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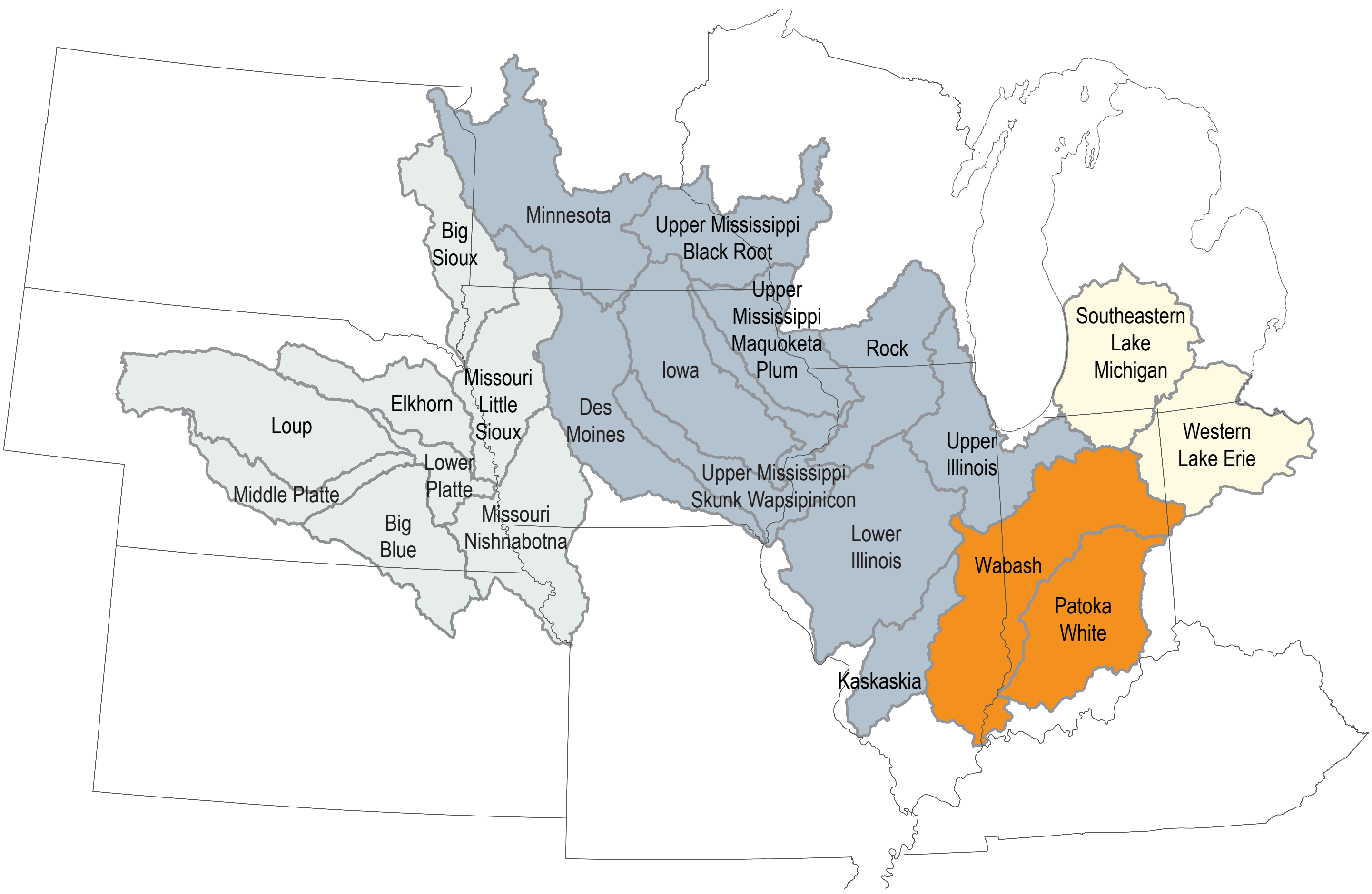
Farmer Perspectives on Agriculture and Weather Variability in the Corn Belt: A Statistical Atlas



USDA United States Department of Agriculture
National Institute of Food and Agriculture

CSCAP: USDA-NIFA Award No. 2011-68002-30190
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CSCAP 0153-2013

This survey of Midwestern corn producers was implemented through a collaboration of two USDA-NIFA supported projects, *Cropping Systems Coordinated Agricultural Project (CAP): Climate Change, Mitigation, and Adaptation in Corn-based Cropping Systems* (Award No. 2011-68002-30190) and *Useful to Usable (U2U): Transforming Climate Variability and Change Information for Cereal Crop Producers* (Award No. 2011-68002-30220). Additional funding was provided by the Iowa Agriculture and Home Economics Experiment Station, Purdue University College of Agriculture, and the Iowa Natural Resources Conservation Service.

The Climate and Corn-based Cropping Systems Coordinated Agricultural Project is a transdisciplinary partnership among 11 institutions: Iowa State University; Lincoln University; Michigan State University; The Ohio State University; Purdue University; South Dakota State University; University of Illinois; University of Minnesota; University of Missouri; University of Wisconsin; USDA Agricultural Research Service – Columbus, Ohio; and USDA National Institute of Food and Agriculture (USDA-NIFA).

For more information contact:
Climate and Corn-based Cropping Systems CAP
317 East Hall
Iowa State University
Ames, Iowa 50011-1070

E-mail: info@sustainablecorn.org
Website: sustainablecorn.org

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Layout and preparation by Renea Miller, Iowa State University

Contents

This research is part of a regional collaborative project supported by the USDA-NIFA,
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1 Study Overview

There is mounting consensus that long-term shifts in annual averages and seasonal patterns of precipitation, temperature, and humidity, as well as more erratic and extreme weather events leading to increased risk of floods, drought and fire (Coumou and Rahmstorf 2012), will continue into the foreseeable future (Beddington et al. 2012; IPCC 2007; NRC 2010a). Projected impacts on agriculture include redistribution of water availability and compromised quality, increased soil erosion, and decreased crop productivity (Hatfield et al. 2011; Howden et al. 2007; McCarl 2010). These threats to agricultural sustainability threaten food security and quality of life, leading to increasingly urgent calls for the development of effective adaptation strategies for agriculture (e.g., Coumou and Rahmstorf 2012; Howden et al. 2007; McCarl 2010; Walthall et al. 2012).

In response to these concerns, in 2011 the USDA funded the Climate and Corn-based Cropping Systems CAP (CSCAP).[1] The CSCAP is a transdisciplinary partnership among 11 institutions creating new science and educational opportunities. The CSCAP seeks to increase resilience and adaptability of Midwest agriculture to more volatile weather patterns by identifying farmer practices and policies that increase sustainability while meeting crop demand (http://www.sustainablecorn.org).

The effectiveness of any adaptation or mitigation action in Corn Belt agriculture depends on the degree to which the region's farmers are willing and able to act. Little is known, however, about farmers' perspectives on these critical topics. Thus, a primary objective of the CSCAP is to conduct social science research that assesses farmer understanding of climate change and attitudes toward adaptive and mitigative practices and strategies. Toward that end, a survey of Corn Belt farmers was conducted in February and March 2012. The survey was carried out in partnership with the Useful to Usable (U2U) project (www.AgClimate4U.org), another USDA-funded climate and agriculture project.

The CSCAP-U2U survey was sent to a stratified random sample of 18,707 farmers with at least US$100,000 of gross sales and a minimum of 80 acres of corn production in 22 six-digit Hydrologic Code Unit (HUC) watersheds (see Appendix A for a comprehensive account of survey methods). The 22 watersheds cover a substantial portion of 11 Corn Belt states—Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, Ohio, South Dakota, and Wisconsin (see Maps 1 and 2)—all of which are classified as "major crop areas" for corn and soybean (USDA 1994). Completed surveys were received from 4,778 farmers for an effective response rate of 26%.

This report provides an overview of the CSCAP-U2U survey results by watershed.[2] Each section contains a tabulated presentation of survey data and a series of maps that visually represent the distribution of responses across the entire study region.

It is our hope that the maps in this document will be useful to extension educators and other stakeholders that work with the agricultural community. To lift a map for use in a Powerpoint presentation or other document, simply use the "Take a Snapshot" tool in the Edit Menu of Adobe Reader or Adobe Acrobat to capture the image, then paste it into your presentation or other document. If you require higher resolution images than your default settings provide, go to the Edit Menu, then Preferences, then General. Click the box for "Use fixed resolution for Snapshot tool images" and increase the pixels/inch until the quality is sufficient (150 is a good place to start). Please cite this report as the source.

[1] The USDA has funded numerous projects that focus on climate change adaptation and mitigation in agriculture (http://www.csrees.usda.gov/fo/climatevariabilityandchangeafri.cfm).

[2] For initial results over the entire region please see Arbuckle et al. (2013).

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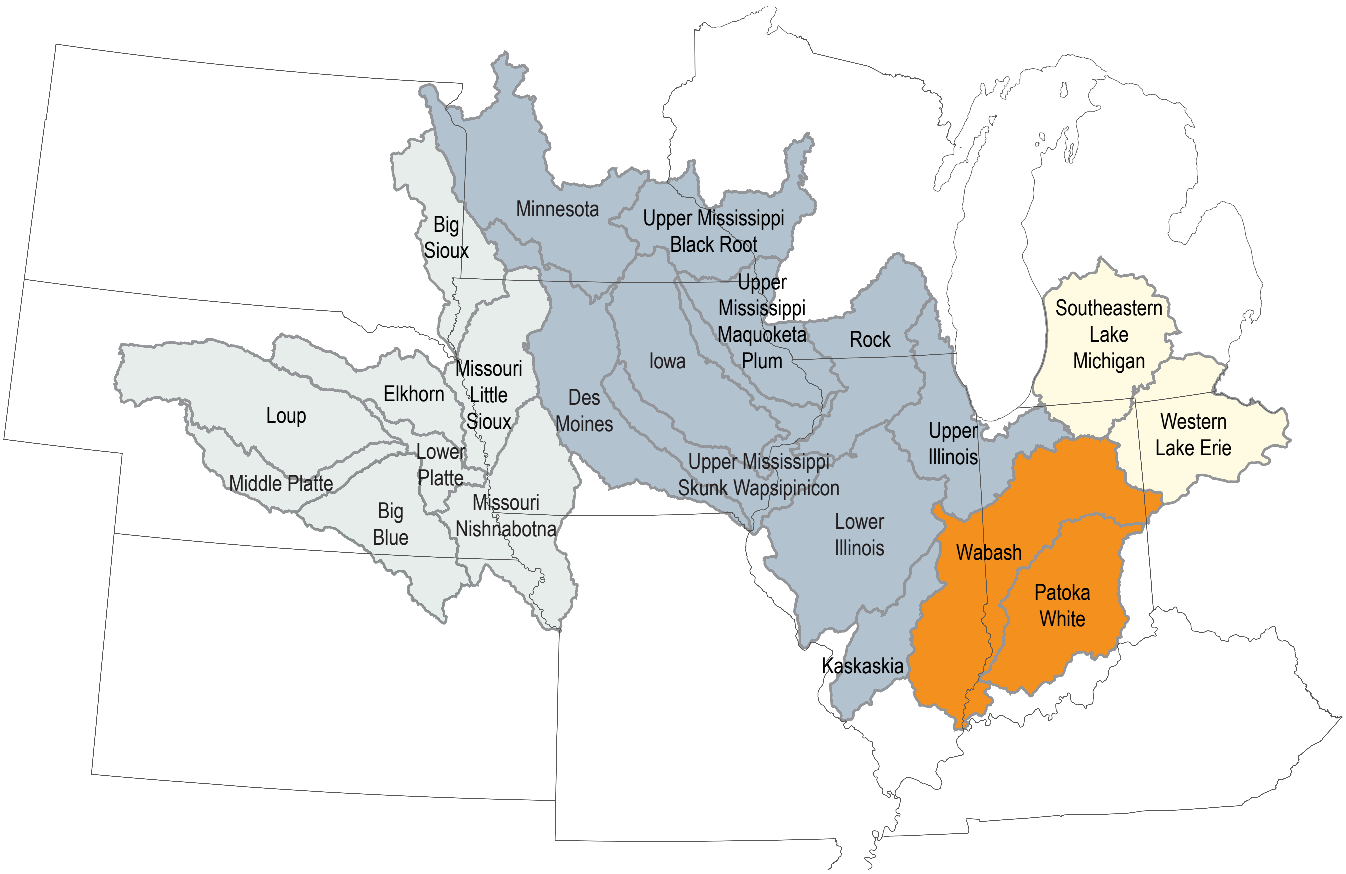

Map 1. Study watersheds.

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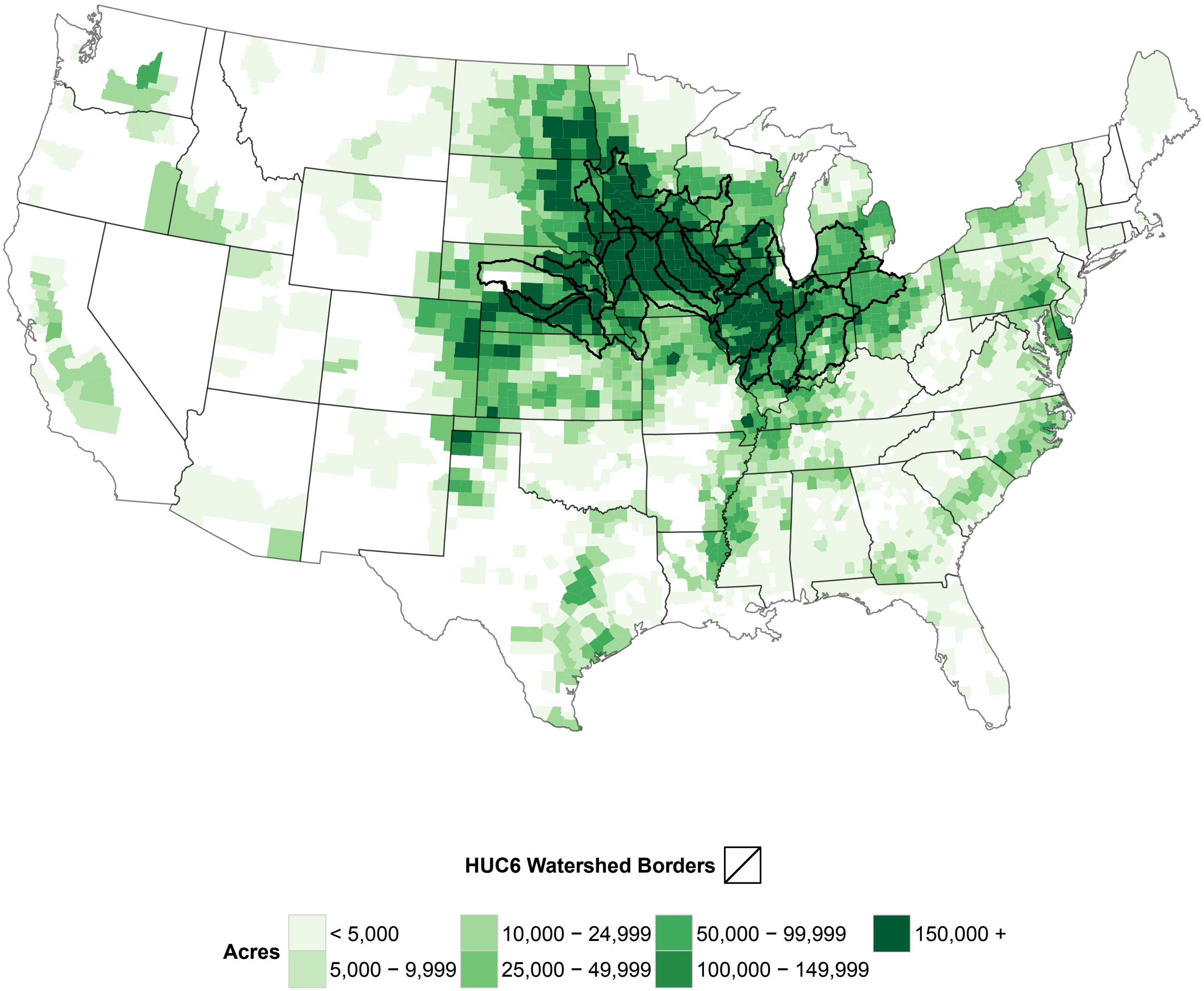

Map 2. Study watersheds overlayed on acres of corn harvested by county in 2007 (USDA 2009a).

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2 Attitudes Toward Adaptive and Mitigative Action

Attitudes are an assessment or subjective evaluation about a specific object, idea, or policy. Frequently, attitudes are intuitive or affect responses (positive, negative, or neutral) rather than analytical objective or factual analyses. The tables and maps in this section summarize Midwest farmers' attitudes toward a number of potential adaptive and mitigative actions. Adaptive actions are adjustments that farmers make as they react to or anticipate changing conditions that are of concern and may place the farm enterprise at risk. Adaptive actions can be technological, economic, social, managerial, and/or advocating institutional adjustments and are often motivated by intentions to reduce risk and vulnerability of the farm enterprise. Mitigation actions are those that reduce greenhouse gas emissions or sequester carbon. Mitigation actions can be individual responses but are most often viewed as collective activities and policies that benefit global conditions.

The survey included 15 adaptation and mitigation items to be rated on a five-point agreement scale from strongly disagree (1) to strongly agree (5). The question set was preceded by the text, "Organizations, agencies, and individuals can do a number of things to prepare for or address potential changes in climate. Please provide your opinions on the following statements."

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Table 1. Attitudes[1] toward various adaptive and mitigative actions to prepare for or address potential changes in climate, percent agree or strongly agree (n = 4,778)

Watershed (HUC6)	Q20A[a]	Q20B[b]	Q20C[c]	Q20D[d]	Q20E[e]	Q20F[f]	Q20G[g]	Q20H[h]	Q20I[i]	Q20J[j]	Q20K[k]	Q20N[n]	Q20O[o]
Weighted Full Sample	65.4	58.0	84.4	62.4	42.9	51.7	49.5	38.4	63.0	22.6	22.8	47.4	17.2
Loup	62.0	46.5	78.2	57.8	38.7	43.7	51.4	39.7	58.9	18.4	22.7	17.7	31.4
Middle Platte	59.4	50.7	86.9	68.6	45.3	48.9	35.0	37.7	59.1	21.7	16.8	27.9	46.7
Elkhorn	64.7	51.0	81.9	64.0	41.3	44.7	50.0	42.8	68.2	18.4	20.3	24.3	29.8
Big Blue	59.8	50.6	82.2	63.6	38.5	43.7	45.7	42.7	62.4	17.8	21.4	19.8	29.6
Lower Platte	65.6	58.0	82.9	67.3	45.7	48.0	51.0	42.0	67.8	25.2	26.0	28.5	25.0
Big Sioux	70.3	60.0	81.7	58.3	42.3	45.1	45.1	33.1	65.7	20.0	18.9	45.1	14.9
Missouri-Little Sioux	65.2	56.9	81.5	65.7	44.6	55.2	52.6	40.7	63.0	23.8	25.2	41.9	14.9
Missouri-Nishnabotna	68.3	64.9	91.2	67.8	45.4	52.7	50.7	38.7	59.6	24.0	20.3	35.2	13.4
Minnesota	66.7	59.0	85.9	60.8	42.7	48.2	45.6	30.7	69.6	22.0	22.0	59.0	16.5
Des Moines	59.8	54.5	84.7	65.2	43.7	50.0	50.4	30.0	54.7	19.9	21.1	55.7	11.9
Iowa	66.8	54.3	83.8	64.7	46.0	54.5	51.1	38.9	58.1	23.8	22.1	48.9	13.3
Black Root	66.8	55.6	78.7	58.0	44.7	45.6	56.7	44.4	74.0	26.7	21.1	29.7	13.6
Skunk Wapsipinicon	62.7	62.3	88.4	60.9	45.4	52.8	50.5	34.4	58.1	21.8	23.6	54.0	10.3
Maquoketa Plum	67.2	52.7	83.8	58.9	44.4	51.7	51.1	42.7	68.5	27.4	19.0	38.4	8.6
Lower Illinois	61.2	56.6	82.4	58.9	42.1	56.1	46.9	38.8	54.6	24.6	28.4	51.3	16.1
Rock	66.1	58.7	85.5	58.9	35.6	47.8	47.2	40.5	64.6	30.1	25.6	39.3	19.1
Kaskaskia	75.8	70.3	82.5	60.6	39.4	56.2	51.6	38.3	66.1	24.5	23.1	52.4	15.2
Upper Illinois	67.6	61.2	86.7	63.7	40.9	61.3	48.9	40.0	65.3	20.6	25.3	58.4	15.3
Wabash	65.6	62.7	87.8	62.6	43.4	57.7	52.1	43.3	61.6	20.0	24.7	59.3	15.7
Patoka-White	73.4	68.1	85.9	66.7	47.9	57.3	45.6	38.0	66.5	17.7	18.0	62.0	18.5
Southeastern Lake Michigan	62.4	57.0	80.5	62.8	41.6	54.6	47.3	40.8	66.7	22.9	26.6	53.0	35.8
Western Lake Erie	65.6	59.2	83.7	61.9	40.2	49.2	54.8	42.9	68.3	21.8	22.7	67.6	18.1

[1]Attitudes were measured on a 5-point agreement scale: strongly disagree, disagree, uncertain, agree, strongly agree.

