N and/or P to the MSR in 2020[i] and are listed as likely contributing to impairments (Table 1).

Table 1. Facilities with an NPDES Permit issued by the EPA in 2020 that discharged nitrogen and/or phosphorus to surface waters in the Upper or Lower Misssissippi River watersheds.

State	Major Source	Non-Major Source	Discharge N, Only	Discharge P, Only	Discharge N & P	Discharge to Main Stem MSR	Total Facilities	City or Town Count
Illinois	0	4	2	1	1	3	4	3
Iowa	0	1	1	0	0	1	1	1
Louisiana	8	5	5	0	8	0	13	9
Minnesota	8	10	0	6	12	17	18	12
Tennessee	1	1	1	1	0	2	2	1
Wisconsin	4	12	0	8	8	15	16	13
Total	***21***	***33***	***9***	***16***	***29***	***38***	***54***	***39***

[i] Facilities confirmed to discharge to surface waters within the Upper or Lower Mississippi River watersheds and are within two kilometers of the MSR.

Point sources that treat wastewater for nutrients prior to discharge can be grouped into three categories:

- Municipal (e.g., government-owned sewage treatment plants)
- Industrial (e.g., private manufacturers)
- Decentralized (e.g., single-residence septic tanks)

Cost Calculations: Costs of treating wastewater to an appropriate standard would be calculated similarly to the costs of treating influent for drinking water (but with more emphasis on both N and P removal, whereas potable water treatment focuses on N):

- Capital and O&M costs associated with nutrient removal
- Monitoring and testing of effluent
- Regulatory procedure development (e.g., TMDL for water bodies)
- Potential costs for falling out of compliance, which may include financial penalties and costs of additional labor and equipment upgrades to return to compliance.

Capital costs may include wastewater treatment upgrades for new technologies and will depend on the type of technology selected for replacement, retrofit, or expansion, as well as other factors like facility design and space for expansion, storage tanks for sludge at different stages of treatment (primary and secondary), recycled water treatment, the degree of automation of wastewater treatment, and the facility size. O&M costs would depend on factors like chemicals, energy, labor, amount of automation, the number of chemical additions in the treatment process, sludge handling costs, and facility size. About 70 percent of O&M costs to facilities for P removal is related to handling and disposal of chemicals and sludge, which means about 30 percent of O&M costs may be unaffected by increased P concentrations.[19]

Cost Data: An EPA (2015) report compiling cost data associated with nutrient pollution identified several studies throughout the country on wastewater treatment costs broken down by technology, cost category, concentrations of N and P in both influent and effluent, and size of facility (in millions of gallons per day).[20] Though most of the compiled data is from outside of the study region, two municipal point source studies are from Minnesota[21] and Illinois.[22]

In 2008, the EPA conducted case studies on nine municipal wastewater treatment plants.[23] Although none of these case studies were conducted in the region, the data collected used N and P as attributes for each variable (e.g., capital costs attributed to N and P), which produced a rich dataset. Data for each facility included:

- Type of nutrient removal technologies and processes
- Percent nutrient removal (performance)
- Capital costs (total and in dollars per gallon per day)
- O&M costs (total and per unit)
- Electricity (kWh per year and dollars per year)
- Chemical costs (dollars per year)
- Sludge amount (tons per year) and costs (dollars per year)

In 2013, the EPA also released a report prepared by Tetra Tech titled *Emerging Technologies for Wastewater Treatment and In-Plants Wet Weather Management*.[24] This report provided a list of over 90 established and emerging technologies for P removal, nitrification-ammonia removal, and/or denitrification-nitrogen removal (among other wastewater contaminants). However, estimated costs were provided for only 6 technologies.

Data from these studies that is normalized into per unit costs could be used for estimating costs of nutrient loading at facilities in the region with similar technologies and processes, especially if the data can be extrapolated for different loading levels of influent. In 2013, Tetra Tech did exactly this, suggesting such a study could be replicated in the future. This study extrapolated the EPA (2008) data on behalf of the Ohio Environmental Protection Agency in order to estimate costs at wastewater treatment plants receiving influent with high P concentrations.[19]

2.2.2. Costs to Manufacturing Sector

Not every industry within the manufacturing sector will be affected by nutrient pollution in the river, because nutrients may not interfere with their water uses. Simply put, some manufacturers need cleaner water than others. Consider the ways in which a food and beverage (F&B) manufacturer and a tire manufacturer may use water. F&B will have stricter safety and quality standards because their products are edible, whereas a tire manufacturer may only need water for basic cleaning. Thus, the most notable industry bearing the costs of nutrient loading is F&B, since its influent needs close monitoring. Furthermore, because of the nature of their production, F&B manufacturers are also more likely to have enriched wastewater that may require nutrient removal prior to discharge.

Other manufacturers, like chemical and fertilizer plants, may have similar concerns. The chemical nature of N and P in influent could disrupt chemical processes or contaminate products, and in turn these types of manufacturers are also more likely to have enriched wastewater. For example, there are two fertilizer manufacturing plants on either side of the MSR owned by the company Mosaic in St. James Parish, LA, upriver of New Orleans. Wastewater from these plants would be highly enriched and thus require nutrient removal technologies that would bear similar costs as described in the *Wastewater Treatment Costs* section.

2.2.2.1. Food and Beverage Manufacturing

Hypothesis: F&B manufacturers that draw water from and discharge effluent to the Mississippi River bear costs of nutrient loading.

Pathway: Data from the EPA Facility Registry Service[25] on all facilities in the region that have a NAICS code beginning in 311 (Food Manufacturing) and 312 (Beverage Manufacturing) were identified. All F&B facilities that fall within 1 mile of the Mississippi River are added to a list of facilities that are most likely to draw water from—and/or discharge wastewater to—the river. According to this analysis, there are 378 F&B facilities within 1 mile of the mainstem MSR.

Cost Calculation: See the *Drinking Water Treatment Costs* and *Wastewater Treatment Costs* sections of this report.

Cost Data: Cost data for nutrient removal from influent for municipal drinking water may be transferrable to the food and beverage manufacturing sector due to similar end uses and safety concerns. However, due to the difference in wastewater composition compared to municipal users, nutrient removal may have different technologies and thus different costs. The EPA 2015 cost data compilation[20] related to nutrient loading included industrial wastewater treatment costs for meat and poultry processing facilities, though the data was not normalized on a cost per unit basis and instead presented as cost per facility. This data also only presents effluent N and P concentrations without influent. This means that the data could likely only be used as a basis for comparison in a future study.

Other nutrient removal cost data described in the *Drinking Water Treatment Costs* and *Wastewater Treatment Costs* sections may be applicable to estimate costs to F&B facilities. Prior to transferring cost estimates from other sources, a future study would need to interview or survey F&B manufacturers to collect data on the following:

- nutrient removal technology;
- wastewater and influent water capacity (gallons per day);
- the nutrient levels of water or wastewater flowing into the system (either influent drawn from the river for use or effluent from the manufacturing process); and

- the nutrient removal performance (percent removal).

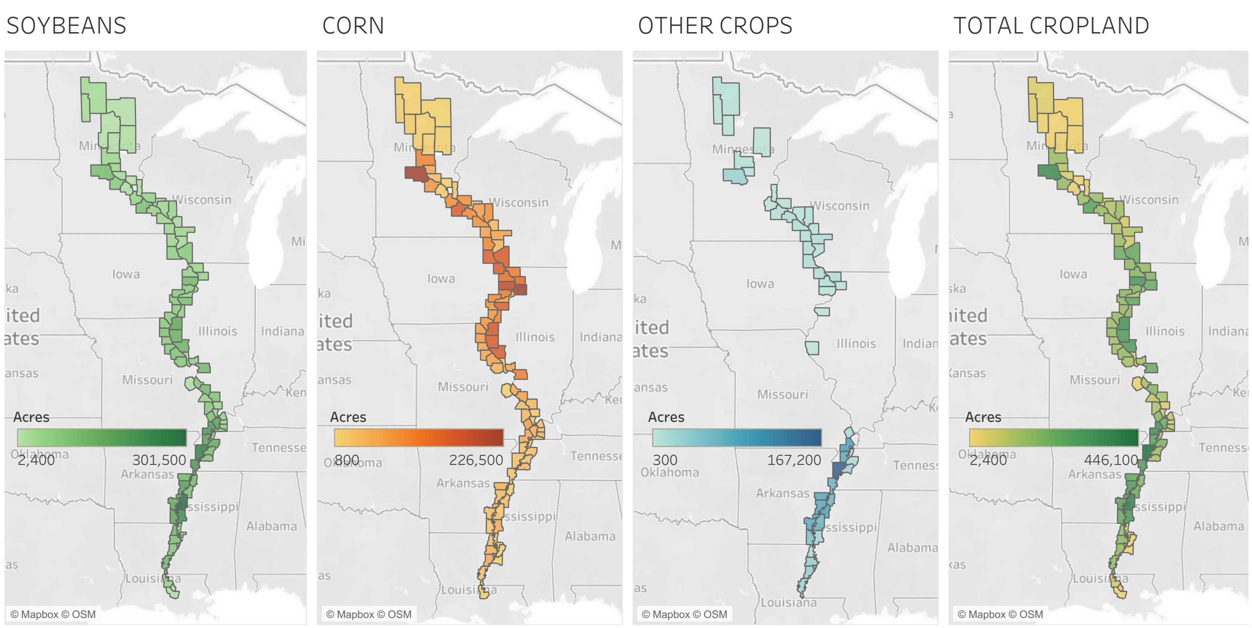
2.2.3. Costs to Agriculture Sector

Replacing the excess nutrients that end up in surface and groundwater every year is costly to farmers. These replacement costs must be acknowledged as an aspect of nutrient pollution. Farmers who are able to retain nutrients in their soils may have lower input costs, while helping to reduce nutrient-loading of ground and surface waters. This study explored the costs of replacing the nutrients lost to runoff within the region and reviewed literature on the regulatory costs to farmers for reducing nutrient pollution.

Hypothesis: Costs of nutrient loading in the MSR to the agriculture sector include costs to develop and implement comprehensive nutrient management plans—required for Concentrated Animal Feeding Operations [CAFOs]—and fertilizer replacement costs for nutrients lost to runoff.

Pathway: This survey identified 93.7 million acres of field and vegetable crops planted in 2020 across the MSR region states (LA, MS, AK, KY, TN, MO, IL, IA, MN, WI)[26] and 35% of land in counties directly along the MSR is cropland.[3] This includes over 5.5 million acres of corn and 6.8 million acres of soybeans—the two dominant crops in the region.[27] The four largest crop growing states in the region, by acreage, are Iowa (25%), Illinois (23%), Minnesota (17%), and Missouri (10%). The MSR valley is also known for being fertile farmland, which would explain why AK, LA, MS, and WI have over a third of their state's cropland in MSR-adjacent counties (Appendix B). Acres of field and vegetable crops planted for all counties along the MSR were analyzed in this study to capture acreage of likely fertilizer application (Figure 2).

Figure 2. Acres of field and vegetable crops planted in 2020 in counties along the Mississippi River. Dashboard[ii] adapted from USDA-NASS.[27] Crops include corn, soybeans, barley, peanuts, cotton, rice, and oats. Counties along the River not pictured in the maps due to either lack of cropland in the area or grouping of counties with too few producers to ensure anonymity.



Because nutrient-related problems like HABs in the Gulf of Mexico have been traced back to agriculture in the Midwest, regulations have been put in place with the goal of reducing the impacts of nutrients contributed by these nonpoint sources. Increased use of fertilizer on croplands is considered a major cause of increased nutrient levels in the MSR over the last several decades,[28] with at least 75 percent of nitrate in the MSR attributed to human activity.[29] Now, many farms—and all CAFOs—are required to develop and implement comprehensive nutrient management plans. For many CAFOs, these plans include

[ii] Online dashboard found at: https://public.tableau.com/app/profile/erin.mackey/viz/CroplandAlongtheMississippiRiver/Dashboard1

expensive nutrient removal technologies for treating their wastewater laden with manure. Some of the more common technologies are liquid-solid separators followed by aerated lagoons (i.e., oxidation ponds) for treating and storing manure before it can be applied to fields in the form of fertilizer.

Using farm data from the USDA's 2017 Ag Census, this study identified almost 19,000 livestock operations in the region (at the county level) with NAICS codes for feedlots and production of beef and dairy cattle, hogs and pigs, and poultry and eggs.

Another costs to farms, though indirect when compared to the treatment of wastewater, is the replacement cost of fertilizers for nutrients lost to runoff. When N and/or P are lost to runoff (and/or erosion), farmers must buy fertilizer to replace those nutrients.

Cost Calculations: To understand the cost of implementing nutrient management plans, it will be necessary to adjust the number of livestock and poultry farms in each area of interest for size (i.e., number of animals) to conservatively estimate costs; only farms of a certain size or type are required to have a comprehensive nutrient management plan. The USDA Ag Census provides data on the number of livestock and poultry farms broken down by range of livestock inventory (e.g., number of operations with 10 to 19 head of cattle, 20 to 40 head, 100 to 199 head, etc.).

Fertilizer replacement costs can be estimated based on fertilizer prices per ton of material (normalized as per ton of N or P) from the USDA Economic Research Service (ERS).[30] The average price per ton of N or P would then be adjusted for inflation and could be applied to an area based on average runoff loads sourced from USGS SPARROW.[27]

Cost Data: The NRCS issued a technical report in 2003 titled *Costs Associated with Development and Implementation of Comprehensive Nutrient Management Plans*, and costs could be updated to current dollars.[31] Fertilizer prices can be found in the dataset maintained by the USDA ERS.[30]

Double counting would not be of concern by estimating CNMP and fertilizer replacement costs, because the NRCS (2003)[31] did not account for financial benefits like savings in commercial fertilizer costs by instead applying manure to additional acreage.

2.2.4. Recreation Costs

Hypothesis: Nutrient loading imposes costs on recreational users who cannot engage in recreation because of water rich in N and P. People value recreation beyond what they pay for it; this difference is an economic value called consumer surplus, which is lost when nutrient-rich water precludes water-based recreation.

Pathway: This study identified no evidence that recreational users respond directly to marginal increases in nutrient loads in the mainstem Mississippi. Some research exists that crafts demand functions for recreation in response to changes in biophysical indicators of water quality, but they are not focused on N and P. While water that is heavily laden with nutrients may smell or be otherwise unappealing to engage with recreationally, there is no way to tell using existing data if an individual decision to forgo recreation is made in response to nutrient levels or simply a general perception of the water as "dirty."

While recreational users may not directly respond to nutrient levels, they do respond indirectly when water bodies that provide recreational opportunities are closed due to harmful algal blooms (HABs). HABs require relatively still water, warm temperatures, and sufficient N and P loads to trigger an event. These algae produce toxins that are a public health hazard for people that contact affected waters.

Cost calculation: When recreational opportunities are lost, recreational users lose consumer surplus: essentially, the welfare they would have gained by enjoying a recreational activity like swimming or fishing, which is measured in dollars. There is a robust literature estimating consumer surplus values for different recreational activities using a variety of methods, but the basic calculation for all of them amounts to total willingness to pay to engage in an activity less the costs incurred to participate in the activity (e.g., travel costs, entrance fees).

The U.S. Fish and Wildlife Service has consumer surplus estimates for freshwater fishing for all 50 states.[32] The consumer surplus estimates for swimming in natural waters and for boating (motorized and nonmotorized) exist in the Recreation Use Values Database (RUVD), maintained by Dr. Randall Rosenberger at Oregon State University. The RUVD contains "…421 documents of economic valuation studies that estimated the use value of recreation activities in the U.S. and Canada from 1958 to 2015, totaling 3,192 estimates in per person per activity day units, adjusted to 2016 USD."[33]

To calculate the cost of nutrient loading to recreational users relevant to MRCTI cities and towns:

- Identify state-owned recreational areas with water bodies that offer fishing and swimming; AND
- Identify those that are "close enough" (metric could include using a set number of road miles, travel time, specific radius, or specific county or counties) to cities and towns to be defined as a "local" recreation amenity.

The basic equation to calculate this cost of closures at each local recreation site is:

- Consumer surplus lost due to closure ($ / day, typically) * total days closed per year * number of recreational users affected.

Data: States do not maintain comprehensive historical records of HAB-related closures. That leaves two pathways for estimating total closures:

- The EPA threshold established in 2019 for exposure to microcystin toxin—the result of HABs—is 8 micrograms per liter.[34] This is the threshold that, if exceeded, could prompt local authorities to issue advisories or closures—strong and clear disincentives to recreational users. State water quality monitoring data measures these toxins over time, and these data are useful for understanding minimum, maximum, and average closures for a given water body.[iii]
- Beach closures are often newsworthy events. By first identifying the relevant local water-based recreation assets subject to closure, it is possible to perform targeted searches to identify recent HAB closures.

Calculating the number of recreational users affected requires two pieces of data: an estimate of the total number of visitors to a given recreation area and an estimate of the proportion of those recreational users that experience lost consumer surplus (i.e., how many people visit so that they can engage in water-based recreation).