[a]Farmers should take additional steps to protect farmland from increased weather variability.
[b]I should take additional steps to protect the land I farm from increased weather variability.
[c]Seed companies should develop crop varieties adapted to increased weather variability.
[d]University Extension should help farmers to prepare for increased weather variability.
[e]State and federal agencies should help farmers to prepare for increased weather variability.
[f]Farm organizations (e.g., Farm Bureau, Corn Growers) should help farmers to prepare for increased weather variability.
[g]Profitable markets for biomass should be developed to encourage planting of perennial crops (grasses, trees) on vulnerable land.
[h]Profitable markets for carbon credits should be developed to encourage use of conservation tillage, cover crops, & other practices.
[i]Profitable markets for small grains and other alternative crops should be developed to encourage diversified crop rotations.
[j]Government should do more to reduce greenhouse gas emissions and other potential sources of climate change.
[k]I should reduce greenhouse gas emissions from my farm operation.
[n]Farmers should invest more in agricultural drainage systems to prepare for increased precipitation.
[o]Farmers should invest more in irrigation systems to prepare for more frequent drought.

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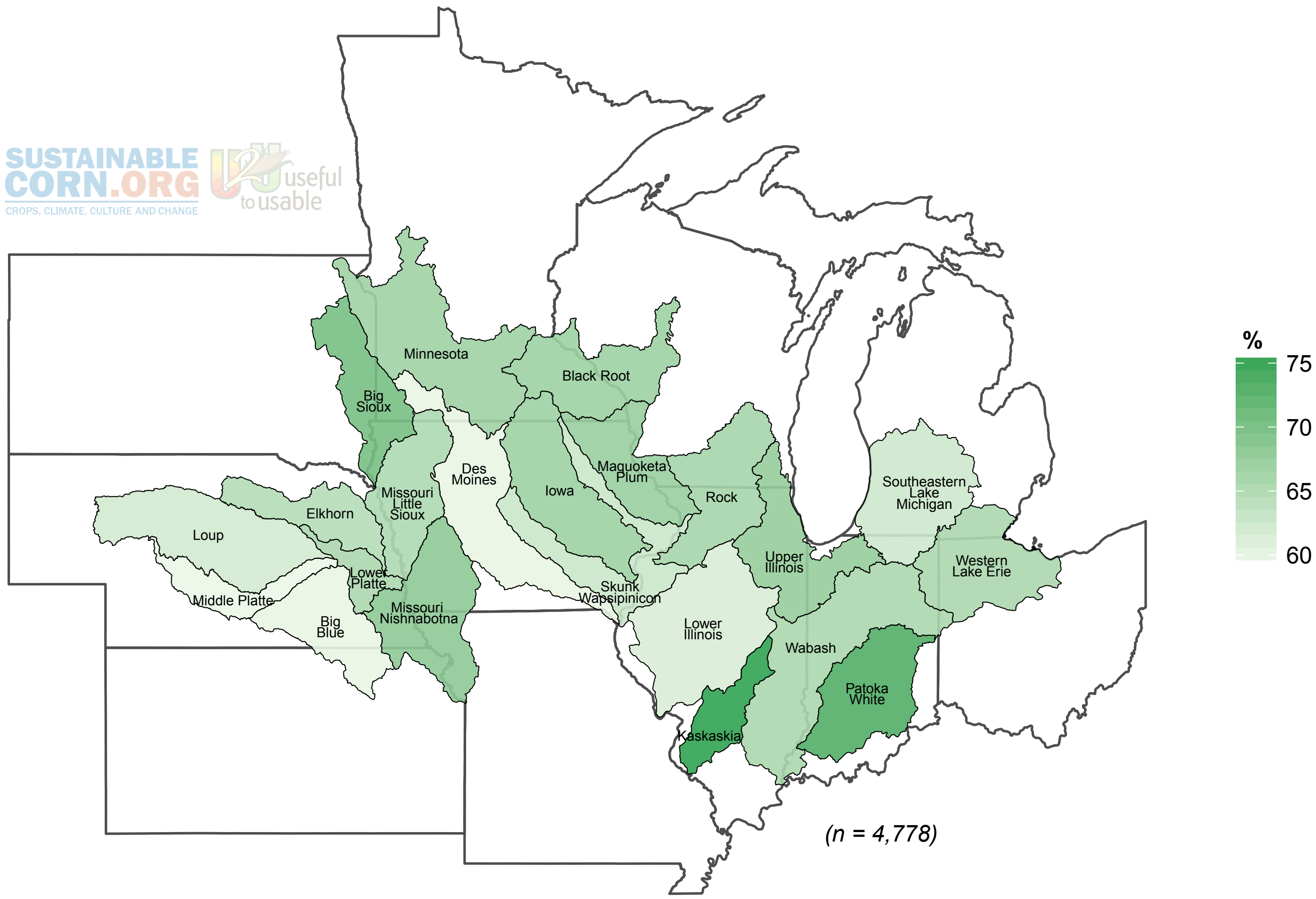

Map 3. Farmers should take additional steps to protect land from increased weather variability (Q20A), percent agree or strongly agree.

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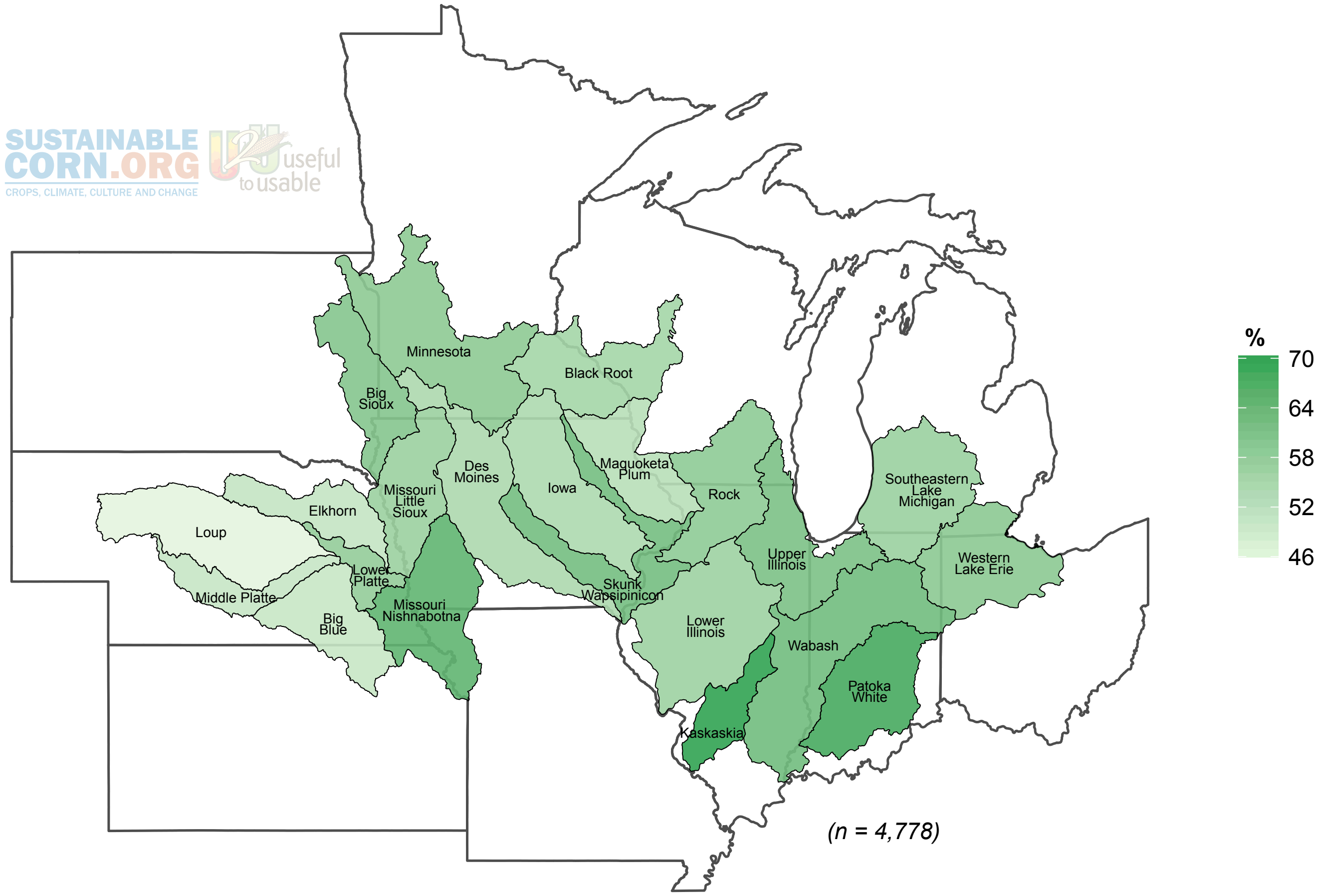

Map 4. I should take additional steps to protect land from increased weather variability (Q20B), percent agree or strongly agree.

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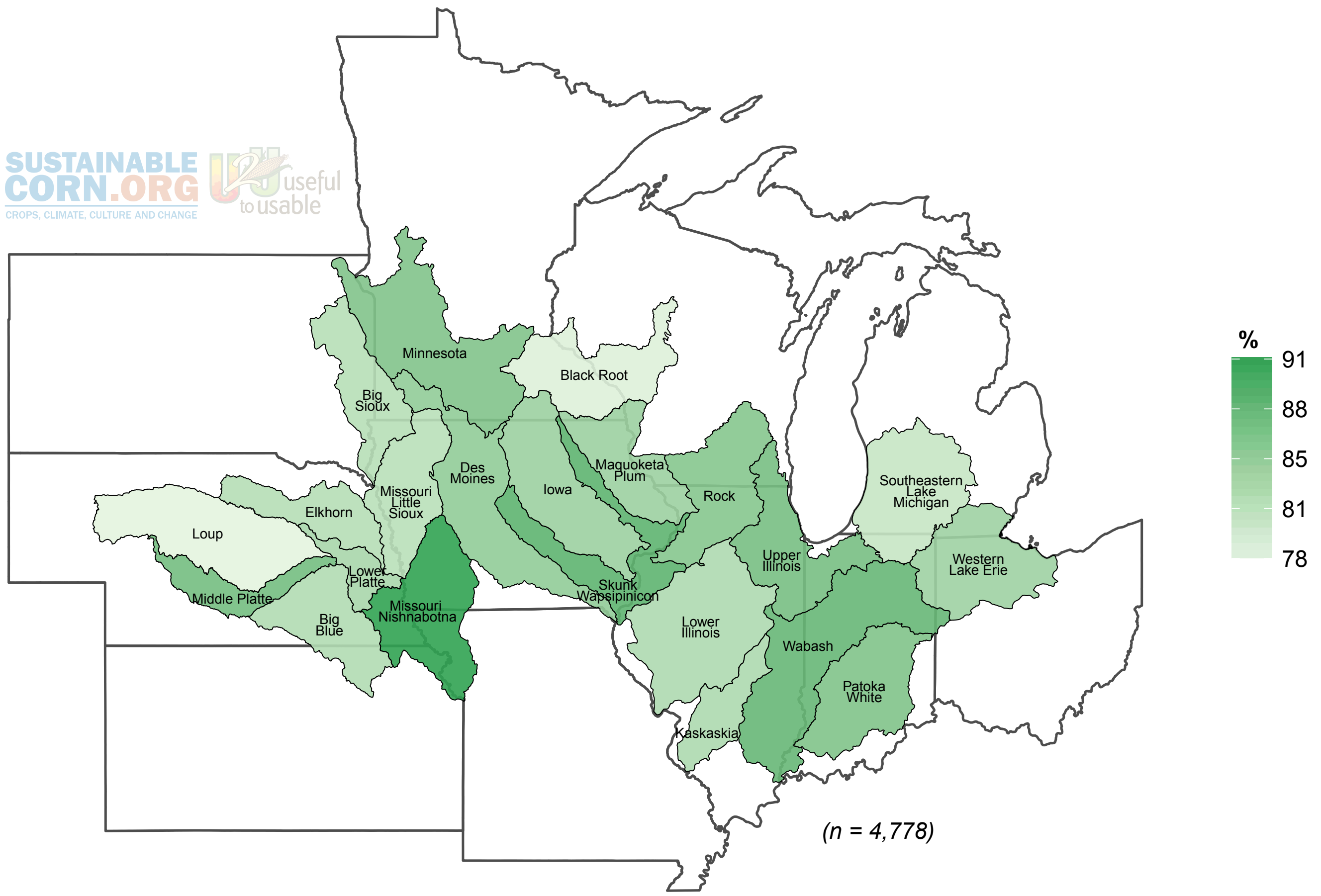

Map 5. Seed companies should develop crop varieties adapted to increased weather variability (Q20C), percent agree or strongly agree.

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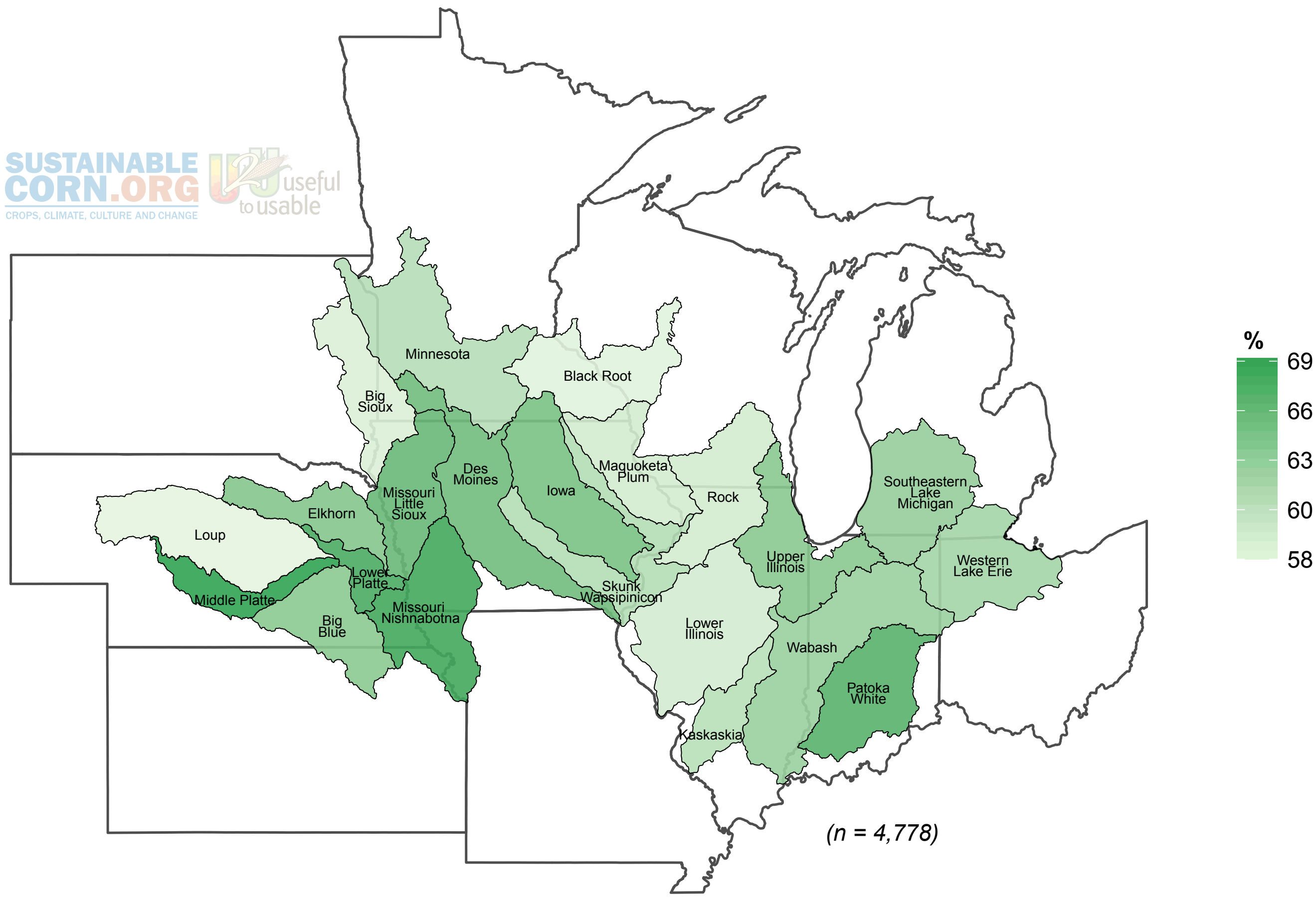

Map 6. University Extension should help farmers to prepare for increased weather variability (Q20D), percent agree or strongly agree.

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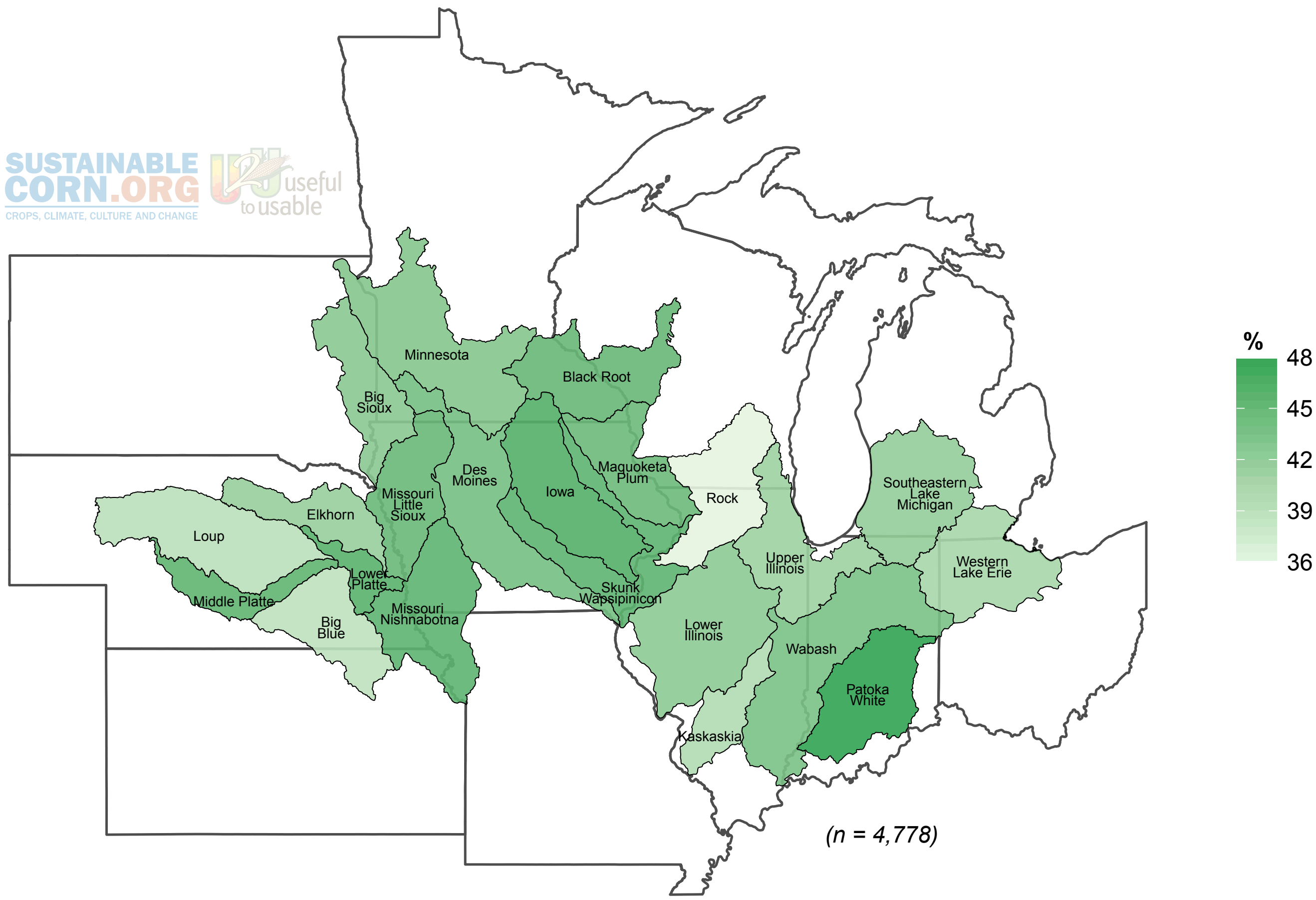

Map 7. State and federal agencies should help farmers prepare for increased weather variability (Q20E), percent agree or strongly agree.