- Estimating the total number of visitors is generally straightforward with state or county parks that track visitation, though assumptions may need to be made to translate annual visitation into daily visitation, and consideration given to seasonality and weekend versus weekday visitation (i.e., the timing of the closure).
- Should total visitation data be unavailable (in the event the park is free to visit, or data are not otherwise tracked), purchasing anonymized cell phone data is the gold standard for counting visitors for recreation analysis.
- The proportion of recreational users that engage in a certain activity can be estimated using data from State Comprehensive Outdoor Recreation Plans (SCORP studies), from the Outdoor Industry Association, or from interest groups.

Additional cost: It is worth noting that recreational users spend money when they recreate. Those dollars are spent and re-spent in the local economy, supporting local jobs, GDP gains, and tax revenues. Recreational spending is important to local economies because, relative to other types of spending, this money is spent at local businesses—food, beverage, retail; this distinction is important because other

[iii] For example, the Iowa DNR's water monitoring database found here: https://programs.iowadnr.gov/aquia/

types of spending (e.g. online, movie theaters) do not support the local economy to the same degree.[35] When recreational dollars are not spent in the local economy and instead are either saved or spent in other sectors, this is also a real cost to cities and towns.

Understanding the magnitude of the effect of recreation spending on the local economy is the domain of input-output (I-O) analysis. Unless recreation spending effects are of particular interest, Because the data required to do this type of analysis has to be purchased for each location and is priced at $2,000 (for a single county) to $5,000 (for a state), this type of analysis is likely beyond the scope of this report.

2.2.5. Other Natural Resource Harvest Costs

Nature has developed clever systems for keeping N and P in balance to support plant and animal life and the natural resources we depend on. Human activities have disrupted this balance, which affects our supply of food, water, and timber products that are all reliant on these nutrient cycles.

Since this research has already described the impacts on water resources (see *Water & Wastewater Treatment Costs*) and the industrial and agricultural side of food supply (see *Costs to Manufacturing Sector* and *Costs to Agriculture Sector*), this section will primarily focus on the economic impacts to fisheries and forests.

2.2.5.1. Fisheries

Hypothesis: The fisheries sectors (commercial fishing and aquaculture) in the region face economic costs as a result of nutrient loading in the MSR, especially ones that depend on the Gulf of Mexico. Shellfish bed closures, fish kills, and fish migration due to HABs and hypoxia have economic consequences in the region.

Pathway: Commercial fisheries landings—the quantity of fish unloaded on shore by commercial fishing boats—in the Gulf of Mexico are the second largest of any area in the United States. In 2016, commercial fisheries in the Gulf had an economic impact of $17 billion (which is also the most recent data available from the National Marine Fisheries Service). That same year, Louisiana's seafood industry generated over $2 billion in sales and $1 billion in value added impact.[36] Notably, recent studies have identified a downward trend in commercial fish landings in the Gulf, though there no causal link to nutrient loading is established.[37,38]

The commercially valuable aquatic ecosystems of the Gulf can be damaged by excess nitrogen flowing from the MSR, which causes an overproduction of microorganisms (e.g., phytoplankton) that die off and deplete the water of oxygen as they decompose, creating hypoxic conditions. Impacts of seasonal hypoxia in the Gulf on marine fish and shellfish species are well documented,[39, 40, 41, 42, 43] but there is limited economic data on the impact this has to commercial fishing and aquaculture in the Gulf of Mexico's "dead zone."

NOAA reported in 1999 that there was not a clear economic effect of hypoxia in the Gulf on the commercial fisheries industry, but that was based on landing data from the 1970s through 1990s.[44] More recent efforts have taken steps towards understanding the economic impacts of the dead zone, though persistent data gaps exist that make it difficult to isolate economic damages of the hypoxic zone from other confounding factors that reduce fish landings, like overfishing, oil spills, or predators pushing shrimp further out to sea.

Two studies from 2017 did identify economic effects of Gulf hypoxia on shrimping: Smith et al. (2017) found that increasing hypoxia in the Gulf lead to increased prices for large brown shrimp.[45] And Purcell et al. (2017) found that shrimping fleets had to spend more time and effort per catch under hypoxic conditions in the Gulf.[46]

Besides commercial fishing, there are also costs to aquaculture, which may suffer losses due to algal blooms or face nutrient removal treatment costs (similar to the manufacturing sector). Using 2017 USDA

Ag Census data, we identified over 130 aquaculture farms in counties along the MSR.

Cost Calculations: Although the economic effect of hypoxia on fisheries is difficult to estimate, future work could investigate the correlation between landing data, shellfish bed closures, and seasonal hypoxia in the Gulf of Mexico. One potential pathway would be to use sales receipts from landing data in an input-output model using economic data from IMPLAN to map out the local economic effects of the fisheries industry, and model observed reductions in fish takings or percentage-based reductions anchored by literature like the shrimping studies to understand how jobs, economic output, contributions to GDP, and tax revenues are reduced as landing are negatively impacted by hypoxia.

Beyond input-output analysis, the shrimping study that demonstrates additional effort per catch during hypoxic conditions relative to non-hypoxic conditions indicates that it is more costly to shrimp, as boats spend more time and range farther to collect a similar catch. Additionally, Smith et al. (2017) note that under hypoxic conditions, the less economically valuable small shrimp proliferate, and the more valuable large shrimp become relatively scarce.[45] Some of these costs may be passed on to the consumer. Using studies similar to these, it may be possible to draw simple conclusions or model simple scenarios about how costs are borne by consumers and by fisherman alike.

Cost Data: Landing data collected by NOAA[47] can be used for determining the approximate size of the commercial fishing sector by species, annually. NOAA also produces an annual report on the economic impacts of the sector ("Fisheries Economics of the United States") which coincides with updates to their interactive tool where they make the economic impact datasets available to the public.[36] These datasets can be used along with the NOAA's Gulf of Mexico Hypoxia Watch historical datasets on the size of the dead zone in the Gulf[48] to investigate whether fish catch decline and hypoxia area are correlated.

The USDA Ag Census of 2017 includes the total number of operations and total sales for aquaculture production by county. Only 19 of the region's counties had enough operations to make aggregate sales data available; however, sales data is available for 8 of the 11 counties along the MSR in Louisiana that have aquaculture operations.

2.2.5.2. Forestry

This survey identified 24 percent of all land is forested in the MSR region's counties. Although forests play an important role in mitigating nutrient pollution, timber harvest is another nonpoint source contributor of nutrients, typically when logging activities create erosion and sediment runoff, which transports P to the MSR. Just like other nonpoint sources there are a suite of best management practices (BMPs) recommended by the USDA NRCS and USDA Forest Service[49] for reducing nutrient pollution from forestry.

Recent local data on the costs of implementing forestry harvest BMPs directly tied to nutrient pollution does not appear to exist. At the national level, the NRCS has estimated implementation costs for individual practices and scenarios.[50] If common BMPs used by timber harvesters in a given area of interest are known, these could be matched to the NRCS cost data in a future study to estimate implementation costs. Additional research identified one additional study that may be applicable that was published in 1996 and provided BMP costs on a per-acre basis in Virginia.[51]

2.2.6. Commercial Navigation Costs

Based on a review of the available literature and an understanding of how N and P act within the MSR to impose costs to different sectors, this study did not identify any documented costs or theoretically supported pathways that nutrient loading imposes on the commercial navigation sector. One study[52] suggests that eutrophication leads to increased siltation, due to nutrients causing overproduction of organic matter that decomposes and then settles to the bottom of water bodies. However, the proportion of siltation and sedimentation eutrophication might contribute in the MSR—relative to silt and sediments contributed from other sources—is unknown. Understanding this figure would be necessary in order to estimate the proportion of dredging costs that could be attributed to nutrient loading.

2.2.7. Energy Generation

Nitrogen oxides are a common byproduct of energy generation; as these cycle through the atmosphere, they can be deposited as acid rain, which then flows into waterways. The EPA identifies coal-fired power plants a major source of nitrogen oxide emissions. Recent regulations on greenhouse gas emissions have resulted in shifts away from coal as a fuel stock and retrofitting coal-fired units with scrubbers to reduce nitrogen oxide emissions. This survey explored the costs associated with nitrogen-removal technologies, as nitrogen oxide is an important nonpoint-source contributor of nutrients to the Mississippi River.

The most recent and comprehensive source of energy generation cost data associated with emissions technology is found in the 2019 report by the U.S. National Energy Technology Laboratory.[53] The models in this report were based on Gulf Coast and Midwest locations, meaning the technology costs are applicable to the MSR region. The authors provide detailed descriptions of each case study, which makes it easier to apply their cost estimates to other plants. They present cost data for every process by equipment, material, direct and indirect labor, and capital costs of engineering, construction, and maintenance. To the extent that this indirect pathway is of interest, it may be possible to use the findings of this report and use them to investigate the costs of nitrogen removal borne by coal-fired power plants in the MSR.

2.3. Other Considerations

Property Values and Public Health

Two other cost considerations that hold potential for future study, but do not feature in the above seven sectors: negative impacts on property values and public health. At this time, no data is evident in the literature on the relationship between property values and N and/or P loading on rivers; however highly eutrophic waters may have an odor and be less desirable to live on even without an active algal bloom, and some literature exists linking algal blooms to reduced property values.[54]

Public health costs can be calculated from anonymized health records on illnesses attributed to toxins produced by HABs (whether from recreating in/near or consuming shellfish harvested from an affected water body).

Ecosystem Service Values

The ecosystem service valuation literature is rich with studies that estimate—using a variety of methods—the value of water quality. One example particularly applicable to the region is Jenkins et al. (2010),[55] which estimates that the value of restored wetlands at mitigating nitrogen in the southern MSR corridor would be between $900 and $1,900 per hectare per year. The nitrogen reduction value used in this study was sourced from a separate study by Ribaudo et al. (2005)[56] that based the value of N on the cost of upgrading and retrofitting point sources with wastewater treatment technologies for nitrate removal.

Two studies published in 2020 aimed to address gaps in the literature by estimating the value of water quality improvements in the Mississippi River Basin (specifically, in a sub-watershed in Illinois[57] and the Gulf of Mexico.[38] Both studies used willingness-to-pay (WTP) surveys for improvements in ecosystem services benefits to value improvements to water quality, including reduced nutrient loading. Although using WTP to model economic value is a widely accepted practice, the study from the Gulf should be treated with care if chosen for use in valuation in the MSR because its WTP data was originally collected in Europe and applied to the United States.

According to the WTP study in Illinois, people value nutrient reduction and the nonuse benefits it conveys (including increased numbers of fish, increased species of game fish, reduced algal blooms, and achieving nutrient reduction targets). The study also found that people prefer nutrient reduction programs closer to the rivers on which they live. These are not costs, but instead demonstrate that nutrient reduction—to the degree that it helps improve local water quality, fish populations, and reduce the total nutrient load reaching the Gulf—has value to residents throughout the region.

Many of the proposed solutions to nutrient loading—floodplain restoration and reconnection, or edge of field practices—offer important co-benefits beyond water quality, including flood reduction and carbon sequestration. There is a robust literature to draw upon to value the other ecosystem services provided by these green spaces; should this be of interest, highlighting the multi-benefit nature of these solutions in dollar terms would be straightforward.

3. SELECTING COMMUNITIES BEST SUITED FOR THE PILOT STUDY

After surveying the available data for measuring the hypothesized costs to cities and towns along the Mississippi, the next step is to begin to narrow the list of cities suitable for a deep dive analysis of nutrient loading costs as outlined in the prior section. This section contains the criteria used to help narrow the list of candidates to an actionable and representative sample of cities for the next phase of the study. A map demonstrating the spatial results of criteria 1 through 4 is presented in Figure 2.[58]

3.1. Criteria

Criterion #1: At least one community needs to draw its water from the mainstem Mississippi River.

This is the first sorting criterion, because this cost category is likely to be the largest. Our research identified 27 cities and towns that draw water directly from the Mississippi. Slight preference was given to cities with municipal rather than private water systems for reasons of data access, though soliciting treatment cost data from private water companies is judged unlikely to be significantly more difficult.

Criterion #2: The selected community or communities should have clear evidence of excessive nutrient loading.

The presence of substantial nutrients is a prerequisite to measuring the costs they impose on cities and towns. The EPA 303(d) impaired water list provides evidence of excessive nutrients: cities and towns with either the nearest upstream section of the Mississippi or surface waters and tributaries that feed into the river listed due to nutrients were considered. Additional spatial data sources used included the USGS SPARROW model of total P and total N nutrient loading[27] and the EPA EnviroAtlas.[59]

Criterion #3: The selected communities should represent a diverse geography.

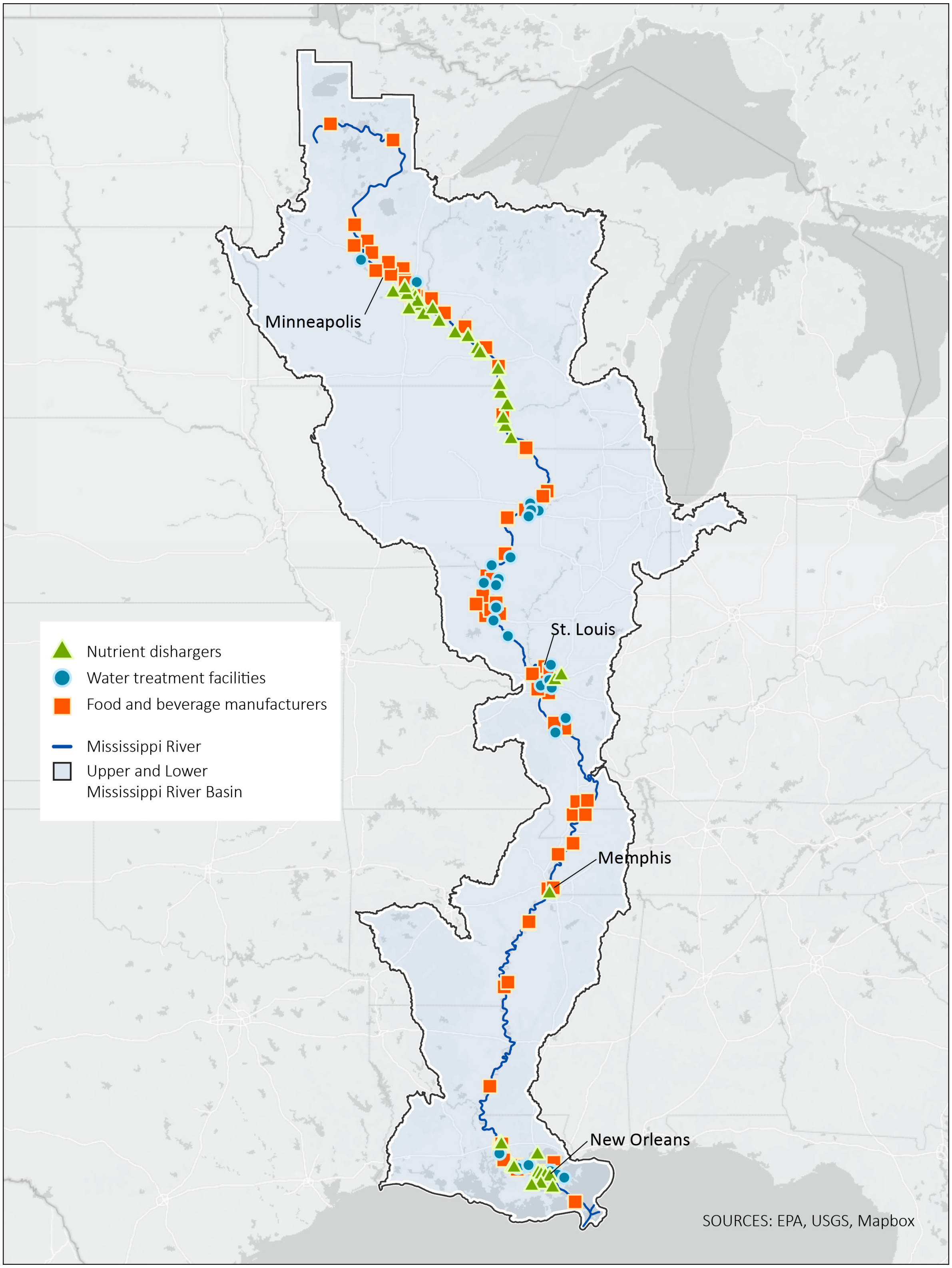
The costs of nutrient loading will vary according to the location along the river, and chosen communities should not be clustered along the same part of the river.

Additionally, the volume and sources of nutrient loading will vary according to the location in the watershed and proportion of forestland versus developed land versus farmland. These differing sources of nutrient loading are likely, in turn, to influence costs. The USGS National Landcover Dataset from 2016 was used to analyze landcovers across the MSR region.[60]

Criterion #4: The economic sectors affected by nutrient loading present in the selected community or communities will have obtainable data.

This criterion is largely focused on the presence of affected sectors in a community aside from its potable water supply, especially the presence of manufacturing (food and beverage; industrial manufacturing) within 1 mile of the river,[25] and the count of livestock farms[61] and total acres of cropland in the immediate HUC12 drainage surrounding the community.[3]

Figure 3. Map of facilities located within 2 kilometers of the Mississippi River that: 1) intake drinking water water from the Mississippi River; 2) discharge nutrients (N and/or P) to surface waters in the watershed and are considered by the EPA contributing to water quality impairment; or 3) are food and beverage manufacturers.