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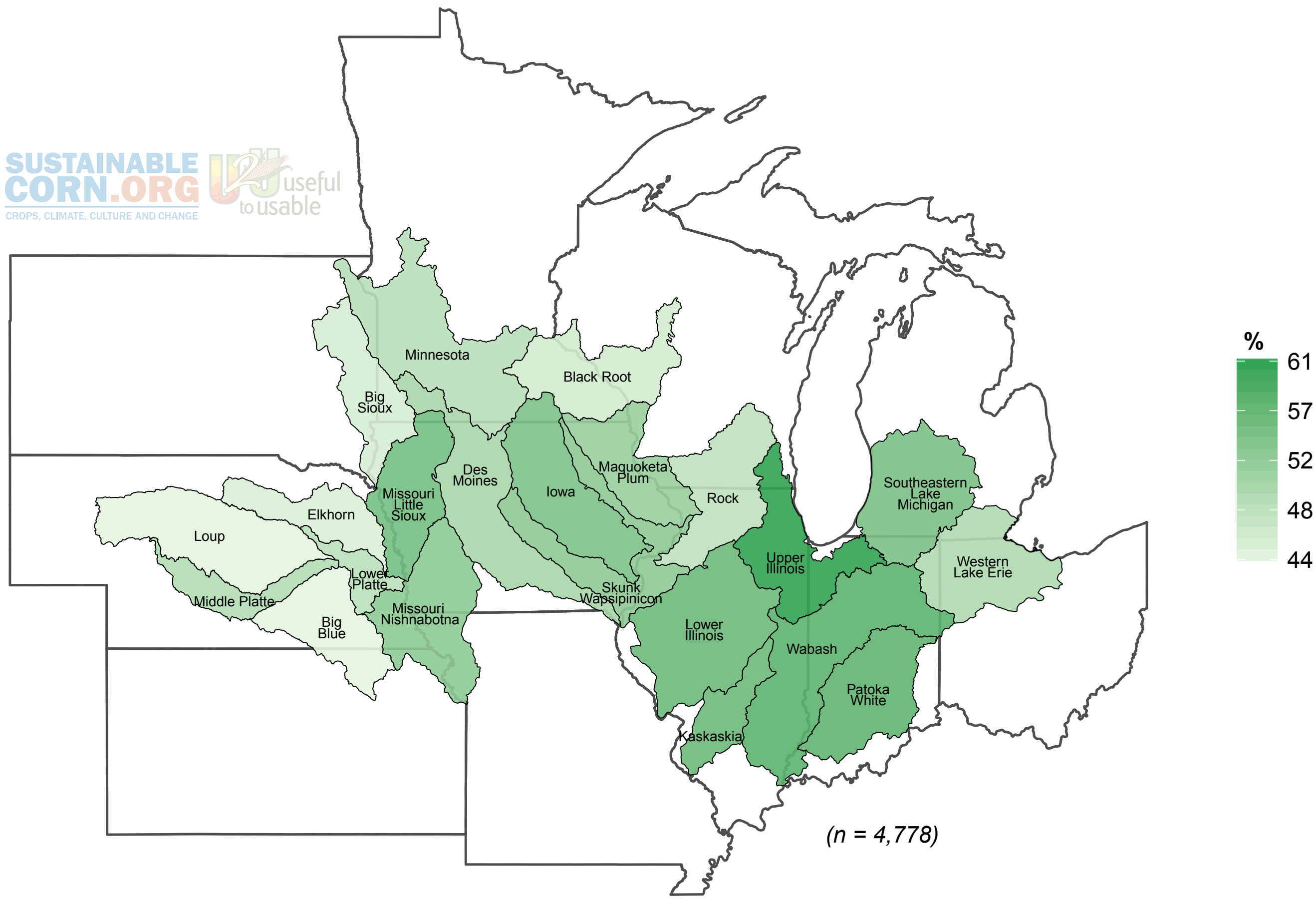

Map 8. Farm organizations should help farmers to prepare for increased weather variability (Q20F), percent agree or strongly agree.

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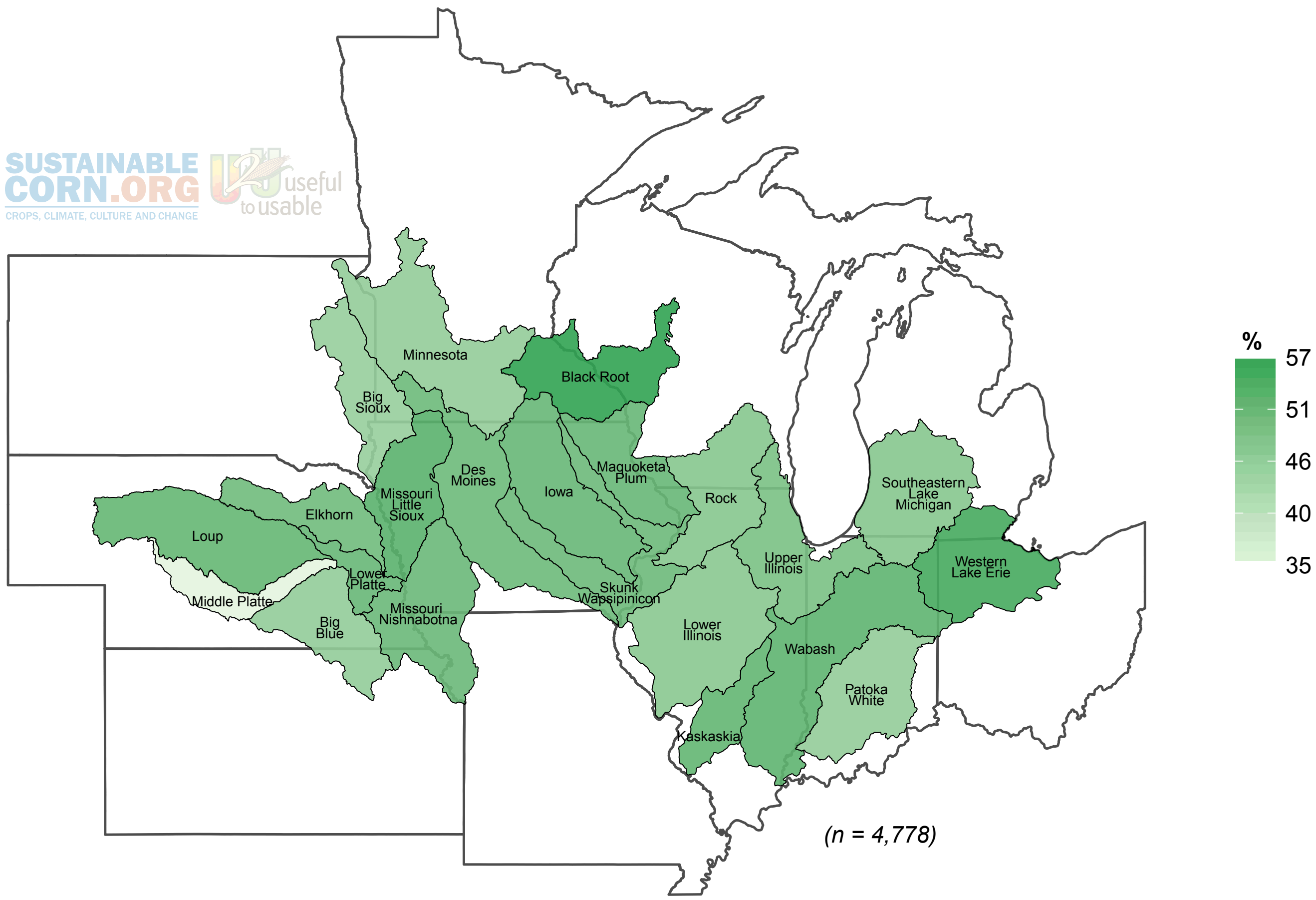

Map 9. Profitable markets for biomass should be developed to encourage planting of perennial crops (grasses, trees) on vulnerable land (Q20G), percent agree or strongly agree.

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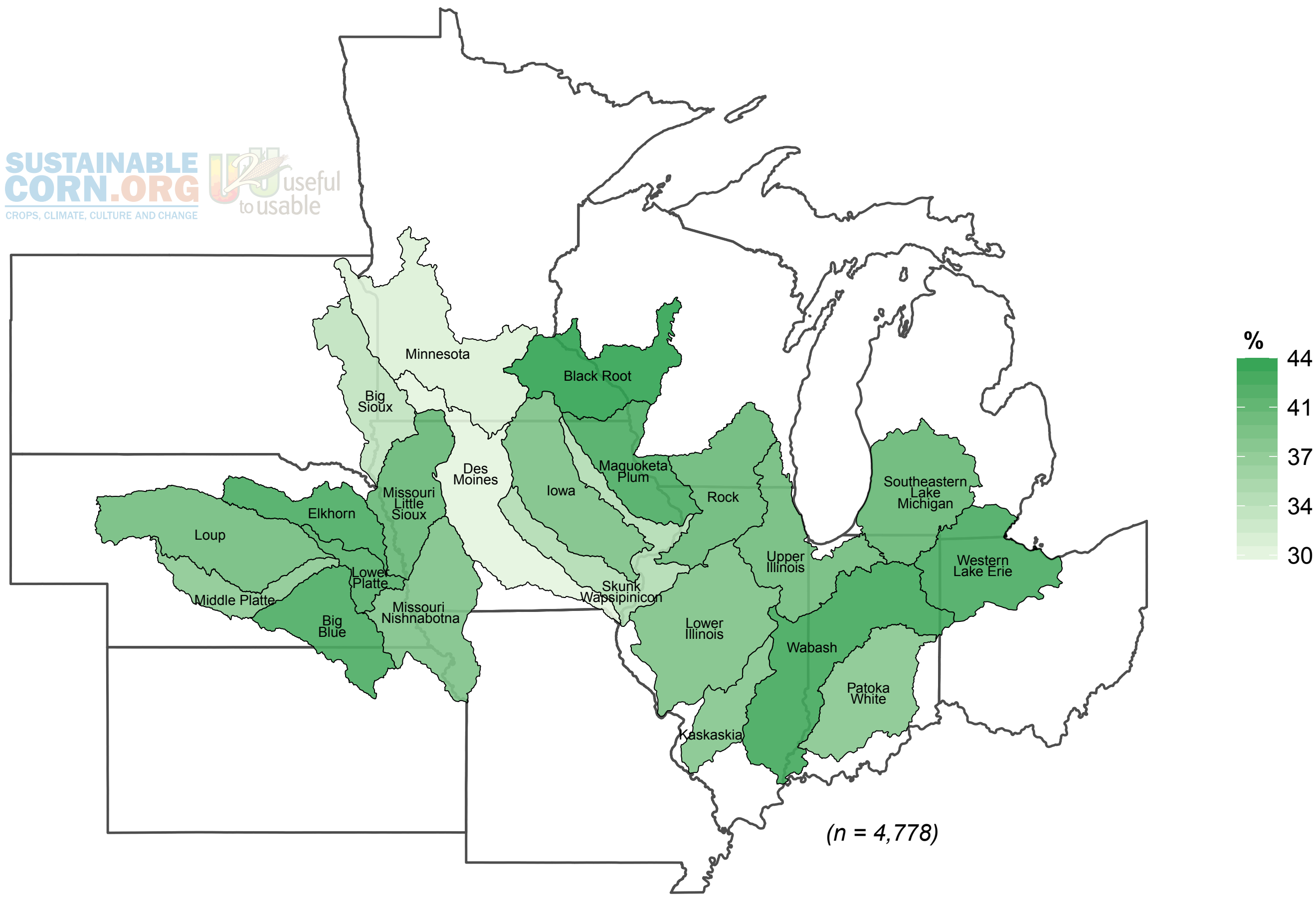

Map 10. Profitable markets for carbon credits should be developed to encourage use of conservation tillage, cover crops, and other practices (Q20H), percent agree or strongly agree.

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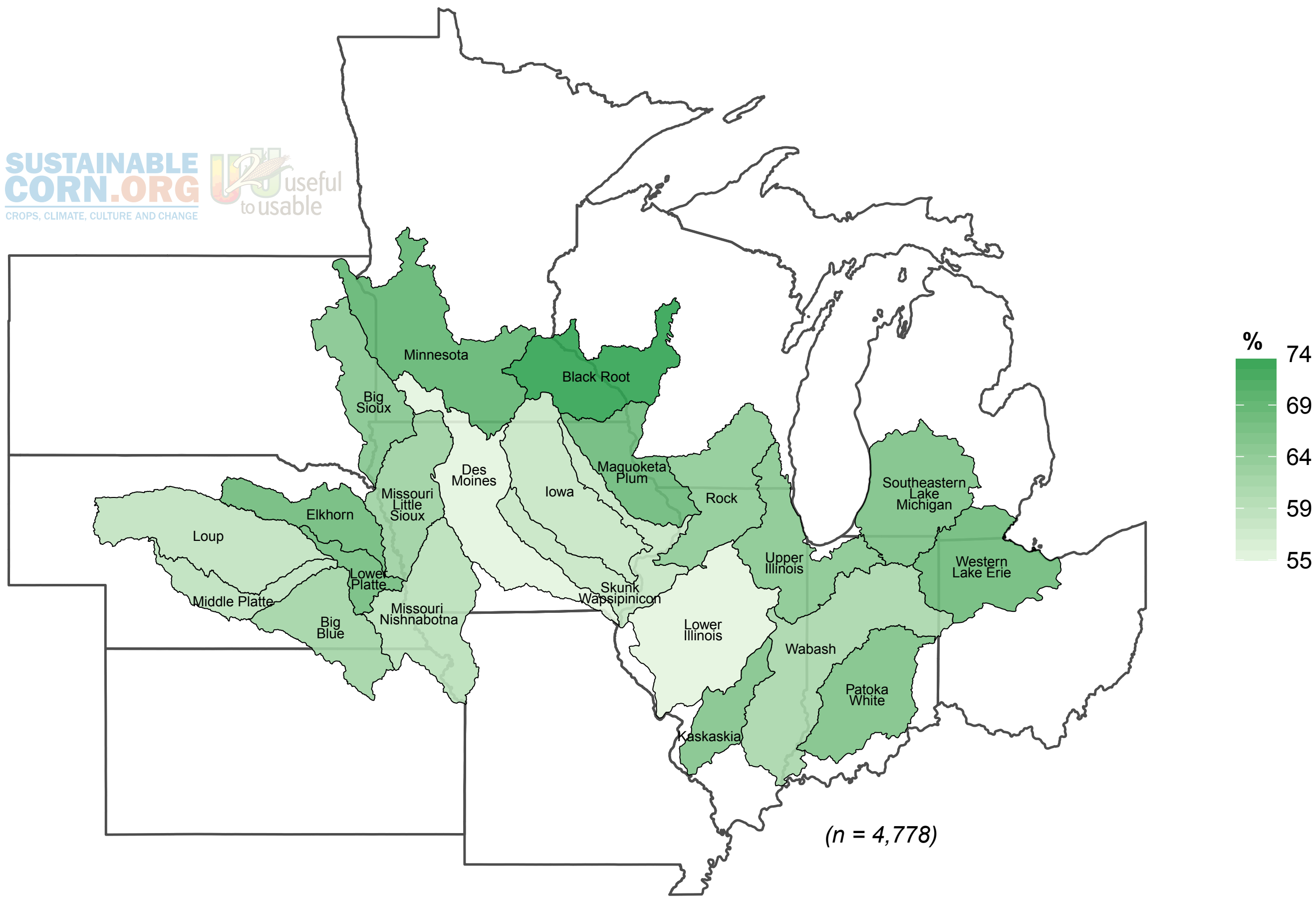

Map 11. Profitable markets for small grains and other alternative crops should be developed to encourage diversified crop rotations (Q20l), percent agree or strongly agree.

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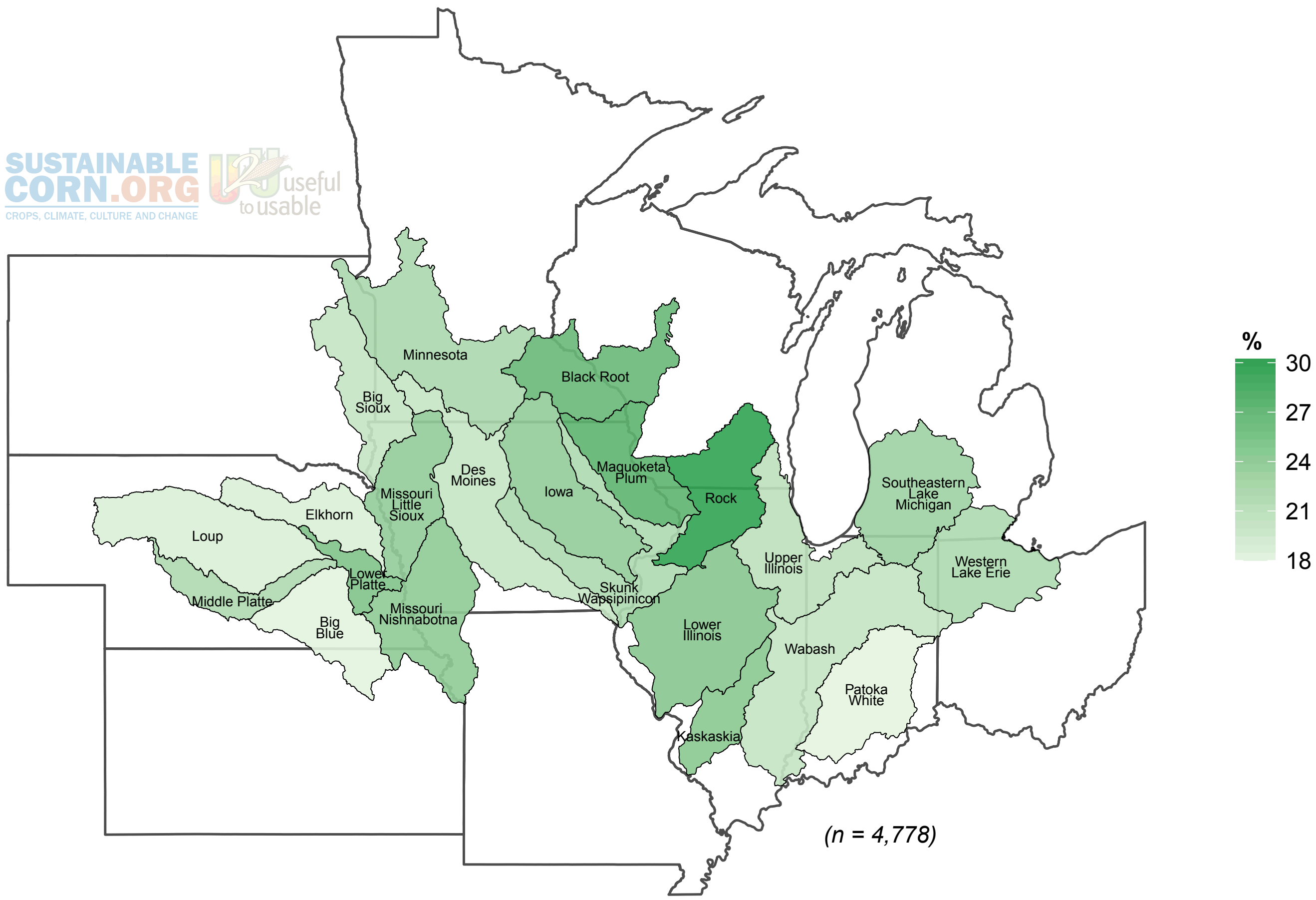

Map 12. Government should do more to reduce greenhouse gas emissions and other potential sources of climate change (Q20J), percent agree or strongly agree.

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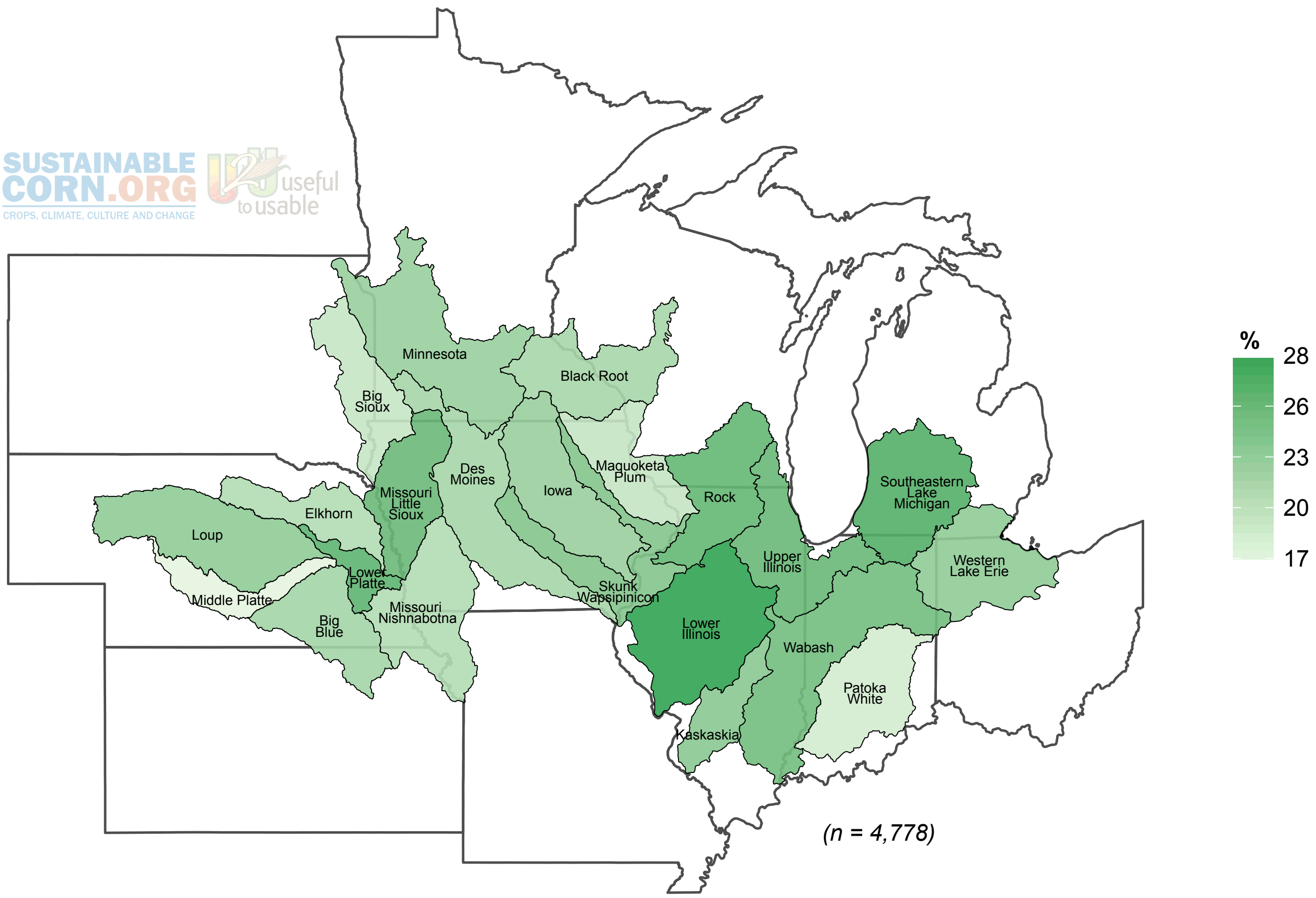

Map 13. I should reduce greenhouse gas emissions from my farm operation (Q20J), percent agree or strongly agree.