Criterion #5: The chosen community or communities should represent a diversity of population.

MRCTI represents cities and towns both large and small. It was important to the study team to avoid the pitfall of simply proposing a study of the costs to the largest cities. Though the largest cities will typically have most cost drivers represented and more resources to spend on data collection, it should be possible to identify a pair of cities that includes one small or midsize city that nonetheless satisfies the other criteria.

Criterion #6: Valuable indicators to consider include Climate Risk, Social Vulnerability, and Community Resilience scores.

These are important to consider because one key driver of climate risk along the MSR is increased flooding; many of the proposed solutions to the nutrient-loading problem have the co-benefit of being useful for flood risk mitigation (e.g., floodplain restoration, edge of field practices). Additionally, social vulnerability and community resilience are part of this criterion because the costs of nutrient loading may be experienced more acutely in more vulnerable and less resilient communities.

Data for spatial analysis was pulled from FEMA's National Risk Index for Natural Hazards (NRI) for six communities of interest in the region (based on the previous five criteria). Community boundaries were determined by including census tracts within the statistical areas defined by the Census Bureau. Climate risk ratings were used for riverine flooding, heatwave, drought, and hurricanes. Community resilience was combined with the inverse of social vulnerability to produce one rating (CRSV). A "regional" average for both the climate risk and CRSV variables was calculated across all six communities. The results for each census tract were then compared to the regional average, and assigned a color based on how they compare. For the climate risk variable, green indicates fewer assets at risk relative to the regional average; for the CRSV variable, green indicates that a census tract is relatively less vulnerable / more resilient (see Figure 3 and Figure 4).

3.2. Selected Communities

Narrowing down the MRCTI cities and towns using the above criteria, this study has identified two communities that, as a group, broadly represent the MRCTI service area, and collectively demonstrate costs of nutrient loading to each of the posited economies. By grouping communities in this way, we avoid the need to analyze every sector in every MRCTI member community. This will also provide a starting point for extending findings to other MRCTI cities and towns according to the presence of the variables highlighted by these criteria and economic sectors.

3.2.1. New Orleans Metropolitan Area

New Orleans was chosen because, in addition to being a larger city meeting the criteria above, its presence nearest the Gulf offers an opportunity to value impacts of nutrient loading to the commercial fishery and associated processing and packing industry. The city also sees significant dredging activity to facilitate boat transport, which stirs up settled nutrients and may contribute to increased costs. Other unique factors which contributed to this choice include the documented presence of HABs in Lake Pontchartrain, the city's location low in the watershed, and a low community resilience + social vulnerability score.

Figure 4. Composite Climate Risk Index, using FEMA's National Risk Index for Natural Hazards (NRI), for specific cities and towns along the Mississippi River, by census tract. Natural hazards included in the index are riverine flooding, heatwave, drought, and hurricanes. Results for each census tract are compared to the regional average and assigned a color based on how they compare. Green indicates fewer assets at risk of natural hazards relative to the regional average, and pink indicates more assets at risk.

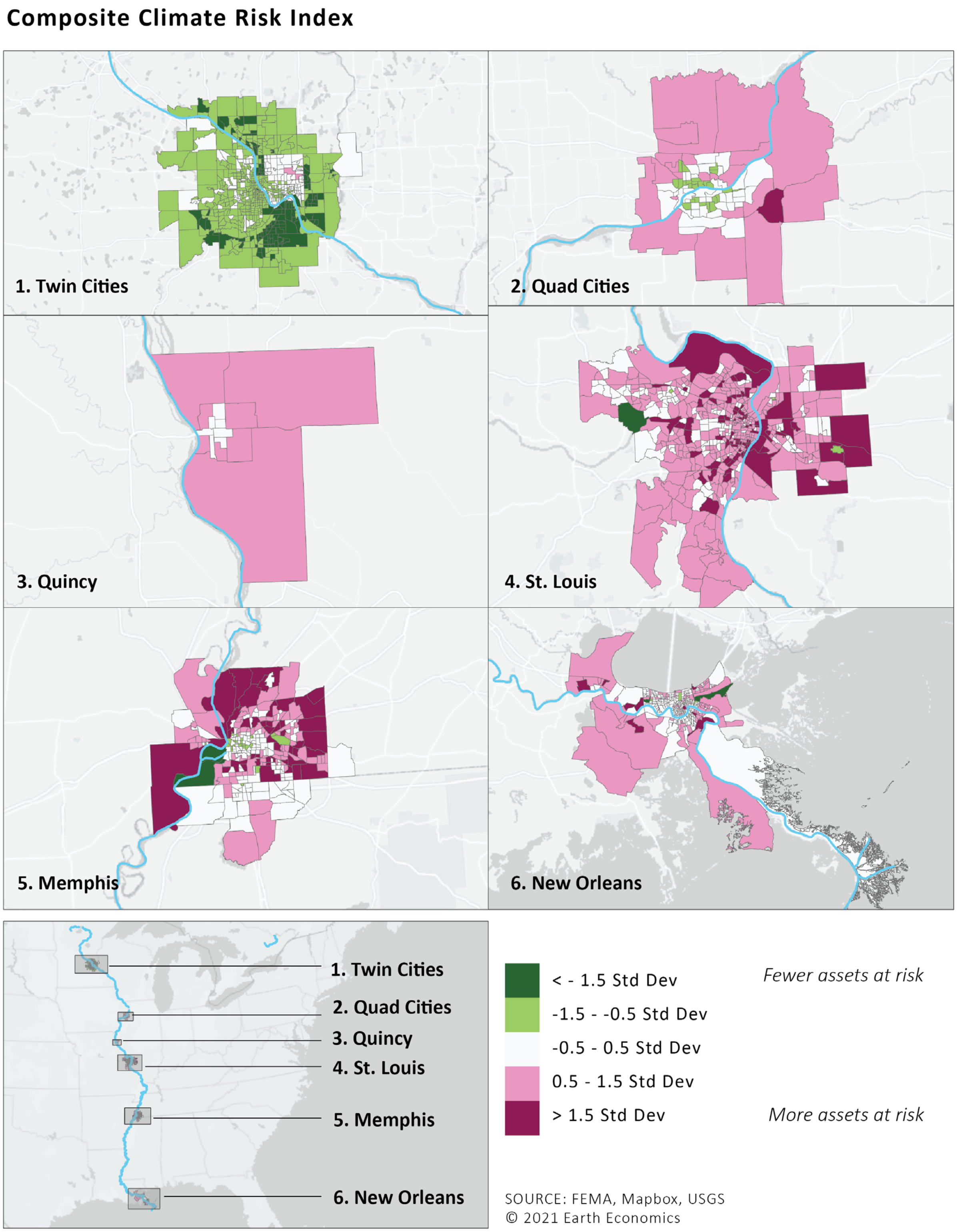
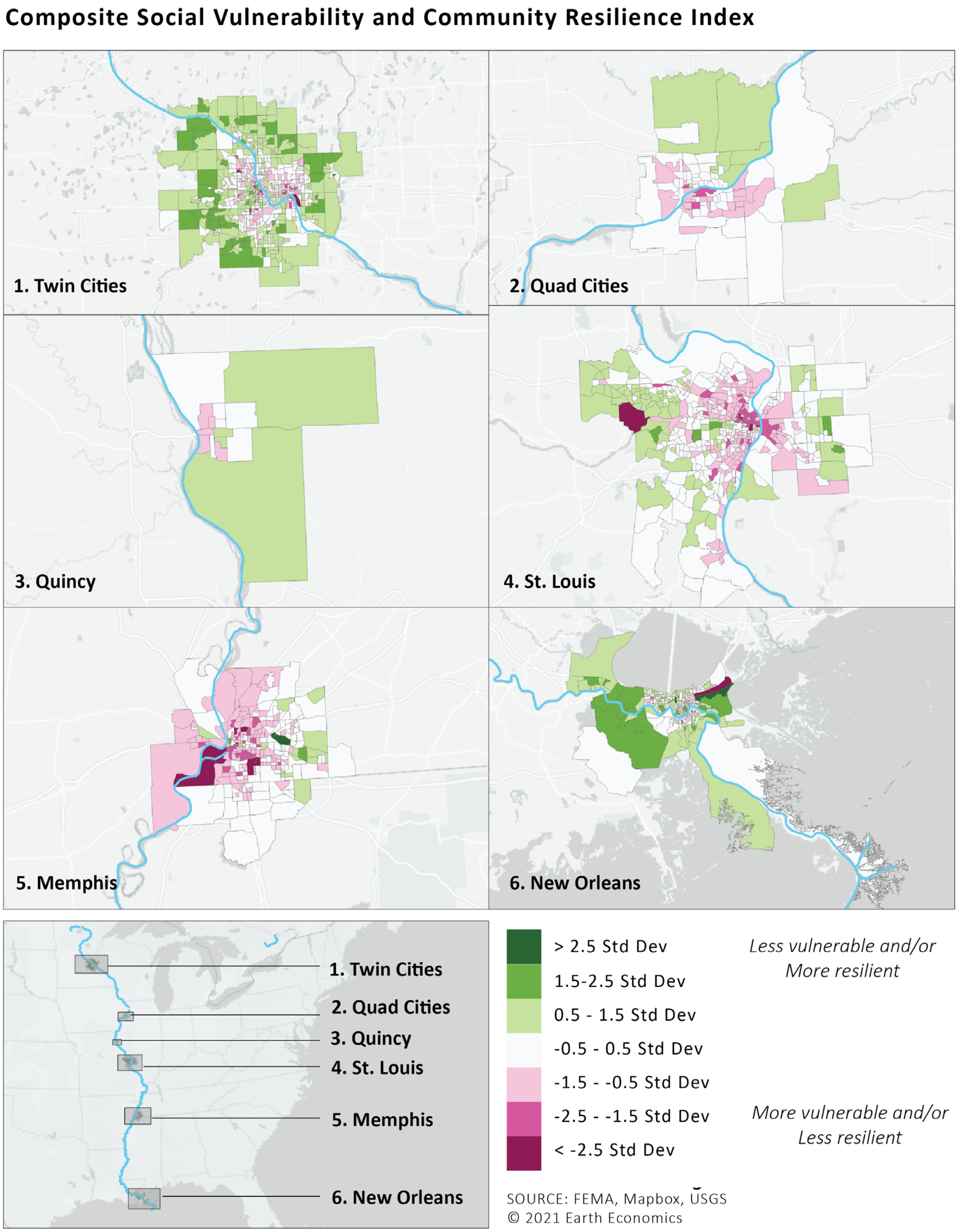


Figure 5. Composite Community Resilience and Inverse of Social Vulnerability Index (CSRV), using FEMA's National Risk Index for Natural Hazards (NRI), for specific cities and towns along the Mississippi River, by census tract. Results for each census tract are compared to the regional average and assigned a color based on how they compare. Green indicates that a census tract is relatively more resilient / less vulnerable relative to the regional average, and pink indicates a tract community is less resilient / more vulnerable.



New Orleans has the following features relevant to nutrient loading cost drivers:

1. Drinking water: treatment facilities sourcing water from the Mississippi River.
2. Wastewater: at least 6 point source facilities that discharge N and P considered to be contributing to water body impairments in the MSR watershed.
3. Manufacturing: approximately 10 food and beverage manufacturers in the metro area within one mile of the MSR and at least 1 phosphorus fertilizer plant (that is also considered a contributing nutrient polluted wastewater discharge facility).
4. Agriculture: at least 60 livestock farms in the parishes that intersect with the statistical area.
5. Recreation: a large recreation and tourism sector around the River and dependent on the Gulf of Mexico.
6. Fisheries: at least 19 aquaculture farms and almost 75 percent of them are for mollusks (thus more susceptible to impacts by HABs). New Orleans is also a major landing for commercial (and recreational) fisheries on which the U.S. seafood industry heavily relies.
7. Commercial Navigation: as mentioned above, the New Orleans section of the MSR has significant dredging activity, because it’s a major international port and thus needs to be deeper than the rest of the River to allow large trade vessels to reach the port.

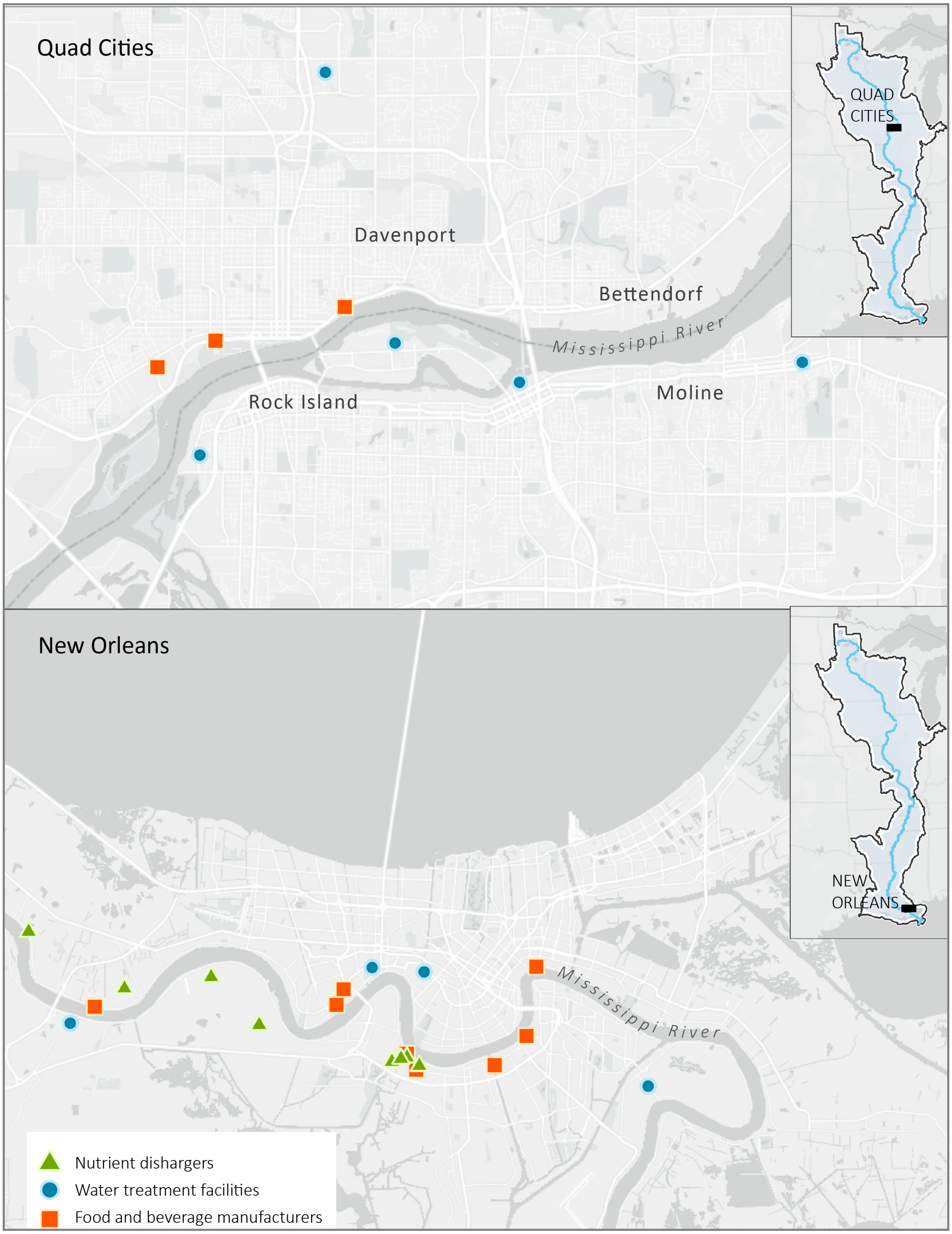
3.2.2. Quad Cities

Quad Cities was chosen because this metropolitan area captures both smaller and midsize cities and is located in an area along the middle stretch of river featuring significant nutrient inputs. The cities collectively meet the criteria above, and the surrounding land is also uniquely forested relative to other options; forestland plays an important role in regulating nutrient loads that reach the river. Because of the abundant cropland in Iowa and Illinois, there’s also significant cost data concerning N and P loading in nearby watersheds that could be applicable to Quad Cities. Other factors that contributed to this choice include the documented presence of HABs, a varied manufacturing presence, and a relatively low climate vulnerability score.

This community has the following features relevant to nutrient loading cost drivers:

1. Drinking water: treatment facilities sourcing water from the Mississippi River.
2. Wastewater: at least 1 point source facility that discharges N and P considered to be contributing to water body impairments in the MSR watershed.
3. Manufacturing: approximately 18 food and beverage manufacturers within one mile of the MSR, including Kraft and Nestle Purina.
4. Agriculture: at least 170 livestock farms in the counties that intersect with the statistical area as well cropland making up over a third of the drainage area into the immediate HUC12. Corn – which is prone to excess nitrogen and phosphorus runoff – actually makes up approximately 20 percent of the total drainage area.
5. Forestry: forests make up 15 percent of the area that drains into the immediate HUC12 and there is a significant forestry and lumber processing presence.
6. Commercial Navigation: documented dredging activity occurs in the Quad Cities section of the MSR.