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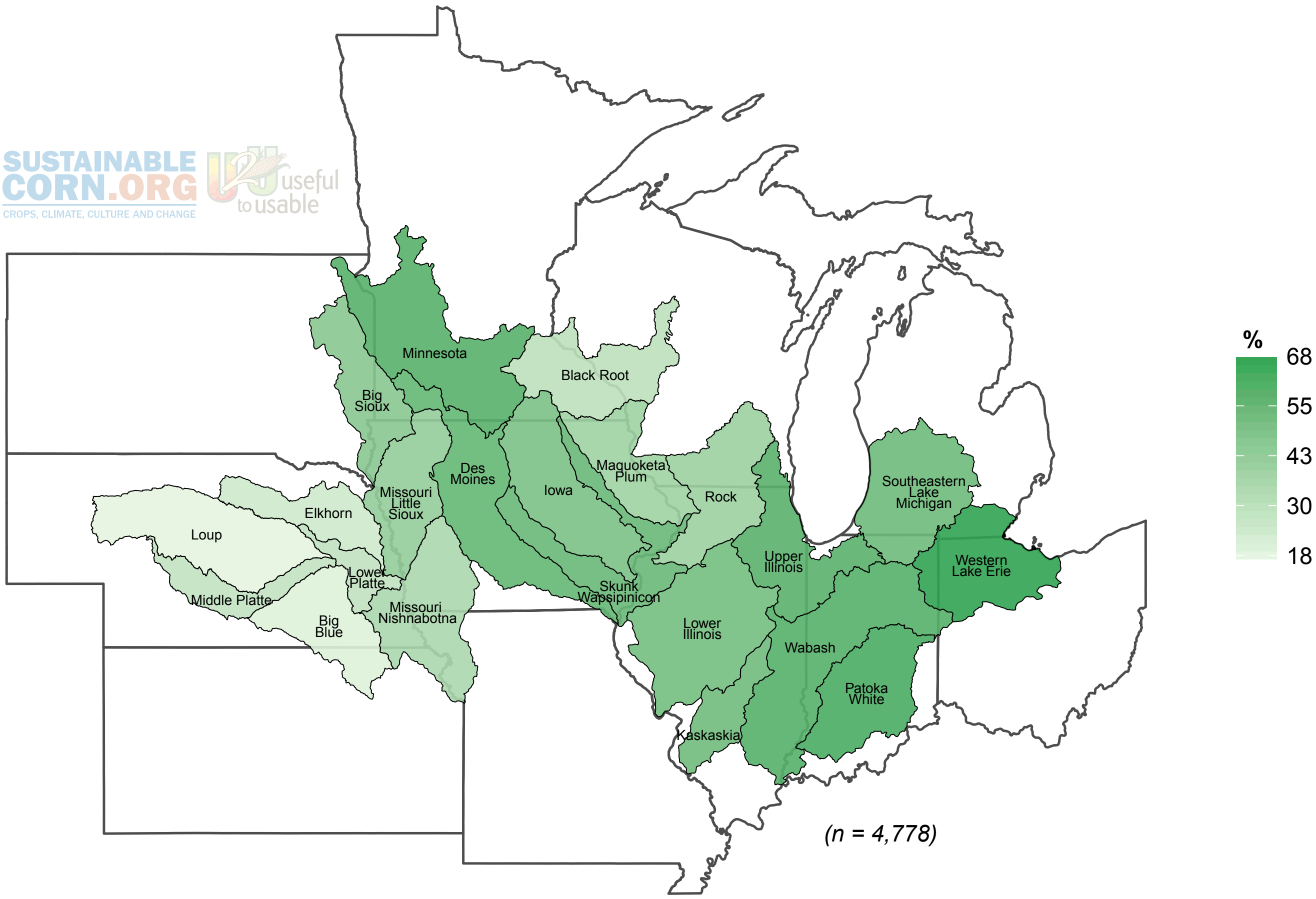

Map 14. Farmers should invest more in agricultural drainage systems to prepare for increased precipitation (Q20N), percent agree or strongly agree.

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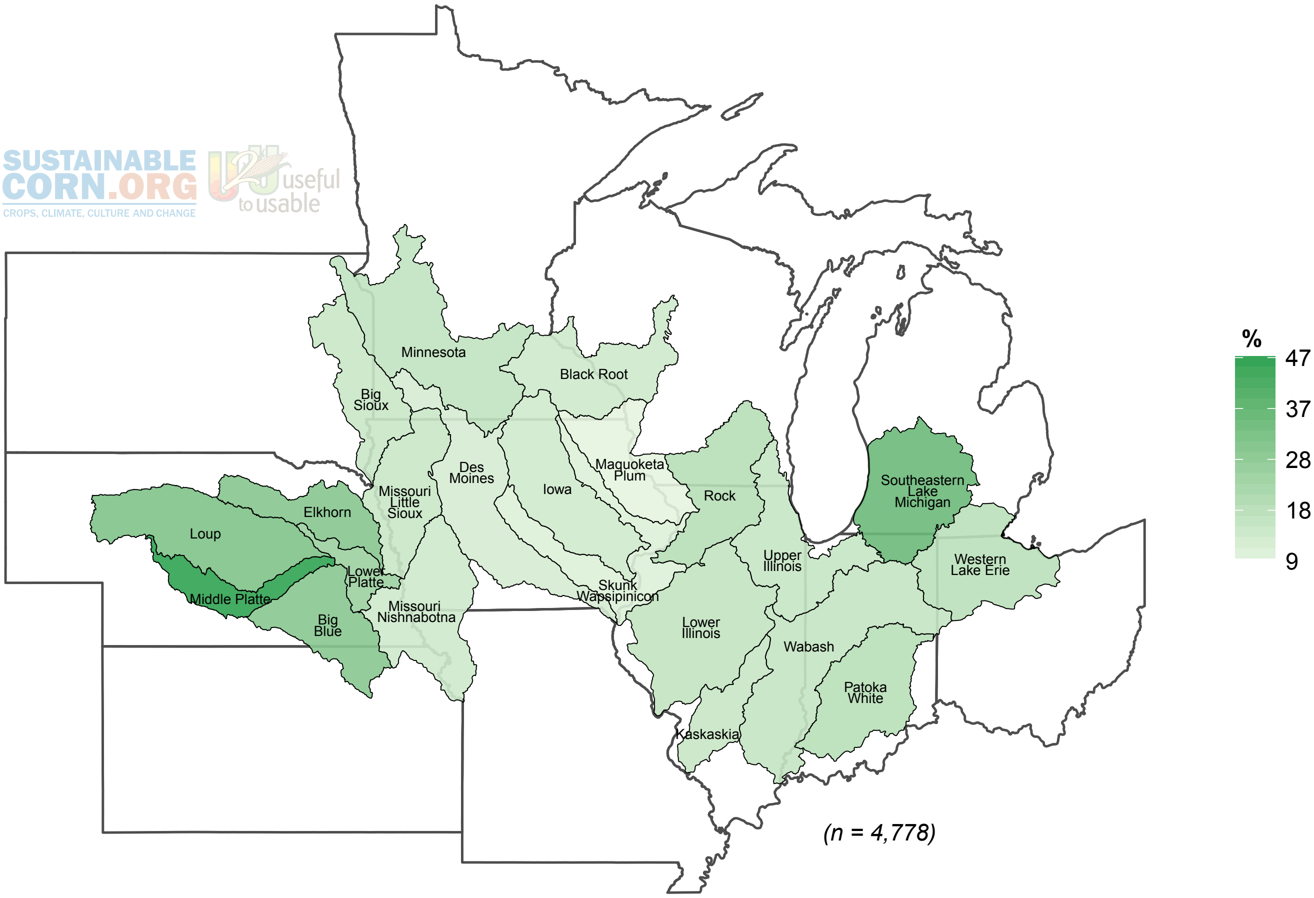

Map 15. Farmers should invest more in irrigation systems to prepare for more frequent drought (Q20O), percent agree or strongly agree.

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3 Beliefs about Climate Change

Beliefs are people's perceptions about the world and how it works. They are statements about what is regarded as true and not true. Beliefs arise from a number of sources, ranging from scientific fact, systematic (or unsystematic) observation, learned behavior, or unverified assumptions. Climate changes are shifts over time in the long-term averages of daily weather. In this section beliefs about whether the climate is changing and perceived causes of climate change are mapped.

Respondents were provided with the introductory text, "There is increasing discussion about climate change and its potential impacts. Please select the statement that best reflects your beliefs about climate change" and given five statements to choose from. These were: climate change is occurring and it is caused mostly by human activities; climate change is occurring it is caused mostly by natural changes in the environment; climate change is occurring and it is caused more or less equally by natural changes in the environment and human activities; climate change is not occurring; and, there is not sufficient evidence to know with certainty whether climate change is occurring or not.

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Table 2. Beliefs about climate change, percent (n = 4,778)

Watershed (HUC6)	CCHUM[1]	CCHUMNAT[2]	CCNAT[3]	CCUNCERT[4]	NOCC[5]
Weighted Full Sample	7.8	33.1	24.6	30.9	3.5
Loup	7.8	31.0	30.3	26.1	4.9
Middle Platte	7.3	27.7	27.7	32.9	4.4
Elkhorn	3.3	33.1	18.8	41.6	3.3
Big Blue	8.1	34.3	18.0	34.9	4.7
Lower Platte	5.9	35.3	24.2	32.0	2.6
Big Sioux	5.8	30.1	27.2	34.1	2.9
Missouri-Little Sioux	10.1	27.4	23.1	37.0	2.4
Missouri-Nishnabotna	8.7	40.4	23.1	25.0	2.9
Minnesota	7.5	37.2	24.8	28.8	1.8
Des Moines	5.2	31.5	25.0	34.7	3.6
Iowa	8.6	30.0	25.8	31.3	4.3
Black Root	8.4	34.2	24.0	28.0	5.3
Skunk Wapsipinicon	9.6	26.9	29.7	28.3	5.5
Maquoketa Plum	9.7	33.8	23.2	31.2	2.1
Lower Illinois	6.1	32.9	27.6	29.4	4.0
Rock	9.9	45.0	16.9	26.0	2.1
Kaskaskia	9.5	35.8	22.1	30.0	2.6
Upper Illinois	11.2	29.2	24.2	33.6	1.8
Wabash	7.5	32.6	26.0	29.5	4.4
Patoka-White	5.9	31.4	27.7	31.9	3.2
Southeastern Lake Michigan	9.3	29.6	25.9	30.1	5.1
Western Lake Erie	7.1	33.9	25.1	30.5	3.4

[1]Climate change is occurring, and it is caused mostly by human activities.
[2]Climate change is occurring, and it is caused more or less equally by natural changes in the environment & human activities.
[3]Climate change is occurring, and it is caused mostly by natural changes in the environment.
[4]There is not sufficient evidence to know with certainty whether climate change is occurring or not.
[5]Climate change is not occurring.

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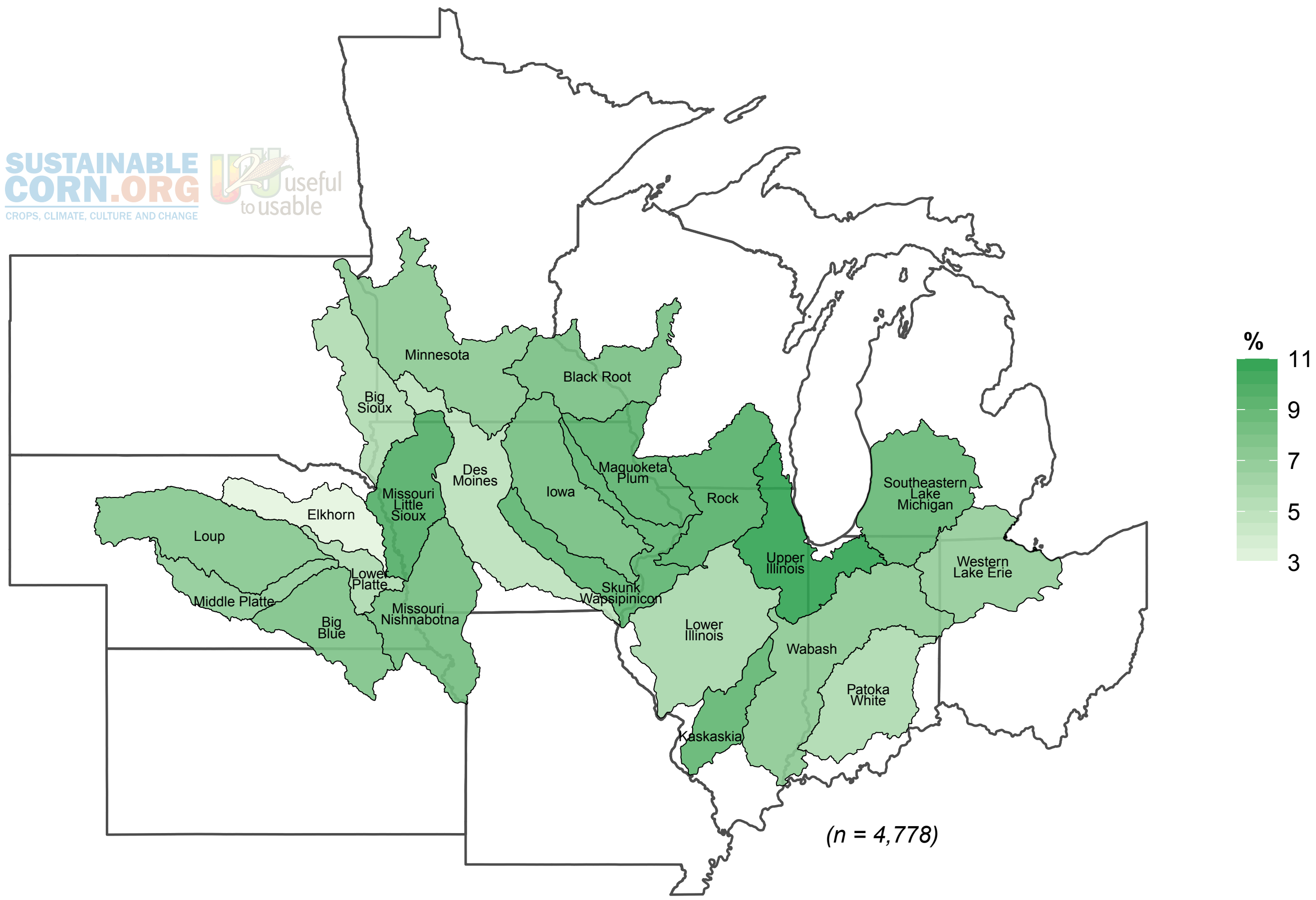

Map 16. Climate change is occurring, and it is caused <u>mostly</u> by human activities (CCHUM), percent.

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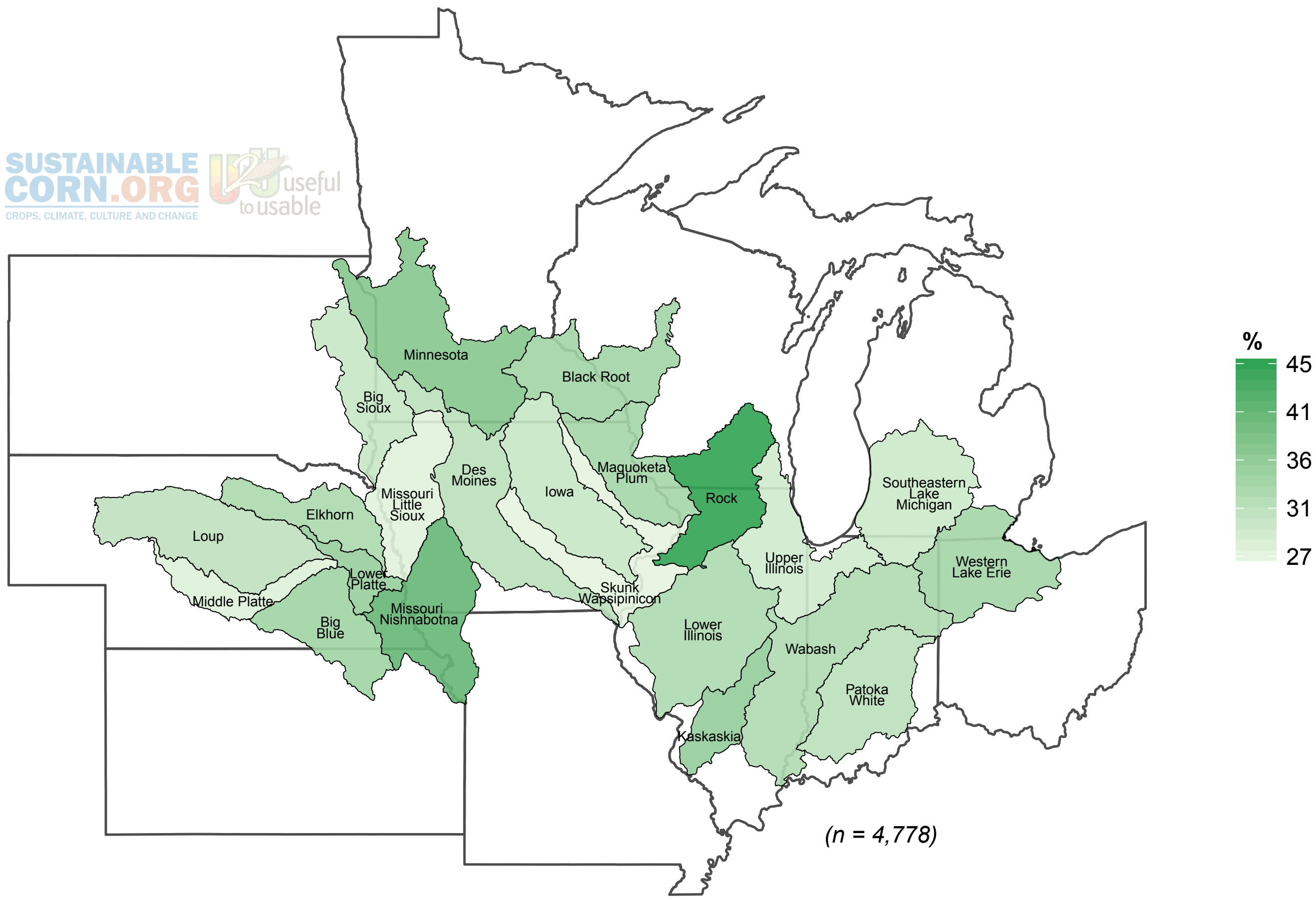

Map 17. Climate change is occurring and it is caused more or less equally by natural changes in the environment and human activities (CCHUMNAT), percent.

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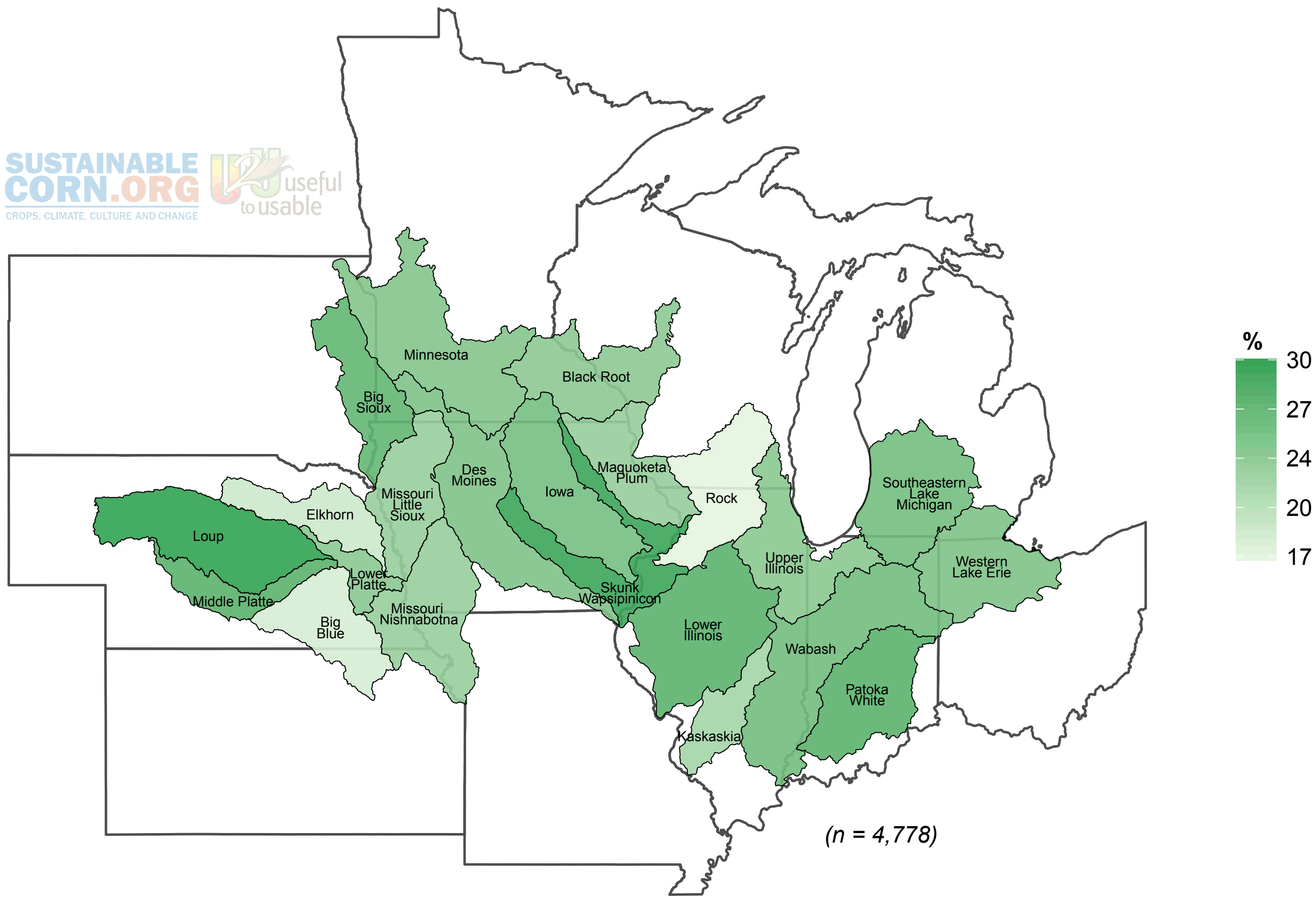

Map 18. Climate change is occurring and it is caused <u>mostly</u> by natural changes in the environment (CCNAT), percent.

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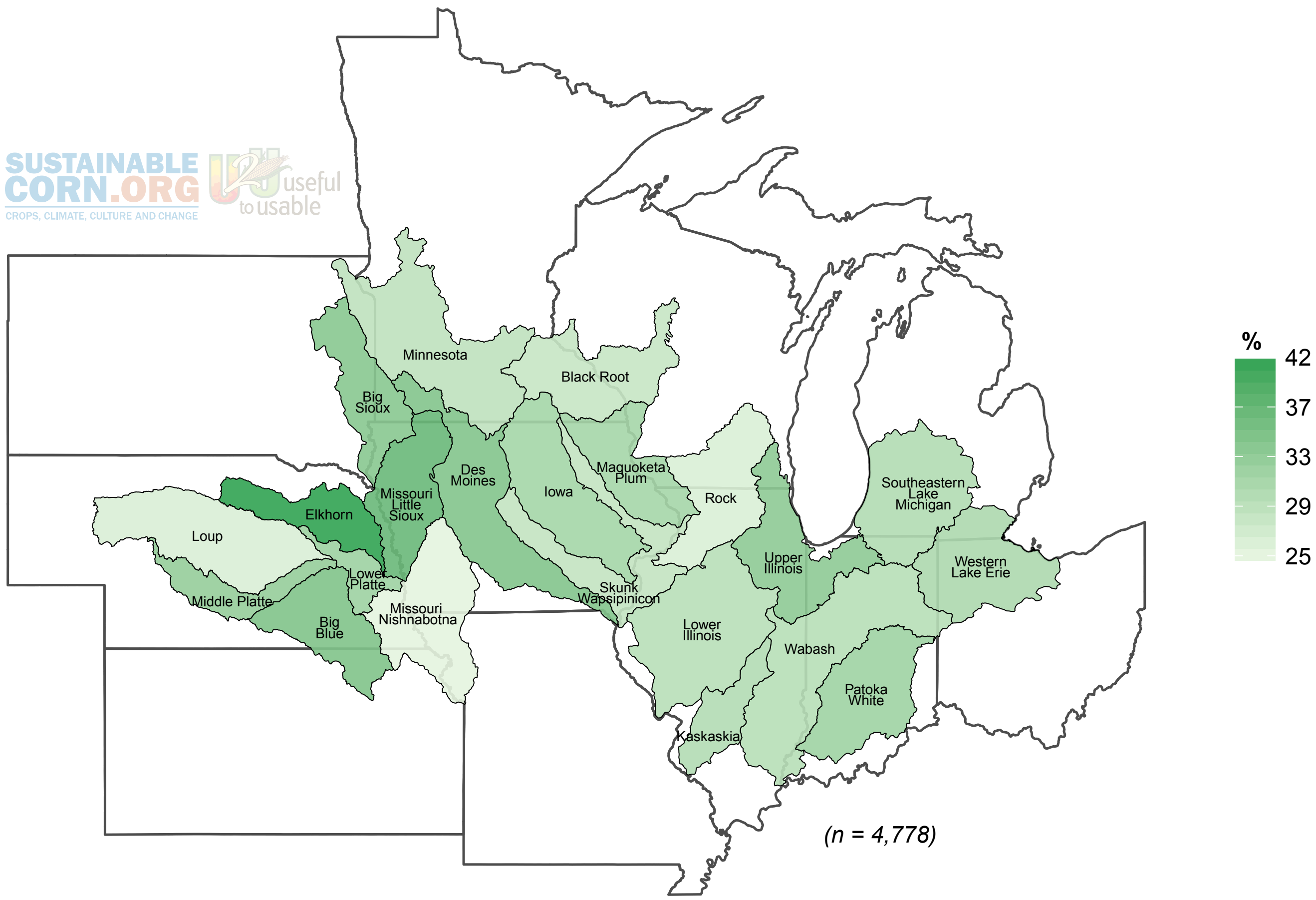

Map 19. There is not sufficient evidence to know with certainty whether climate change is occurring or not (CCUNCERT), percent.

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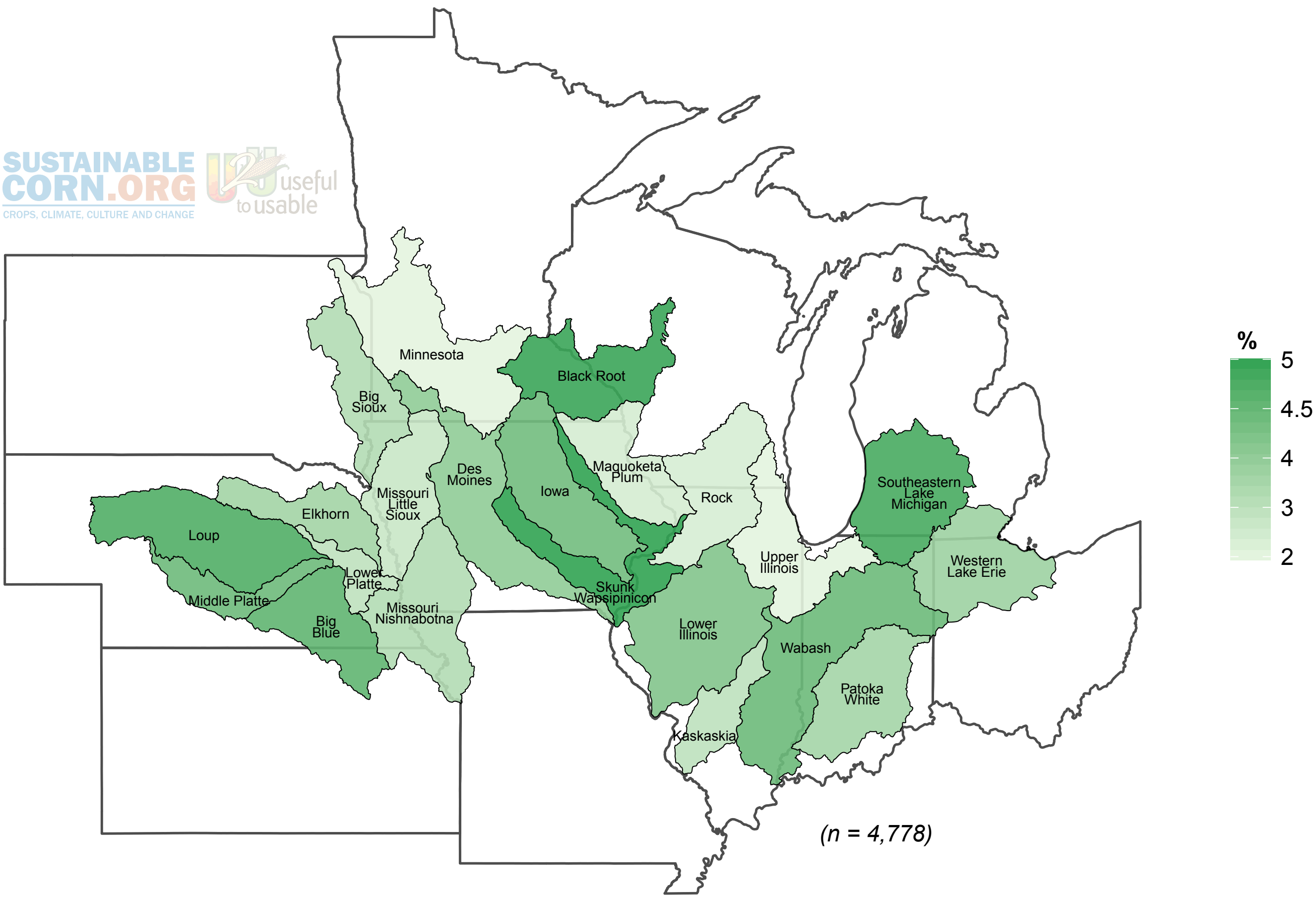

Map 20. Climate change is not occurring (NOCC), percent.

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4 Perceived Risk and Experienced Hazard

Perceptions of risk are subjective assessments people use to understand and cope with danger and uncertainties in life. Risk assessments vary based on the problem identified, perceptions of probability of loss, type and accumulation of exposure to the risk, resources available to address risk, and involve both affective and reasoning responses (Slovic 2009). Farmers are continually assessing and managing risk in their agricultural enterprises. These risks include production risks (yield loss), price/market volatility, institutional change (regulations), and social norm expectations. When experiences are vivid and easy to recall, perceptions of risk and concern about impacts are often heightened. Experiences with hazards such as weed pressure, crop disease, extreme rains, heat stress, drought and saturated soils, soil erosion, nutrient and sediment loss into streams and rivers, and greenhouse gas emissions can lead to concern and judgments about whether the hazard is a problem or not.

The survey provided a list of potential impacts of climate change that climatologists predict for the Corn Belt region. Farmer concerns regarding climate-related risks were measured through a four-point scale ranging from “not concerned” (1) to “very concerned” (4). The survey also asked farmers if they had experienced any of a series of extreme weather events (e.g., floods) over the previous five years.

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Table 3. Concern[1] about various climate-related threats to farm operations, percent concerned or very concerned (n = 4,778)

Watershed (HUC6)	Q5A[a]	Q5B[b]	Q5C[c]	Q5D[d]	Q5E[e]	Q5F[f]	Q5G[g]	Q5H[h]	Q5I[i]	Q5J[j]
Weighted Full Sample	25.6	58.5	48.8	49.8	50.4	49.6	41.7	52.3	32.8	37.6
Loup	14.4	67.6	55.9	48.7	59.2	34.2	19.1	51.4	24.3	30.9
Middle Platte	23.5	50.0	48.0	37.7	46.6	38.7	32.0	47.0	22.8	20.4
Elkhorn	17.9	63.1	40.6	44.4	46.3	37.4	27.6	55.3	24.7	29.8
Big Blue	7.3	69.9	51.7	42.4	53.9	31.1	13.6	60.7	23.6	34.5
Lower Platte	19.6	70.7	50.6	47.8	51.9	42.4	24.5	65.2	30.8	36.7
Big Sioux	24.3	54.1	47.5	49.4	50.3	37.0	37.9	45.0	31.9	34.3
Missouri-Little Sioux	22.4	63.9	50.5	53.5	56.8	38.7	29.1	53.6	27.7	30.0
Missouri-Nishnabotna	24.6	63.9	55.0	53.7	55.7	52.8	41.1	61.3	30.5	48.9
Minnesota	21.9	58.4	45.1	49.4	49.6	46.4	41.6	45.5	29.9	24.7
Des Moines	27.3	56.3	52.0	53.5	55.3	51.4	48.4	52.3	35.4	35.2
Iowa	19.6	51.4	50.0	57.0	54.5	49.4	40.8	46.5	24.6	38.8
Black Root	12.7	55.7	38.4	46.2	46.6	36.6	24.4	43.6	25.7	33.9
Skunk Wapsipinicon	28.1	52.4	50.2	51.7	56.5	50.9	42.4	47.8	38.5	48.0
Maquoketa Plum	19.1	44.5	37.7	48.0	49.0	58.5	28.6	40.6	34.3	44.0
Lower Illinois	31.7	63.2	51.5	55.9	47.7	54.9	50.4	62.0	36.7	38.4
Rock	28.1	52.6	41.6	48.8	47.1	50.2	44.9	44.0	31.9	34.1
Kaskaskia	35.1	66.8	66.2	50.0	47.9	62.2	56.5	63.0	38.5	54.2
Upper Illinois	34.1	51.3	44.4	46.8	42.1	49.6	49.1	52.4	33.5	30.2
Wabash	34.8	59.7	53.0	42.4	48.3	58.4	56.4	60.3	42.0	43.1
Patoka-White	43.2	68.2	48.2	44.9	43.2	67.2	56.6	59.9	39.4	50.0
Southeastern Lake Michigan	17.4	58.8	43.9	48.0	46.1	43.6	40.0	46.0	22.3	29.5
Western Lake Erie	41.6	62.8	52.4	50.8	45.0	71.9	64.4	55.4	54.0	49.8

[1]4-point concern scale: not concerned, somewhat concerned, concerned, very concerned.
[a]Increased flooding.
[b]Longer dry periods and drought.
[c]Increased weed pressure.
[d]Increased insect pressure.
[e]Higher incidence of crop disease.
[f]More frequent extreme rains.
[g]Increases in saturated soils and ponded water.
[h]Increased heat stress on crops.
[i]Increased loss of nutrients into waterways.
[j]Increased soil erosion.

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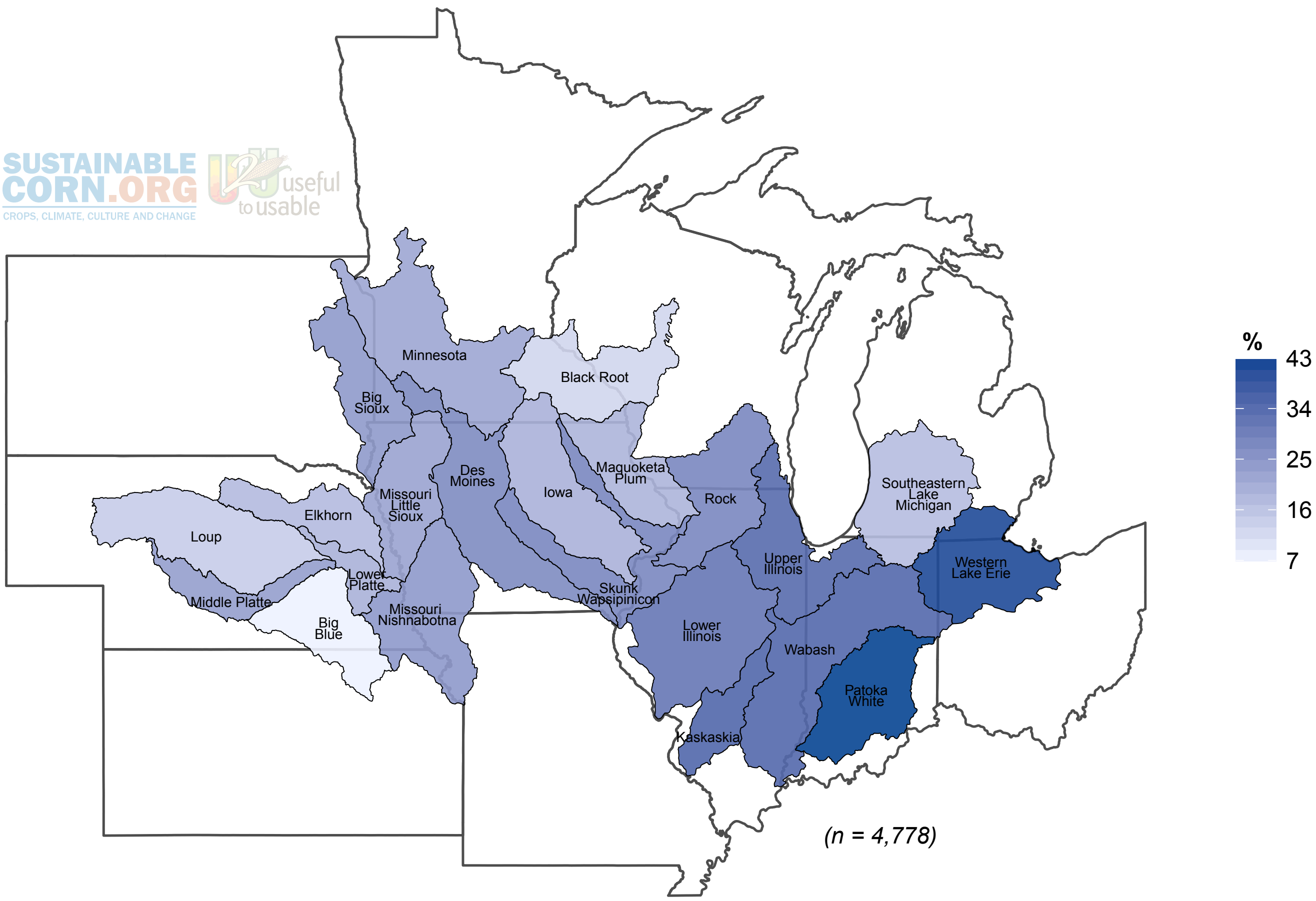

Map 21. Increased flooding (Q5A), percent concerned or very concerned.

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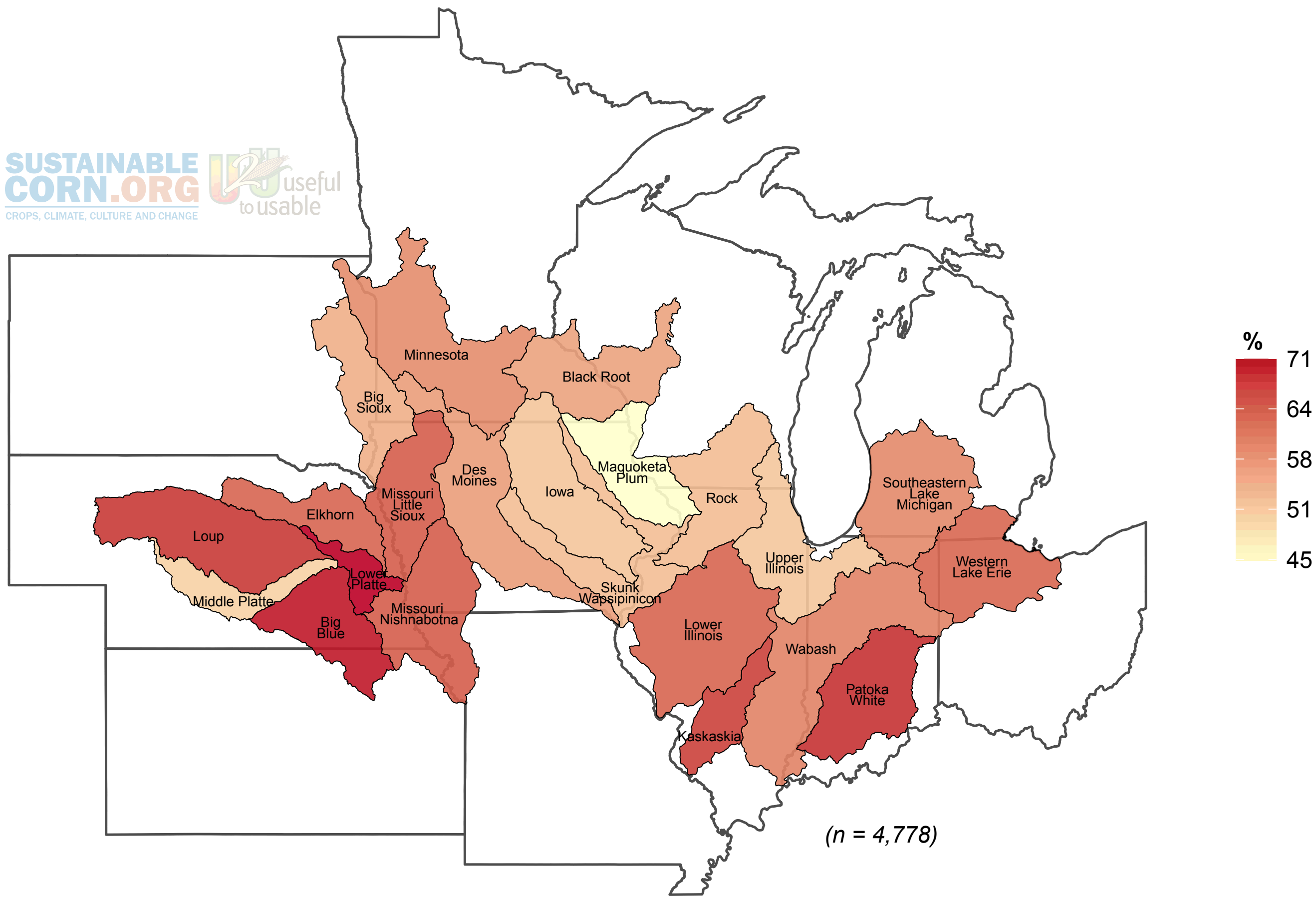

Map 22. Longer dry periods and drought (Q5B), percent concerned or very concerned.