Figure 6. Map of facilities located within 2 km of the Mississippi River at the selected future study sites that 1) intake drinking water from the Mississippi River; 2) discharge nutrients (N and/or P) to surface waters in the watershed and are considered by the EPA contributing to water quality impairment; or 3) are food and beverage manufacturers.



3.3. Alternate Communities

Sorting cities and towns according to these criteria also yielded a short list of alternate study sites that could substitute for or augment the selected communities, as necessary.

Minneapolis / St. Paul

- Pros
  - Social vulnerability score in aggregate is low, but at the census tract level there is significant variation (i.e., lower scores are concentrated around the river).
  - Significant documented recreational closures due to local algal blooms
  - Significant food and beverage manufacturing presence (quantity and national brands like General Mills and Purina Mills)
- Neutral
  - High in watershed; likely to bear less of a cost burden than other communities
  - Significant forestry presence
- Cons
  - Low climate risk relative to other options

Quincy, IL

- Pros
  - Smaller city, still meets most criteria
  - Presence of food and beverage / industrial manufacturing
  - Significant cropland and livestock farm presence
- Neutral
  - Smaller city
- Cons
  - Lower climate risk and social vulnerability relative to other options

St. Louis, MO

- Pros
  - High social vulnerability and climate risk scores relative to other options
  - Significant manufacturing presence (national brands like Hershey, Frito Lay, and Nestle)
- Neutral
  - Both government owned and privately owned drinking water treatment facilities
- Cons
  - Another large metropolitan area

4. CO-BENEFITS OF NUTRIENT LOADING MITIGATION STRATEGIES

Many nutrient mitigation strategies—like wetland restoration, floodplain reconnection, and edge of field practices—offer additional ecological and economic benefits beyond nutrient reduction. These are called co-benefits, and they take many forms: green spaces can slow and store stormwater and runoff, helping to ease flooding; they sequester carbon, helping keep it out of the atmosphere; they can offer recreational spaces, improve habitat, and improve soil stability.

Because ecosystems are living systems, natural assets like floodplains are often more resilient and less costly to maintain than built infrastructure. Consider a healthy floodplain and a water treatment plant; both are effective at reducing nutrient loads, however two differences are notable. First, the water treatment plant requires continual operations and maintenance costs and eventual replacement, whereas the floodplain does not. Second, the floodplain does more than purify water; it offers a number of economically valuable ecosystem services as co-benefits. Acknowledging the economic value of nature often shows nature-based solutions to be more cost effective than built infrastructure, while raising awareness of the long-term connections between people and these natural assets. Understanding these values is critical to making informed land-use decisions, and there is a robust ecosystem service valuation literature to support this effort.

In recognition of the efficacy of green infrastructure at reducing nutrient loads and providing other important co-benefits, the NRCS incentivizes farmers to implement conservation practices that improve water quality by providing free conservation planning services and cost-sharing for practices that produce natural assets like grassed waterways. Understanding these benefits, and who benefits from them, reveals that incentive payments do not necessarily need to come from the public sector.

Take for example the water quality improvements effected by NRCS, the 77 Ranch in Blooming Grove, Texas, and MillerCoors brewery in Fort Worth.[62] Ranchers Gary and Sue Price enrolled part of their land in the NRCS National Water Quality Initiative, implementing sustainable practices for capturing manure and nutrient runoff and thus improving water quality for the millions of downstream residents served by their watershed. MillerCoors brewery also recognized the importance of clean water to its business, these practices on private lands to their bottom line, and has supported water quality investments on upstream public lands by investing $385,000 in incentive payments and technical assistance for landowners in the watershed interested in better managing nutrient runoff.[63]

A deeper dive into the costs of nutrient loading—and the co-benefits of proposed mitigation solutions—that outlines who is in a position to provide and receive those benefits could help produce novel collaborations that spread costs and unlock benefits across the Mississippi River Basin.

5. DISCUSSION

The most significant conclusion from this survey study is the need for a comprehensive analysis of the impacts of nutrient loading to different sectors of the economy—locally, regionally, and across a diversity of communities. Understanding how these costs vary across the basin is an important step to developing a coordinated response that can match the distributed nature of the nutrient loading problem.

Nutrient Loading and the Gulf Hypoxia Action Plan

The costs of nutrient loading are relevant beyond the MRCTI-member communities; the 2008 Hypoxia Task Force Action Plan[64]—still implemented today—brings together state and federal leaders to coordinate the response to hypoxia in the Gulf, and makes robust state nutrient reduction plans the cornerstone of its efforts. The Plan suggests a basin-wide 45% reduction in N and P levels from the average load between 1980-1996.

Although not every state has released numerical reduction goals, they all provide a framework outlining the process of nutrient reduction. States in the upper portion of the Mississippi tended to provide numerical goals, while those further south did not. States with quantified goals include:

- Minnesota set a goal of reducing phosphorus loads by 45% by 2025 and nitrogen loads by 20% before 2025, with a 45% reduction by 2040 (based on the 1980–1996 average)
- Iowa set a goal to reduce nonpoint N and P loads by 41% and 29% respectively
- Wisconsin set an overall reduction goal of 45% for N and P levels from a 1995 baseline amount
- Illinois plans to reduce N loads by 15% and P loads by 25% before 2025

In their reduction strategies, Missouri, Kentucky, Tennessee, Arkansas, Mississippi, and Louisiana did not present clear nutrient reduction goals, but rather outlined ways in which to determine such a goal and reduce nutrient loads. The use of agricultural best management practices (BMPs) is a common suggested action to reduce nutrient loads from nonpoint sources along the Mississippi River. BMPs include using cover crops to absorb nutrients, balancing use of fertilizer and manure with more sustainable practices and implementing other strategies to reduce N and P pollution. In addition, using a permit system for point source N and P discharge sites encourages innovation and nutrient load reductions, but can be costly to monitor.

Consequently, the valuation approach presented here may be useful state and federal partners—especially those states that have yet to quantify reduction goals, as it presents a pathway for estimating the magnitude of the negative effects of the nutrient loading that drives hypoxic conditions in the Gulf.

In General, Smaller Communities Bear Higher Costs Per Person

Another significant finding of this report is the need to understand how the nutrient loading costs vary by community size. Additional research should focus on measuring these costs on a per-capita basis, and the extent to which utilities pass these costs on to individuals. For example, the capital costs of water treatment plant retrofitting and expansions are often quite large, and theory suggests that small- to medium-sized communities will bear larger costs per resident served than larger cities. Although there may be federal programs to help small towns with those capital costs, medium-sized towns may not qualify. In the shared Mississippi River Basin, this speaks to the need for cooperation between communities upstream and downstream on nutrient mitigation, as cost burdens, ability to pay, and total nutrient contributions vary by size, location, and land use.

Data Limitations and the Way Forward

Future analysis could draw on many of the economic studies presented in this report as a first step towards quantifying the costs of eutrophication of the Mississippi River by sector. The literature and cost data reviewed in this study prioritizes evidence from the Mississippi River Basin, and reviews other evidence that may be relevant when no local studies exist. This study revealed that comprehensive, locally specific, publicly available primary data does not exist for every economic sector affected by nutrient loading.

As such, future analysis will need to determine when secondary data—evidence on the costs of nutrient loading collected elsewhere—is transferrable to communities across the Mississippi River Basin. The benefit transfer method takes value estimates from different study sites and applies them to the site of interest—in this case, the Mississippi River Basin. One familiar application of the benefit transfer method is a property assessment in which the estimated value of taxable property is determined not by a visit by a home inspector, but by comparing the features of the property (e.g., number of bedrooms, lot size, view, recent remodel) with prices of similar properties in similar markets. As a means of indirectly estimating values, the benefit transfer method can generate a wide range of reasonable value estimates for a fraction of the time and money required to collect site-specific data in the field. This methodology is widely used in the field of ecosystem service valuation.

The evidence presented in this study has been collected to facilitate this analysis, and focuses on key variables for transferability, discusses the suitability of available data for benefit transfer, and highlights additional research that may be necessary to facilitate valuation. When publicly available data need to be augmented through targeted primary research, factors including the size of the data gap, the ease of conducting such research, and the level of interest in a specific sector (e.g., recreation, manufacturing, et al.) will need to be considered. For example, in order for certain existing cost data for individual water treatment technologies to be transferred to the Mississippi River Basin, additional data collection would be required from water treatment facilities. For example, to quantify costs of wastewater treatment at a food and beverage manufacturer, researchers would need to understand characteristics like the wastewater capacity (e.g., in millions of gallons treated per day), the concentration of N and P in the influent, and the exact technologies and processes used.

Ultimately, this study has identified important data on the costs of nutrient loading to different sectors of the economy. Some of these data are local, others are not; these in turn will need to be scaled, normalized, and augmented with targeted primary data collection, and paired with a clear understanding of the ecological process by which nutrients impose costs on communities. Additional research in the selected deep-dive communities based on this study will be a unique and important effort that brings together data from multiple sources to focus on how nutrient-loaded water imposes additional costs to communities large and small across the Mississippi River Basin.

APPENDIX A. REGION OF STUDY

The "region" referred to in this report includes all cities, towns, and counties directly adjacent to the Mississippi River. For a list of counties included in the region, see Figure 7 and Table 2, below.

Figure 7. Map of counties included in the study region.

Table 2. All counties within the study region.

Arkansas
- Chicot County
- Crittenden County
- Desha County
- Lee County
- Mississippi County
- Phillips County

Illinois
- Adams County
- Alexander County
- Calhoun County
- Carroll County
- Hancock County
- Henderson County
- Jackson County
- Jersey County
- Jo Daviess County
- Madison County
- Mercer County
- Monroe County
- Pike County
- Randolph County
- Rock Island County
- St. Clair County
- Union County
- Whiteside County

Iowa
- Allamakee County
- Clayton County
- Clinton County
- Des Moines County
- Dubuque County
- Jackson County
- Lee County
- Louisa County
- Muscatine County
- Scott County

Kentucky
- Ballard County
- Carlisle County
- Fulton County
- Hickman County

Louisiana
- Ascension Parish
- Concordia Parish
- East Baton Rouge Parish
- East Carroll Parish
- East Feliciana Parish
- Iberville Parish
- Jefferson Parish
- Madison Parish
- Orleans Parish
- Plaquemines Parish
- Pointe Coupee Parish
- St. Bernard Parish
- St. Charles Parish
- St. James Parish
- St. John the Baptist Parish
- Tensas Parish
- West Baton Rouge Parish
- West Feliciana Parish

Minnesota
- Aitkin County
- Anoka County
- Beltrami County
- Benton County
- Cass County
- Clearwater County
- Crow Wing County
- Dakota County
- Goodhue County
- Hennepin County
- Houston County
- Hubbard County
- Itasca County
- Morrison County
- Ramsey County
- Sherburne County
- Stearns County
- Wabasha County
- Washington County
- Winona County
- Wright County

Mississippi
- Adams County
- Bolivar County
- Claiborne County
- Coahoma County
- DeSoto County
- Issaquena County
- Jefferson County
- Tunica County
- Warren County
- Washington County
- Wilkinson County

Missouri
- Cape Girardeau County
- Clark County
- Jefferson County
- Lewis County
- Lincoln County
- Marion County
- Mississippi County
- New Madrid County
- Pemiscot County
- Perry County
- Pike County
- Ralls County
- Scott County
- St. Charles County
- St. Louis County
- Ste. Genevieve County

Tennessee
- Dyer County
- Lake County
- Lauderdale County
- Shelby County
- Tipton County

Wisconsin
- Buffalo County
- Crawford County
- Grant County
- La Crosse County
- Pepin County
- Pierce County
- Trempealeau County
- Vernon County

APPENDIX B. CROPLAND SURVEY RESULTS

Cropland data was obtained from the USDA National Agriculture Statistics Services (NASS) Quick Stats. Criteria chosen included total acres planted in 2020 of all field crops and vegetable crops, by county and by crop, for all ten states in the MSR region. Table 3 is a summary of the results including state-level and county-level acreage by crop and by state, as well as comparisons to in-state and regional acreage.

Using Arkansas corn as an example: 11.4 percent of Arkansas's total cropland planted in 2020 was corn; 2.9 percent of Arkansas's total cropland was planted with corn and found in MSR counties; 0.7% of all cropland across all ten MSR states (regional) was corn planted in Arkansas state; and 1.2% of cropland planted across all MSR counties (regional) was corn planted in Arkansas MSR counties.

Table 3. Cropland planted in 2020 with field and vegetable crops. Cropland presented by crop at both state- and MSR-county levels in acres and percent of in-state and regional cropland.

State	Crop	State-Level, Acres	MSR County-Level, Acres	Percent of State Cropland, In-State	Percent of State Cropland in MSR Counties, In-State	Percent of Cropland in MSR States, Regional	Percent of Cropland in MSR Counties, Regional
AR	**Subtotal**	**5,426,000**	**1,726,800**		**31.8%**	**5.8%**	**12.8%**
	Corn	620,000	159,700	11.4%	2.9%	0.7%	1.2%
	Cotton	525,000	253,700	9.7%	4.7%	0.6%	1.9%
	Rice	1,461,000	259,400	26.9%	4.8%	1.6%	1.9%
	Soybeans	2,820,000	1,054,000	52.0%	19.4%	3.0%	7.8%
IL	**Subtotal**	**21,660,000**	**2,850,000**		**13.2%**	**23.1%**	**21.1%**
	Corn	11,300,000	1,608,600	52.2%	7.4%	12.1%	11.9%
	Oats	60,000	13,200	0.3%	0.1%	0.1%	0.1%
	Soybeans	10,300,000	1,228,200	47.6%	5.7%	11.0%	9.1%
IA	**Subtotal**	**23,170,000**	**1,769,700**		**7.6%**	**24.7%**	**13.1%**
	Corn	13,600,000	1,144,200	58.7%	4.9%	14.5%	8.5%
	Oats	170,000	34,200	0.7%	0.1%	0.2%	0.3%
	Soybeans	9,400,000	591,300	40.6%	2.6%	10.0%	4.4%
KY	**Subtotal**	**3,340,000**	**308,000**		**9.2%**	**3.6%**	**2.3%**
	Corn	1,490,000	114,600	44.6%	3.4%	1.6%	0.8%
	Soybeans	1,850,000	193,400	55.4%	5.8%	2.0%	1.4%
LA	**Subtotal**	**2,200,000**	**695,500**		**31.6%**	**2.3%**	**5.1%**
	Corn	500,000	148,000	22.7%	6.7%	0.5%	1.1%
	Cotton	170,000	65,700	7.7%	3.0%	0.2%	0.5%
	Rice	480,000	23,500	21.8%	1.1%	0.5%	0.2%
	Soybeans	1,050,000	458,300	47.7%	20.8%	1.1%	3.4%
MN	**Subtotal**	**15,725,000**	**1,706,400**		**10.9%**	**16.8%**	**12.6%**
	Barley	70,000	1,900	0.4%	0.0%	0.1%	0.0%
	Corn	8,000,000	1,031,000	50.9%	6.6%	8.5%	7.6%

State	Crop	State-Level, Acres	MSR County-Level, Acres	Percent of State Cropland, In-State	Percent of State Cropland in MSR Counties, In-State	Percent of Cropland in MSR States, Regional	Percent of Cropland in MSR Counties, Regional
	Oats	255,000	73,400	1.6%	0.5%	0.3%	0.5%
	Soybeans	7,400,000	600,100	47.1%	3.8%	7.9%	4.4%
MS	**Subtotal**	**3,319,000**	**1,116,700**		**33.6%**	**3.5%**	**8.3%**
	Corn	510,000	108,700	15.4%	3.3%	0.5%	0.8%
	Cotton	530,000	140,400	16.0%	4.2%	0.6%	1.0%
	Peanuts	23,000	0	0.7%	0.0%	0.0%	0.0%
	Rice	166,000	89,600	5.0%	2.7%	0.2%	0.7%
	Soybeans	2,090,000	778,000	63.0%	23.4%	2.2%	5.8%
MO	**Subtotal**	**9,823,000**	**1,992,700**		**20.3%**	**10.5%**	**14.7%**
	Corn	3,450,000	595,800	35.1%	6.1%	3.7%	4.4%
	Cotton	295,000	122,800	3.0%	1.3%	0.3%	0.9%
	Rice	228,000	53,400	2.3%	0.5%	0.2%	0.4%
	Soybeans	5,850,000	1,220,700	59.6%	12.4%	6.2%	9.0%
TN	**Subtotal**	**2,800,000**	**501,700**		**17.9%**	**3.0%**	**3.7%**
	Corn	870,000	89,500	31.1%	3.2%	0.9%	0.7%
	Cotton	280,000	38,200	10.0%	1.4%	0.3%	0.3%
	Soybeans	1,650,000	374,000	58.9%	13.4%	1.8%	2.8%
WI	**Subtotal**	**6,300,000**	**862,100**		**52.2%**	**6.7%**	**6.4%**
	Corn	4,000,000	554,000	63.5%	33.6%	4.3%	4.1%
	Oats	300,000	29,900	4.8%	1.8%	0.3%	0.2%
	Soybeans	2,000,000	278,200	31.7%	16.9%	2.1%	2.1%
Total		***93,763,000***	***13,529,600***				

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