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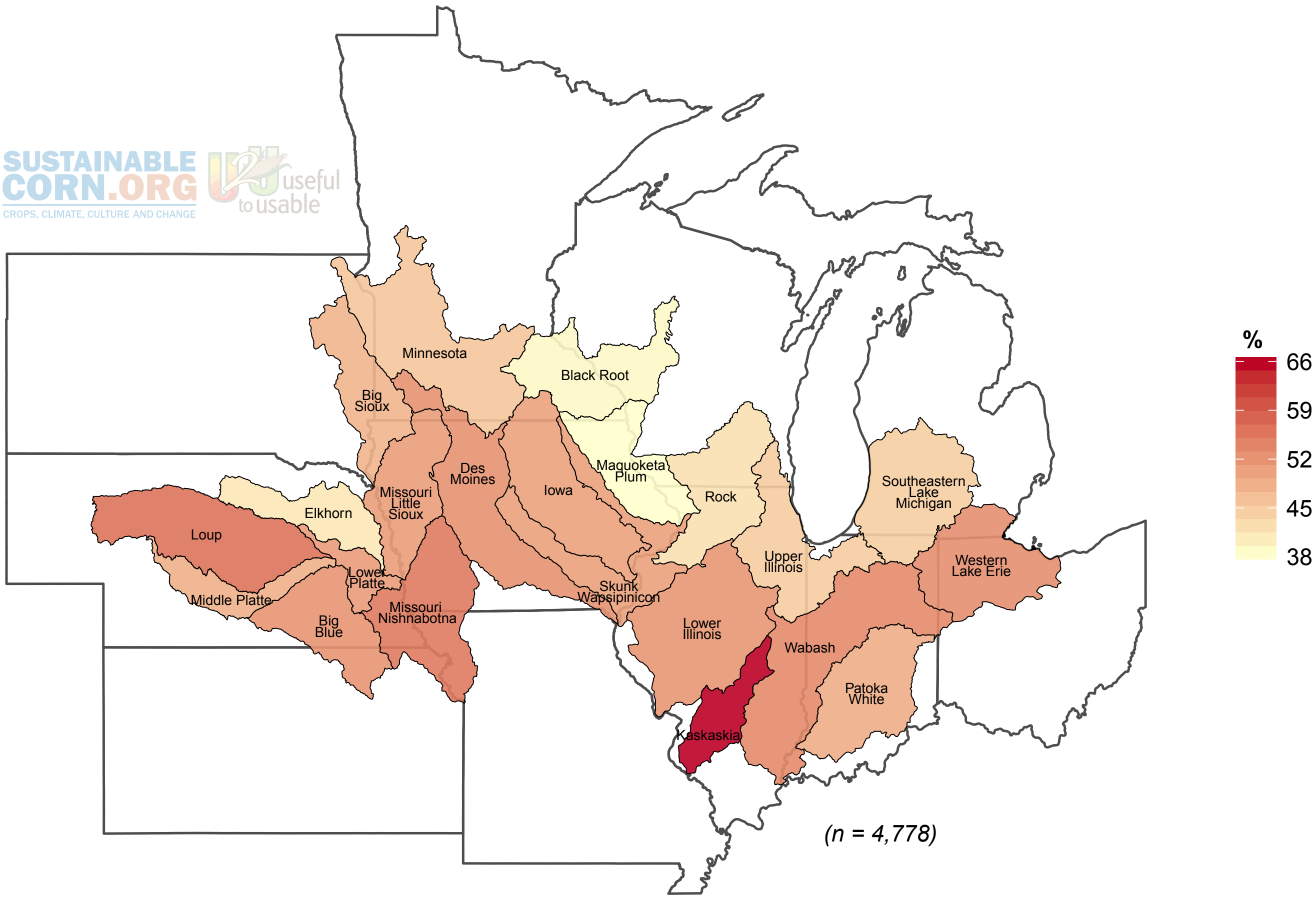

Map 23. Increased weed pressure (Q5C), percent concerned or very concerned.

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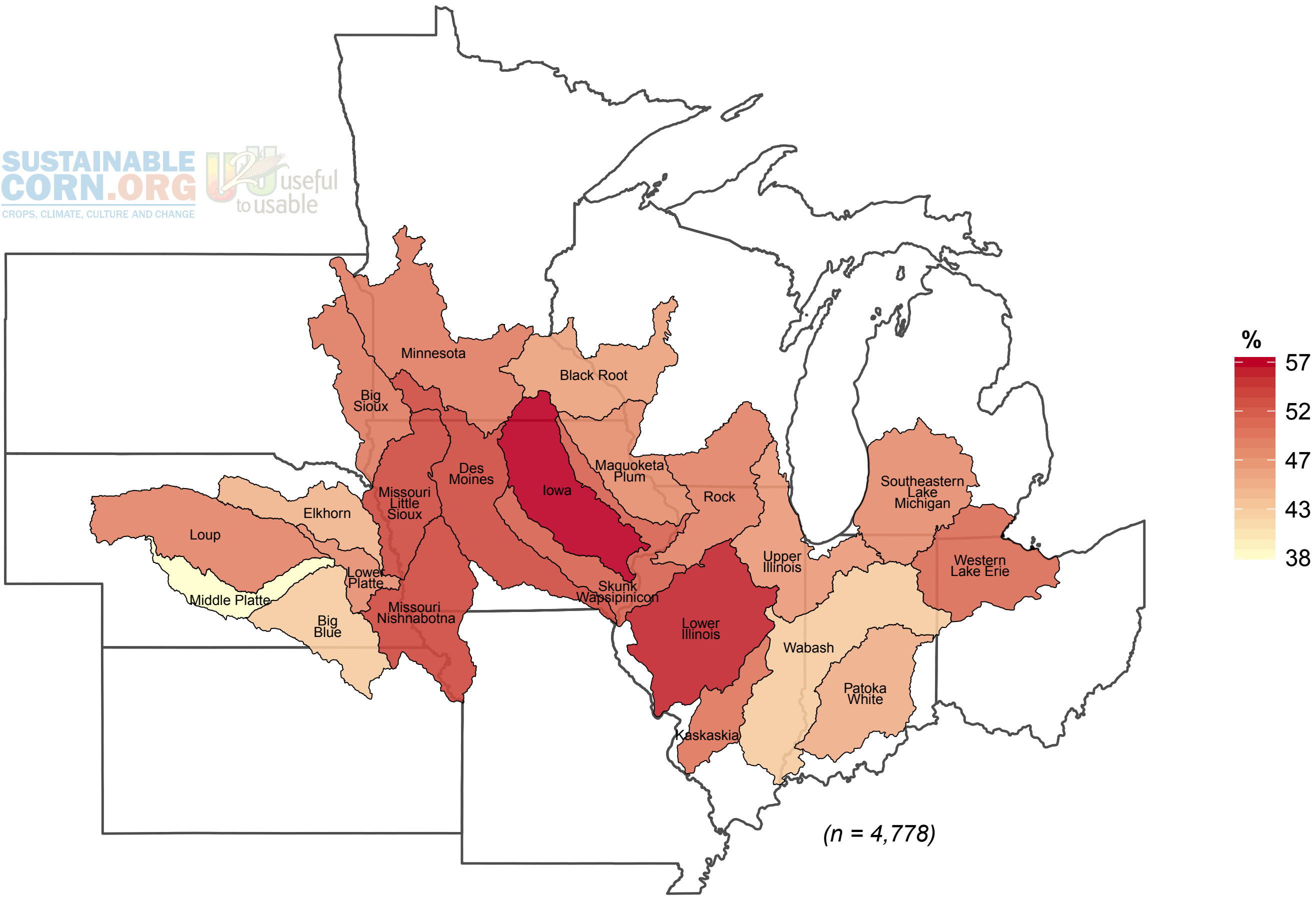

Map 24. Increased insect pressure (Q5D), percent concerned or very concerned.

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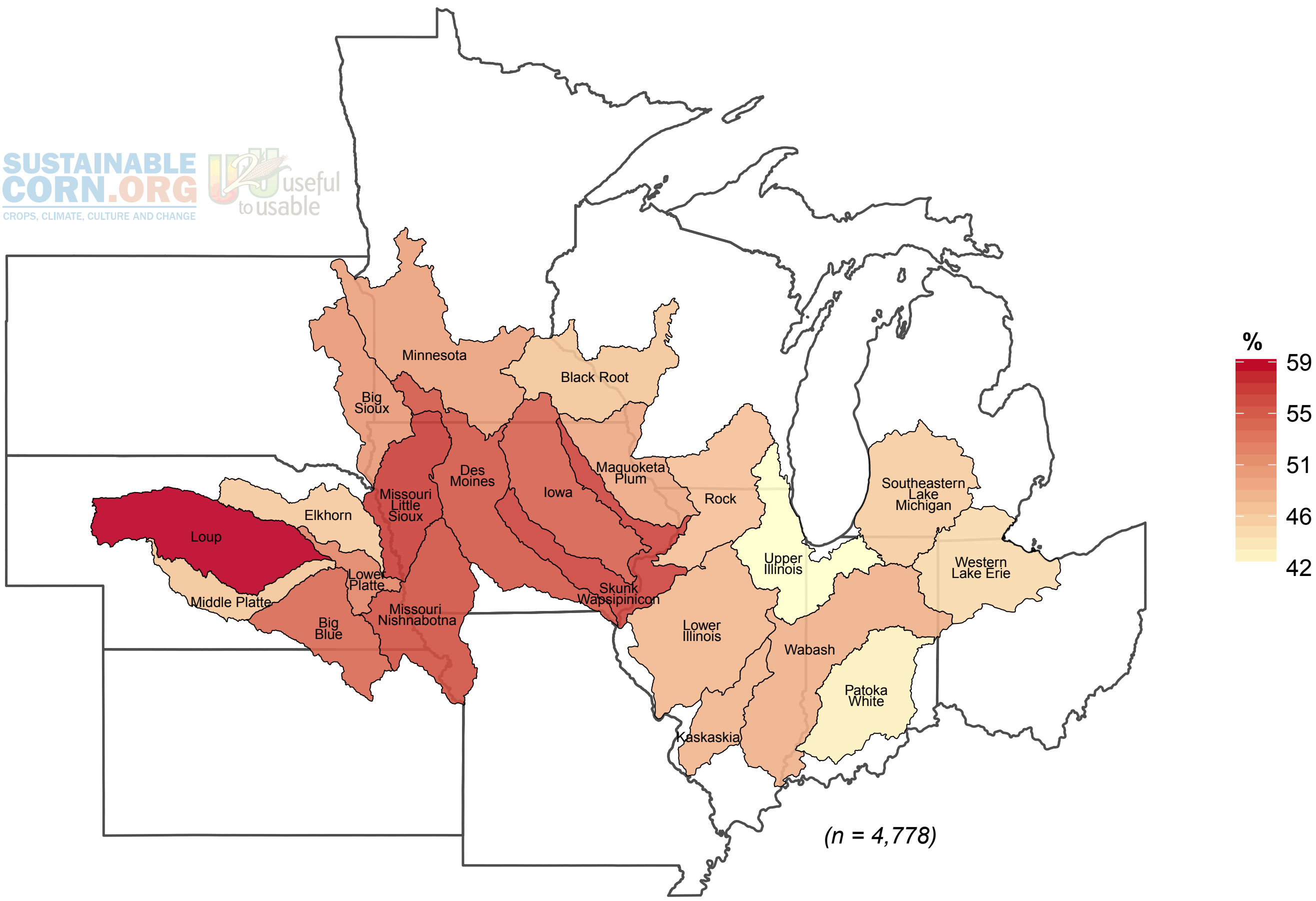

Map 25. Higher incidence of crop disease (Q5E), percent concerned or very concerned.

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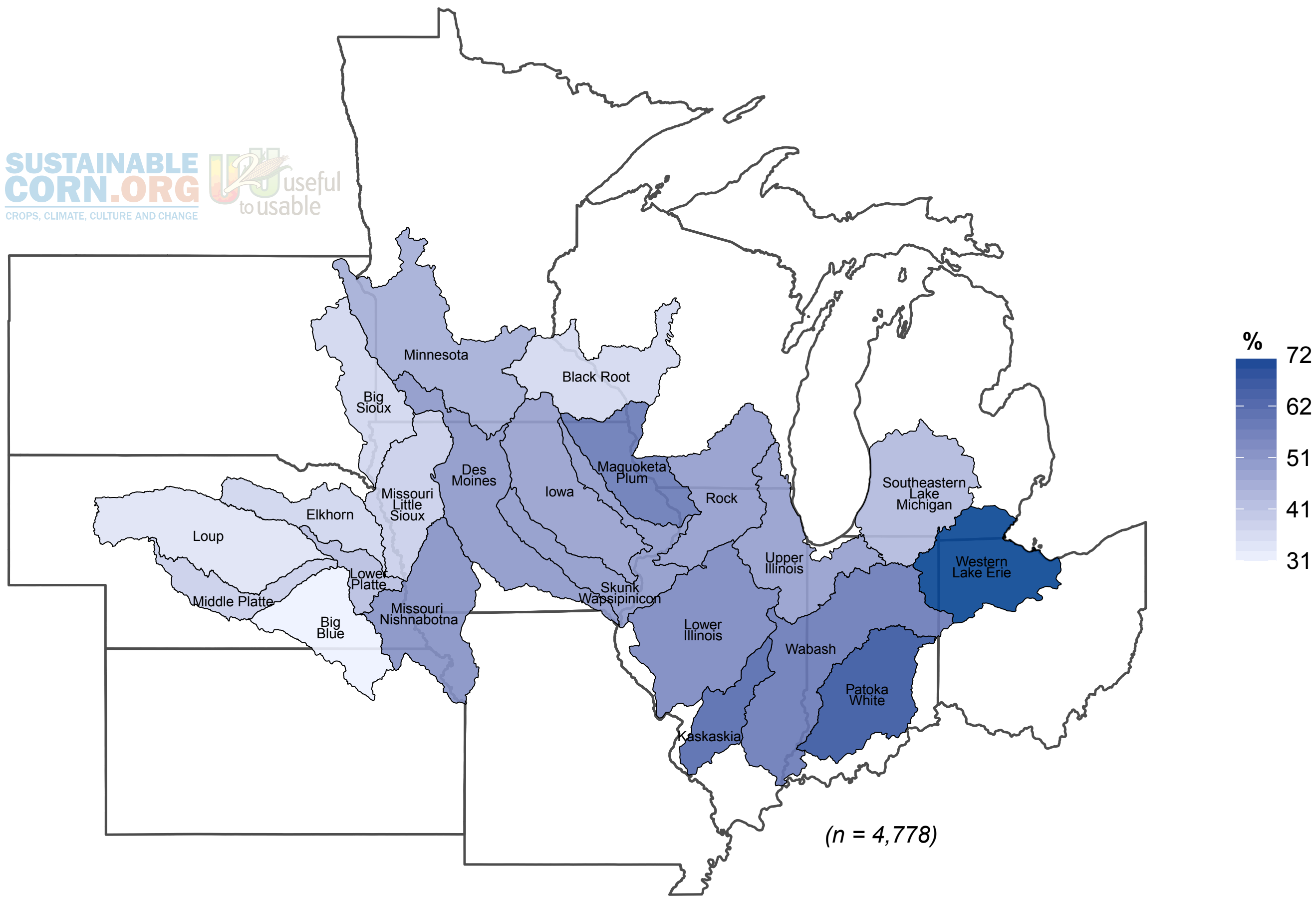

Map 26. More frequent extreme rains (Q5F), percent concerned or very concerned.

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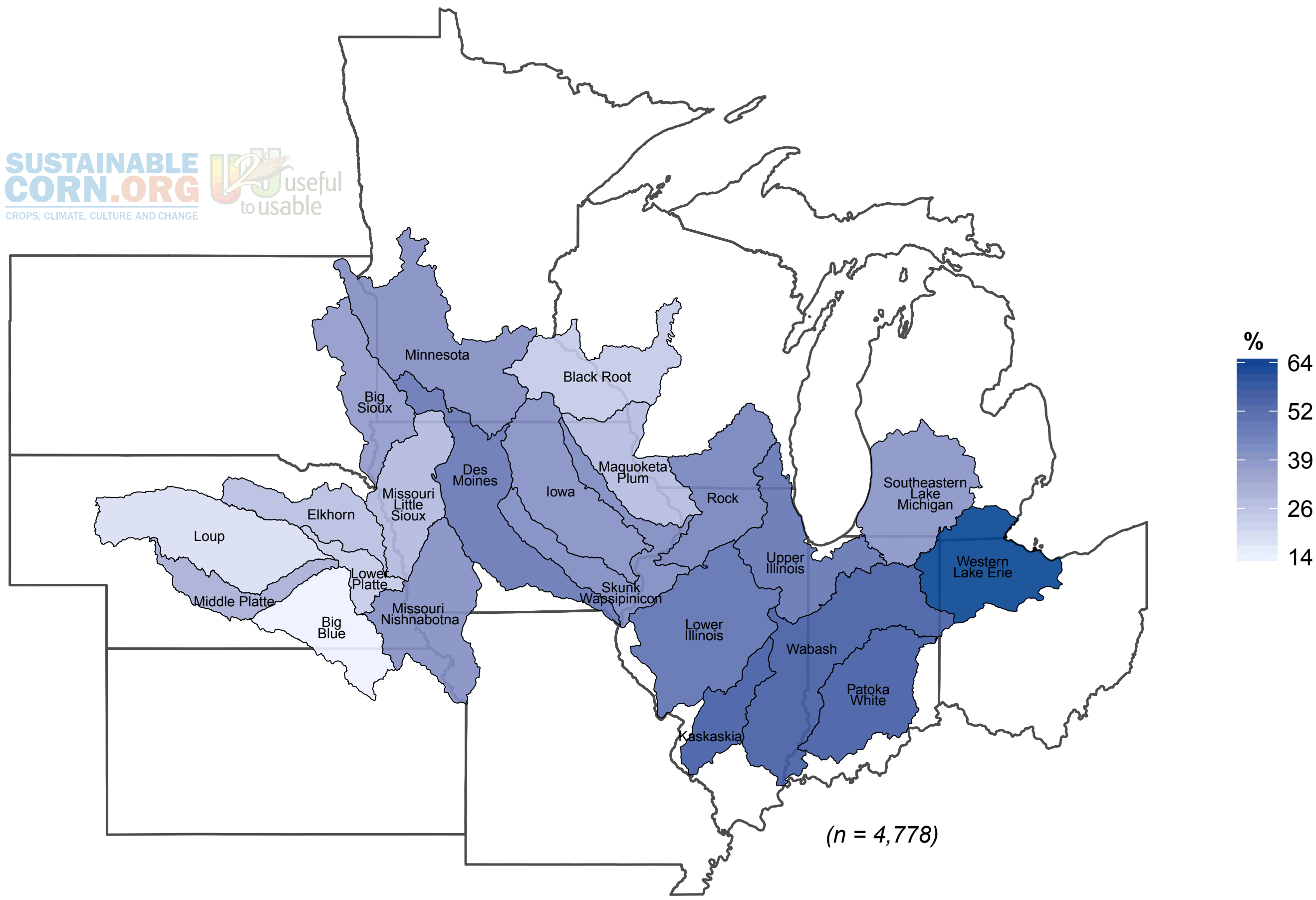

Map 27. Increases in saturated soils and ponded water (Q5G), percent concerned or very concerned.

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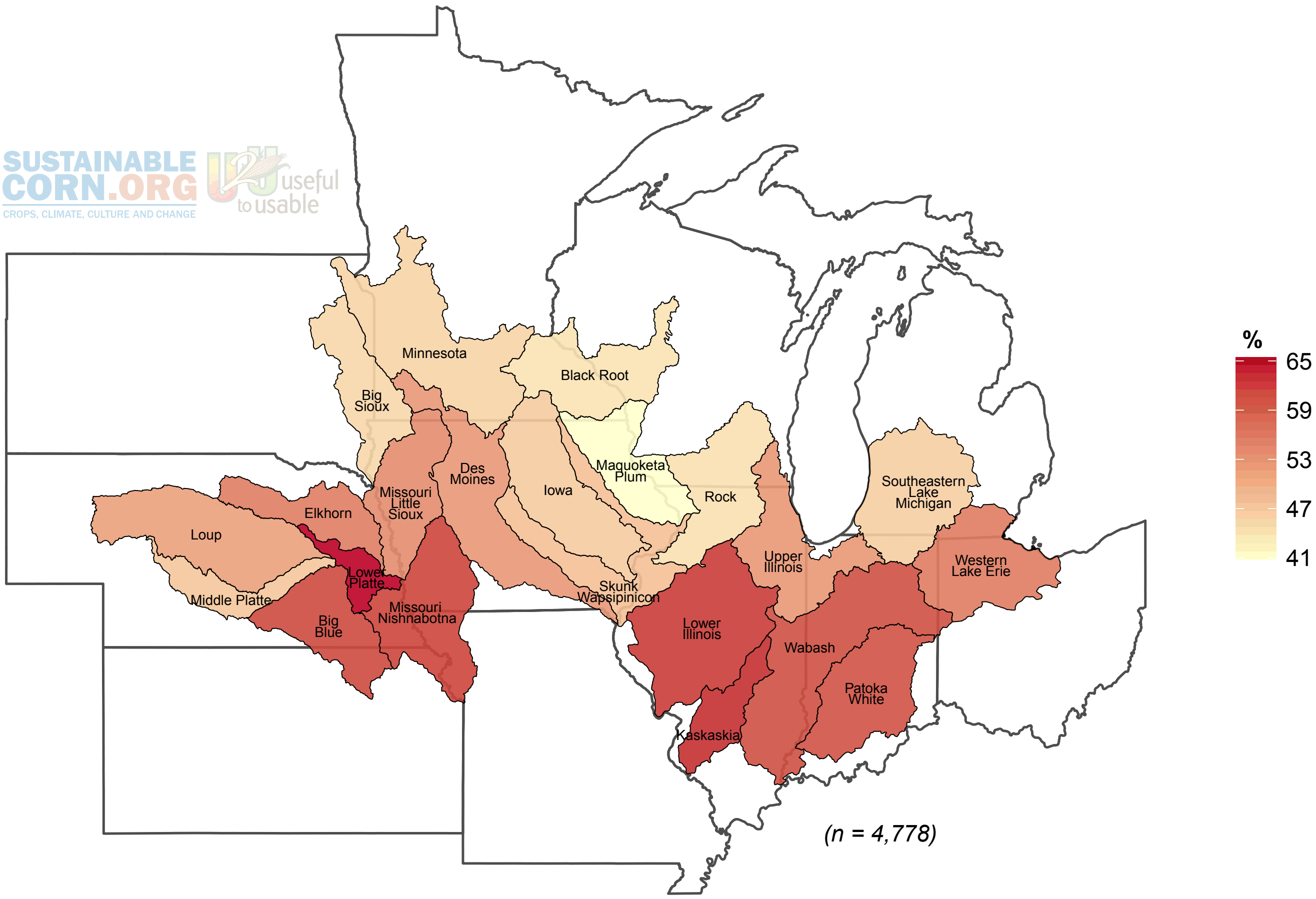

Map 28. Increased heat stress on crops (Q5H), percent concerned or very concerned.

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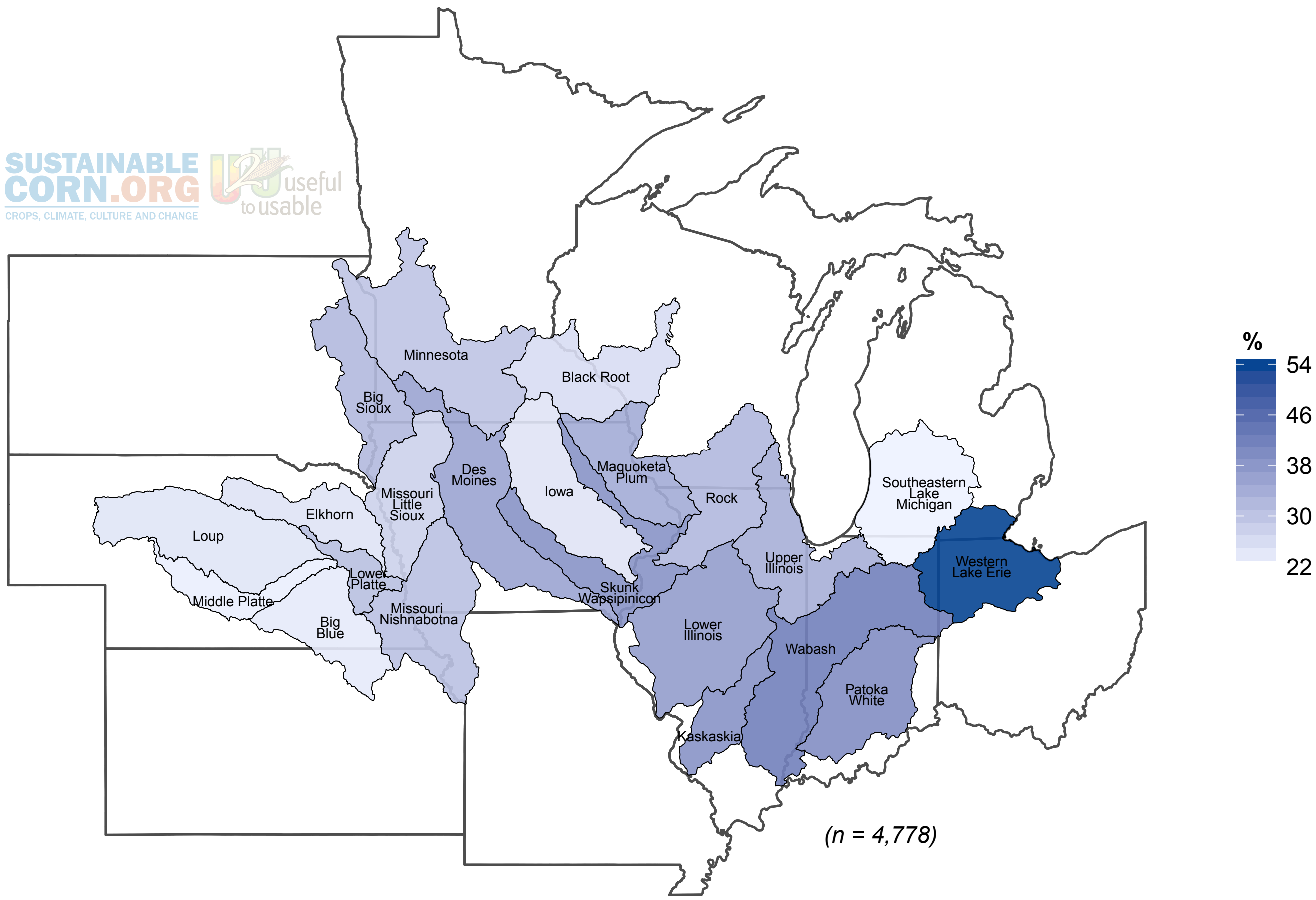

Map 29. Increased loss of nutrients into waterways (Q5I), percent concerned or very concerned.

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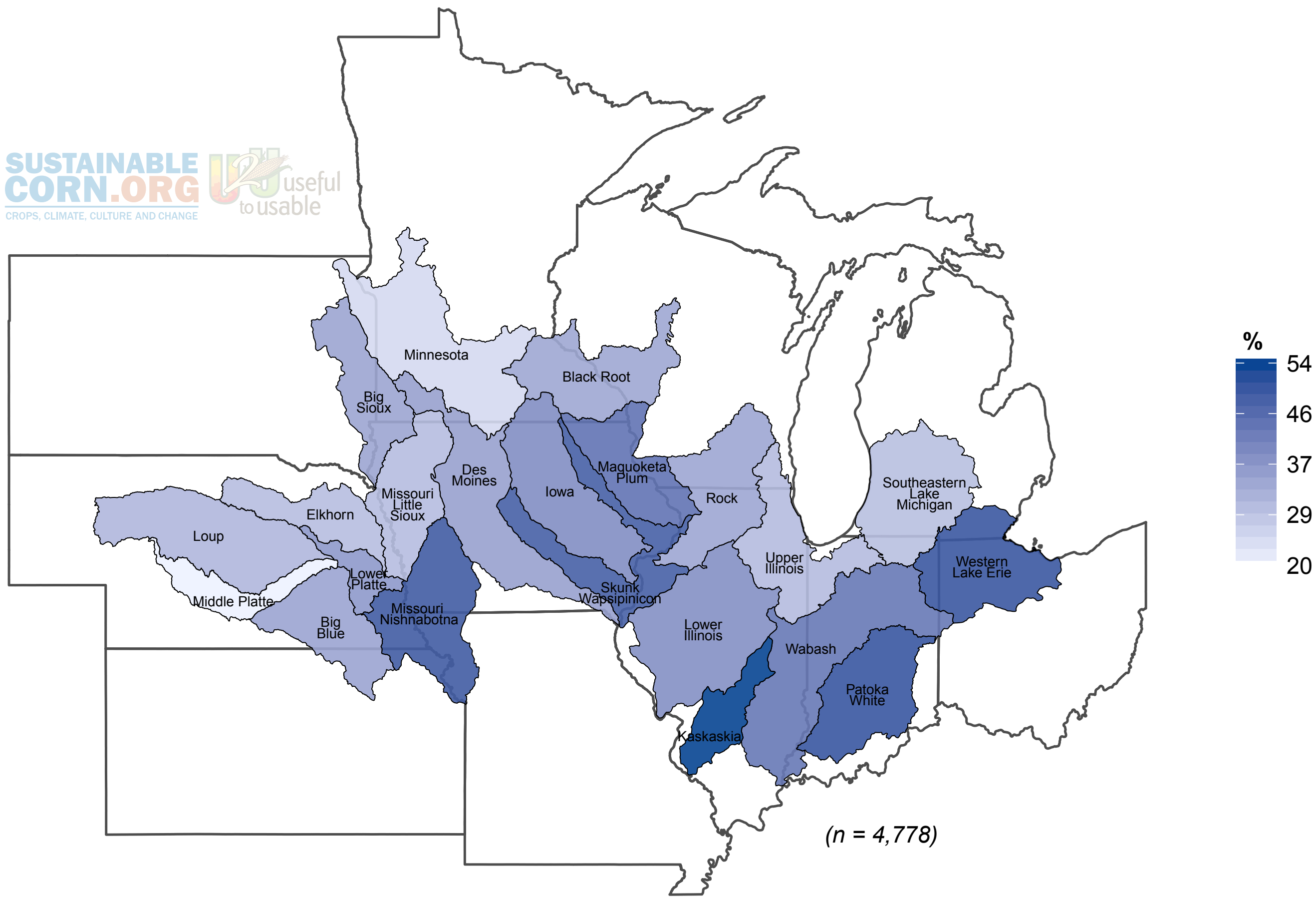

Map 30. Increased soil erosion (Q5J), percent concerned or very concerned.

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Table 4. Experience with various hazards on land farmed, last five years (2007–2011), percent (n = 4,778)

Watershed (HUC6)	Drought	Saturated Soils	Flood	Erosion
Weighted Full Sample	29.5	75.9	37.1	26.5
Loup	20.3	43.8	24.5	15.4
Middle Platte	28.0	61.7	36.9	10.3
Elkhorn	11.0	66.3	39.3	16.9
Big Blue	27.9	45.0	26.3	17.1
Lower Platte	17.0	59.8	30.8	36.8
Big Sioux	14.2	81.3	43.3	24.4
Missouri-Little Sioux	25.9	67.7	34.1	22.9
Missouri-Nishnabotna	16.2	64.1	34.5	37.3
Minnesota	37.8	85.7	34.5	14.0
Des Moines	22.3	88.8	40.1	26.9
Iowa	17.2	71.0	34.8	23.2
Black Root	25.6	58.0	30.0	15.4
Skunk Wapsipinicon	22.7	83.3	46.5	45.2
Maquoketa Plum	10.1	51.2	31.7	35.3
Lower Illinois	37.4	87.4	33.6	32.3
Rock	16.7	76.7	37.0	23.0
Kaskaskia	52.6	89.5	49.2	47.3
Upper Illinois	35.5	82.7	35.5	21.2
Wabash	46.8	87.2	40.9	31.8
Patoka-White	76.8	89.3	59.3	38.9
Southeastern Lake Michigan	35.7	74.6	19.7	17.0
Western Lake Erie	50.8	90.4	49.4	25.0

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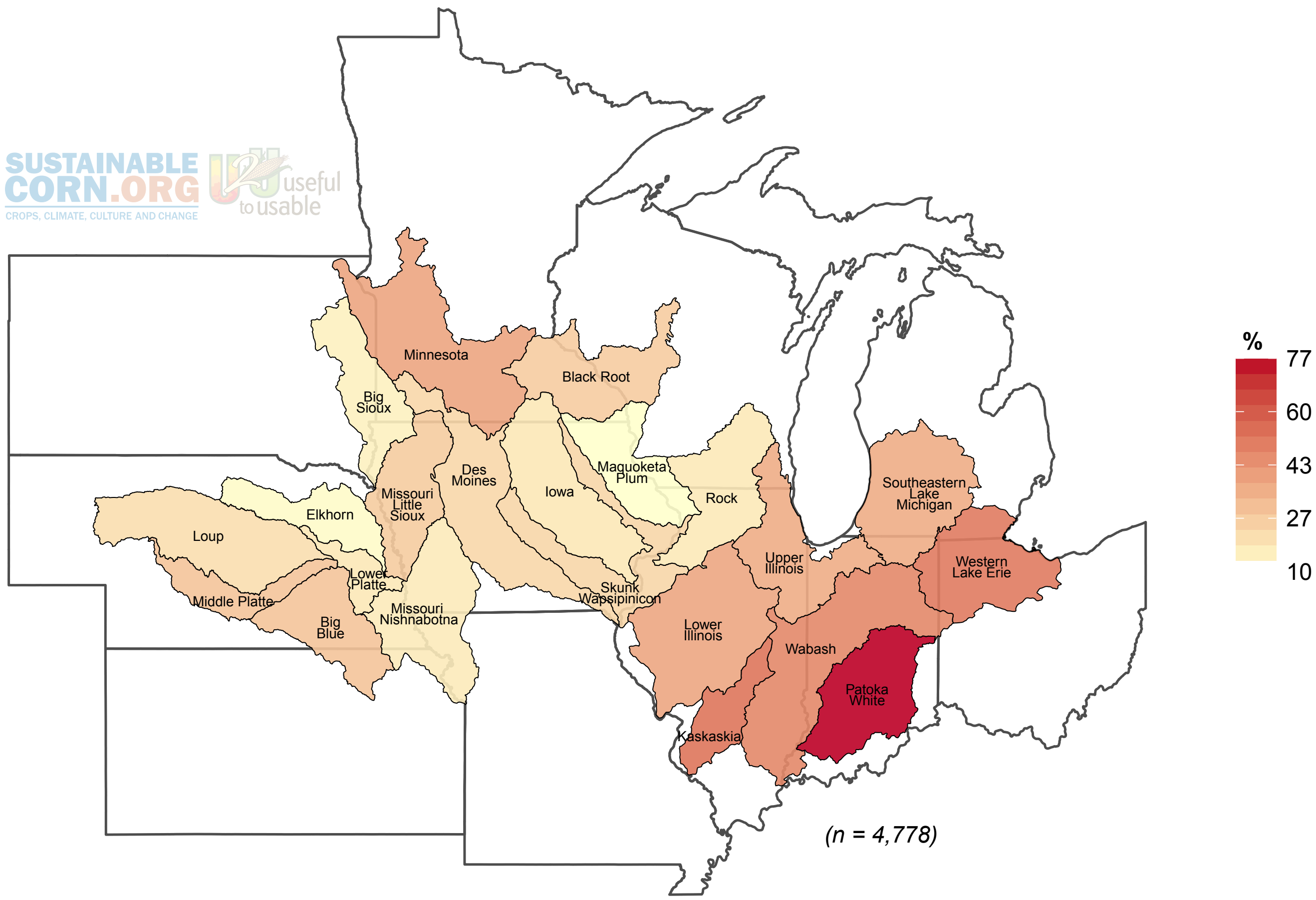

Map 31. Experienced significant drought over the past five years (2007–2011), percent.

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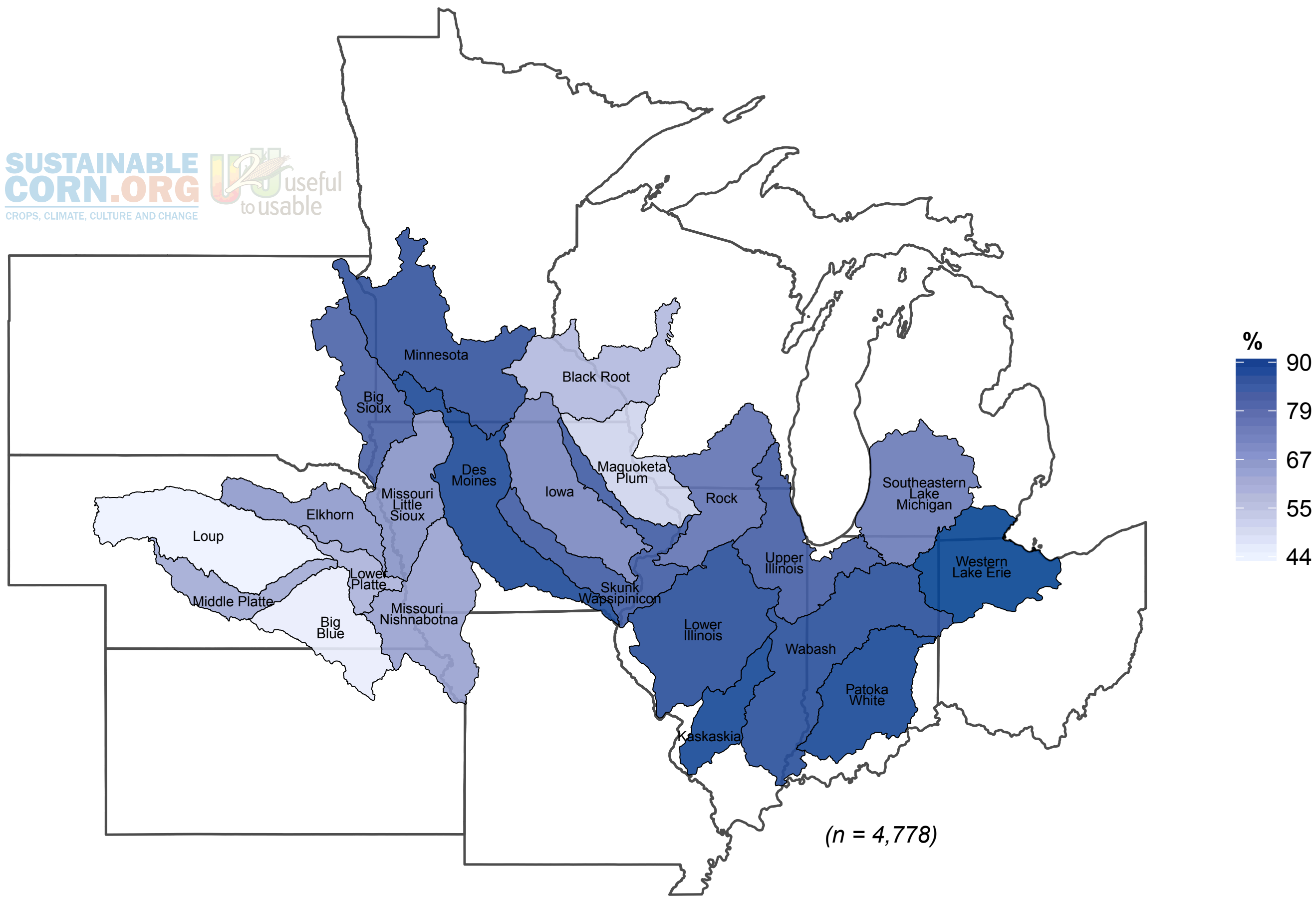

Map 32. Experienced significant problems with saturated soils or ponding over the past five years (2007–2011), percent.

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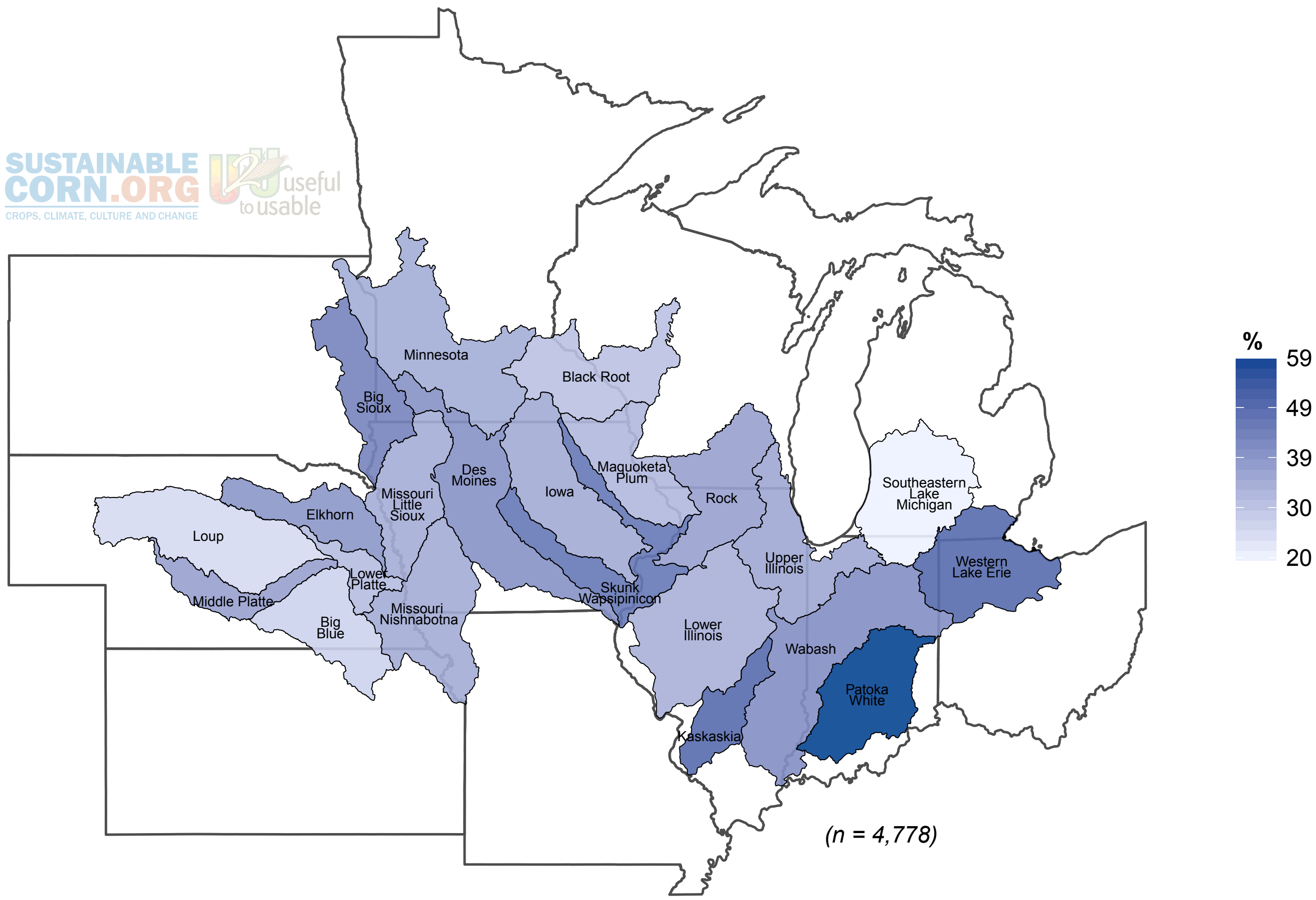

Map 33. Experienced significant flooding over the past five years (2007–2011), percent.

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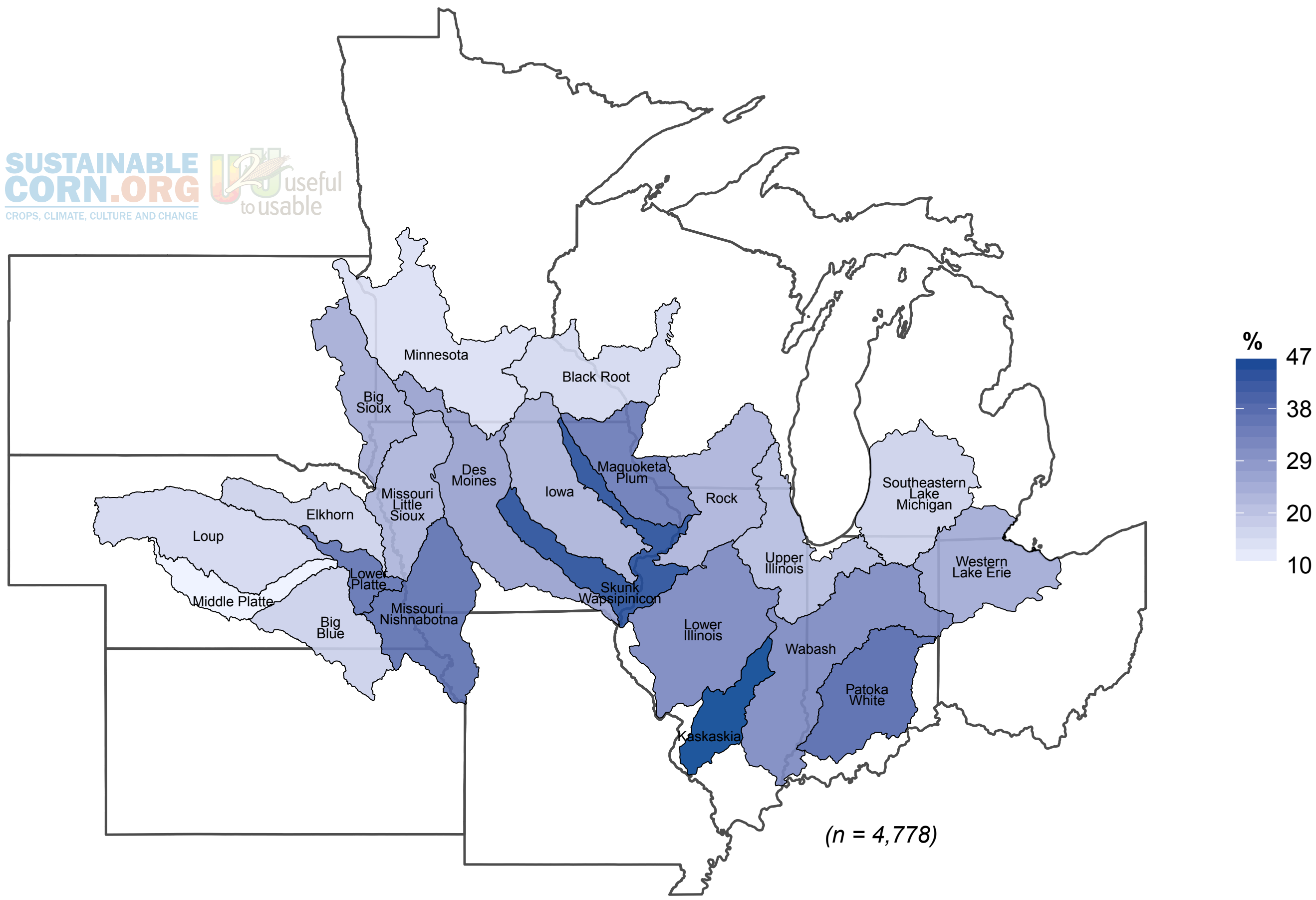

Map 34. Experienced significant erosion on at least some of my land over the past five years (2007–2011), percent.

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Table 5. Awareness of negative impacts of nutrients and sediment from agriculture on water quality (n = 4,778)

Watershed (HUC6)	Percent Agree[1]
Full Weighted Sample	33.7
Loup	30.6
Middle Platte	22.2
Elkhorn	31.2
Big Blue	41.9
Lower Platte	33.3
Big Sioux	31.3
Missouri-Little Sioux	32.7
Missouri-Nishnabotna	33.6
Minnesota	27.0
Des Moines	36.0
Iowa	39.0
Black Root	39.0
Skunk Wapsipinicon	44.7
Maquoketa Plum	30.3
Lower Illinois	31.6
Rock	34.8
Kaskaskia	33.5
Upper Illinois	31.5
Wabash	28.6
Patoka-White	30.2
Southeastern Lake Michigan	26.9
Western Lake Erie	42.9

[1]Includes those respondents who either agree or strongly agree on a 5-point scale.

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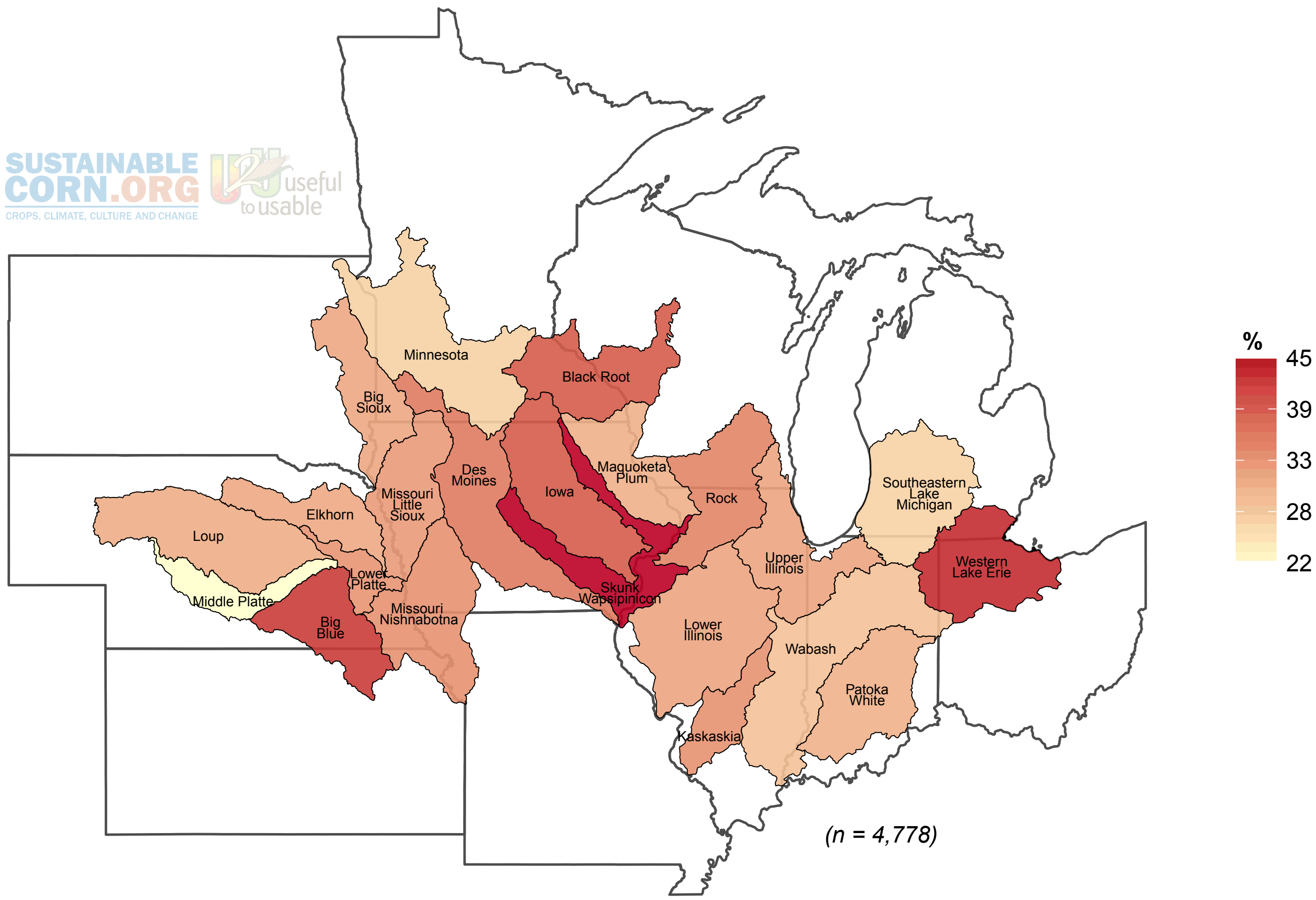

Map 35. Nutrients and sediment from agriculture have negative impacts on water quality in my state, percent agree or strongly agree.

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5 Influence of Agricultural Actors

There are a number of different groups and individuals that influence farmers' decisions about agricultural practices and strategies. Social power is the ability of one person to influence another person. Influence is the pressure a person, organization and/or institution exerts on someone else that leads to changes in attitudes, opinions, values, goals, and/or behaviors (Morton 2011). In farming, agricultural advisors, organizations and agencies are sources of data and information transfer, technology exchange, as well as values, beliefs, attitudes, and social pressure.

The survey provided a list of major agricultural and environmental organizations and agencies and asked farmers the degree to which the groups influence their decisions. The list was preceded by the text, "please indicate how influential the following groups and individuals are when you make decisions about agricultural practices and strategies." Degree of influence was measured on a five-point scale ranging from "no contact" (0) to "strong influence" (4).

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Table 6. Influence[1] of various agricultural advisors on decisions, average (n = 4,778)

Watershed (HUC6)	Seed Dealer	Farm Chemical Dealer	NRCS	State Climatologist	University Extension	Conservation NGO	State Department of Agriculture
Weighted Full Sample	2.7	2.9	2.2	1.4	1.7	1.1	1.5
Loup	2.6	2.8	2.1	1.4	1.5	1.2	1.5
Middle Platte	2.6	2.7	2.0	1.4	1.6	1.0	1.4
Elkhorn	2.8	2.9	2.3	1.5	1.7	1.2	1.4
Big Blue	2.7	2.9	2.2	1.6	1.9	1.1	1.5
Lower Platte	2.8	2.9	2.2	1.6	2.0	1.1	1.4
Big Sioux	2.8	2.9	2.1	1.4	1.7	1.1	1.4
Missouri-Little Sioux	2.8	2.9	2.2	1.7	1.9	1.2	1.6
Missouri-Nishnabotna	2.7	2.9	2.4	1.5	1.8	1.1	1.5
Minnesota	2.7	2.9	2.1	1.3	1.6	1.0	1.6
Des Moines	2.8	2.9	2.2	1.7	1.8	1.1	1.5
Iowa	2.8	2.8	2.3	1.7	1.9	1.2	1.6
Black Root	2.7	2.8	2.2	1.2	1.6	1.0	1.5
Skunk Wapsipinicon	2.8	2.9	2.3	1.6	1.7	1.1	1.4
Maquoketa Plum	2.6	2.7	2.2	1.4	1.6	1.1	1.5
Lower Illinois	2.7	2.9	2.2	1.3	1.7	1.1	1.5
Rock	2.7	2.8	2.2	1.2	1.5	1.0	1.5
Kaskaskia	2.7	2.8	2.2	1.3	1.7	1.2	1.5
Upper Illinois	2.6	2.8	2.1	1.2	1.6	0.9	1.3
Wabash	2.7	2.8	2.2	1.2	1.5	1.0	1.3
Patoka-White	2.7	2.9	2.2	1.2	1.5	0.9	1.3
Southeastern Lake Michigan	2.6	2.8	2.0	1.2	1.7	1.1	1.4
Western Lake Erie	2.7	2.8	2.3	1.2	1.7	1.0	1.5

[1]Influence was measured on a 5-point scale: no contact (0), no influence (1), slight influence (2), moderate influence (3), strong influence (4)

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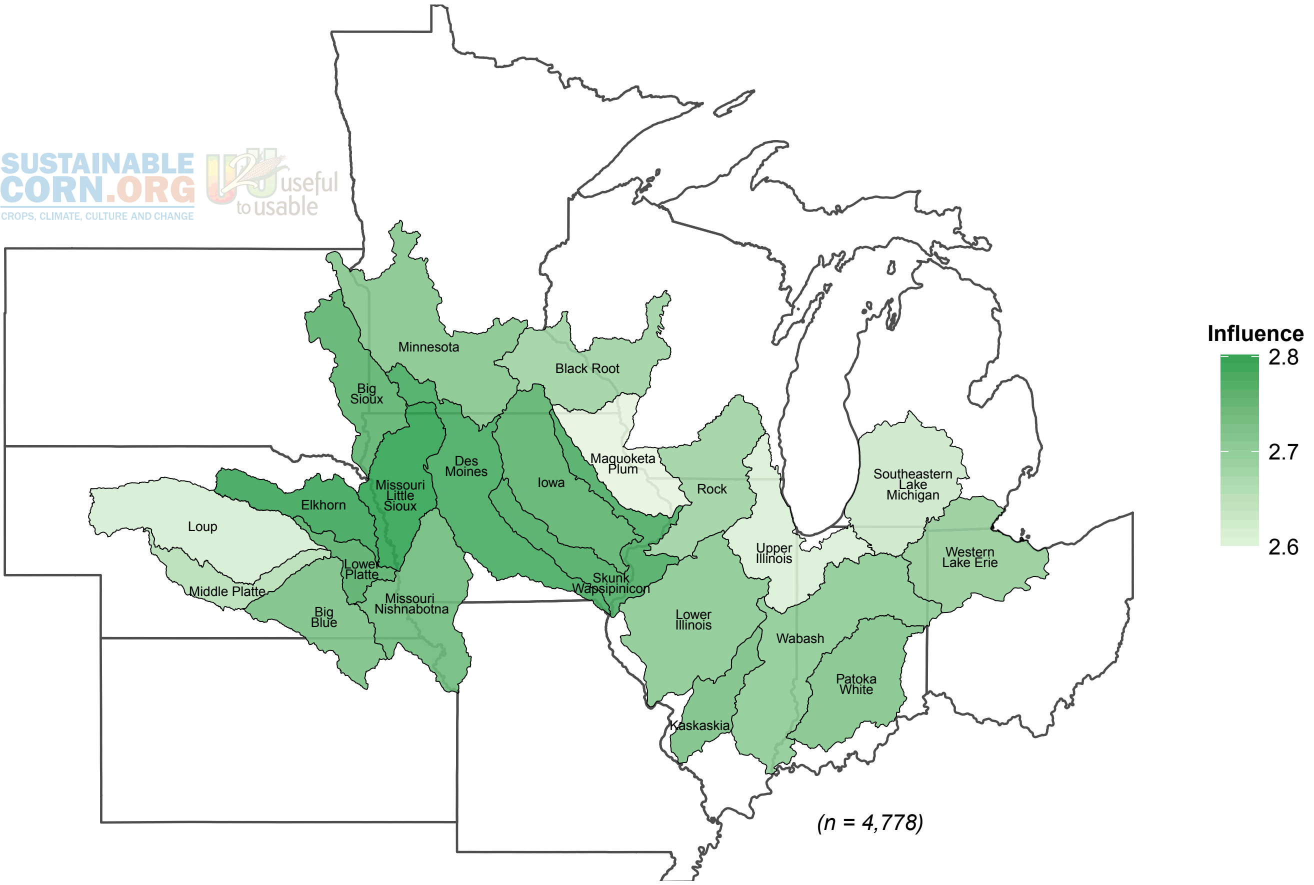

Map 36. Influence of seed dealers on decisions about agricultural practices and strategies, average.

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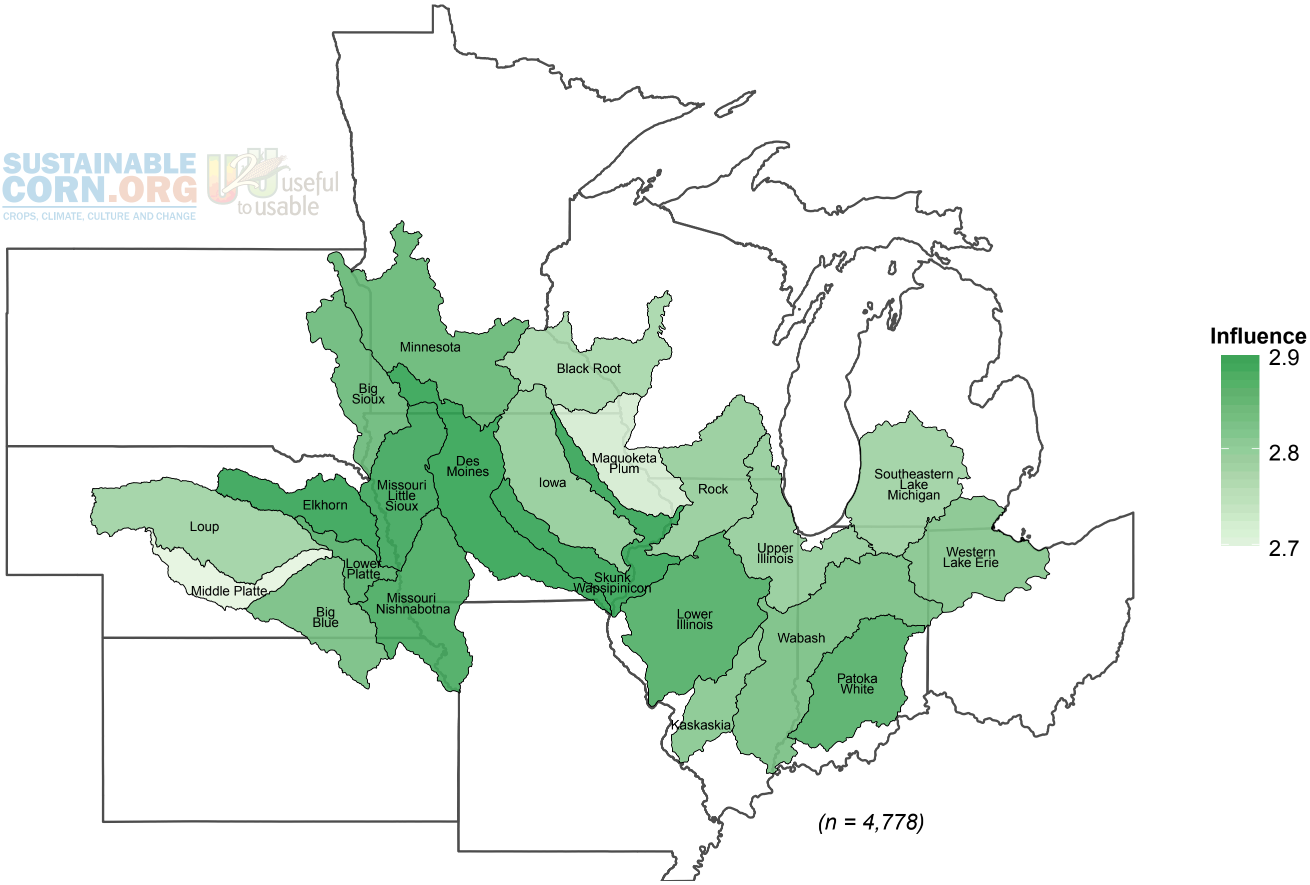

Map 37. Influence of farm chemical dealers on decisions about agricultural practices and strategies, average.

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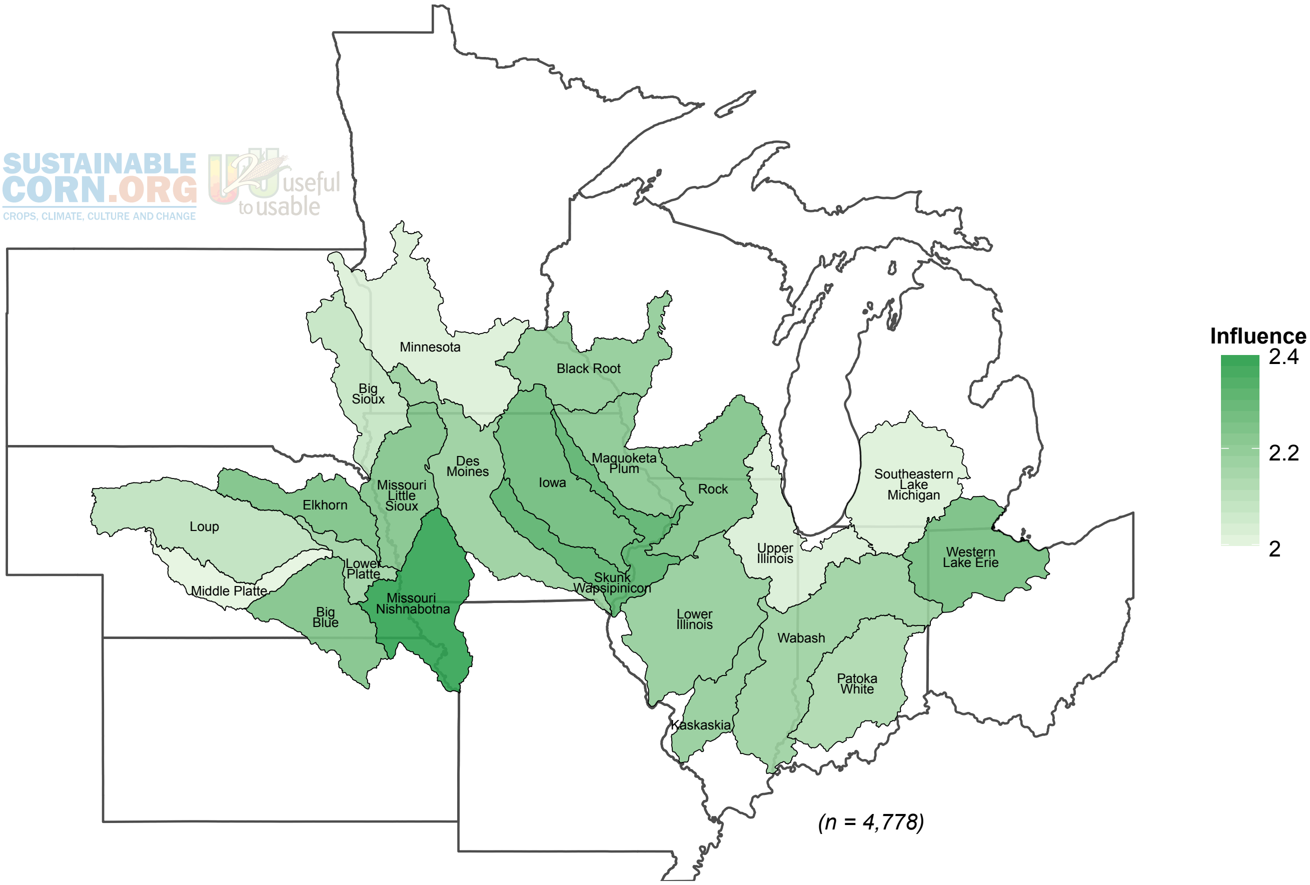

Map 38. Influence of NRCS or county Soil and Water Conservation District staff on decisions about agricultural practices and strategies, average.

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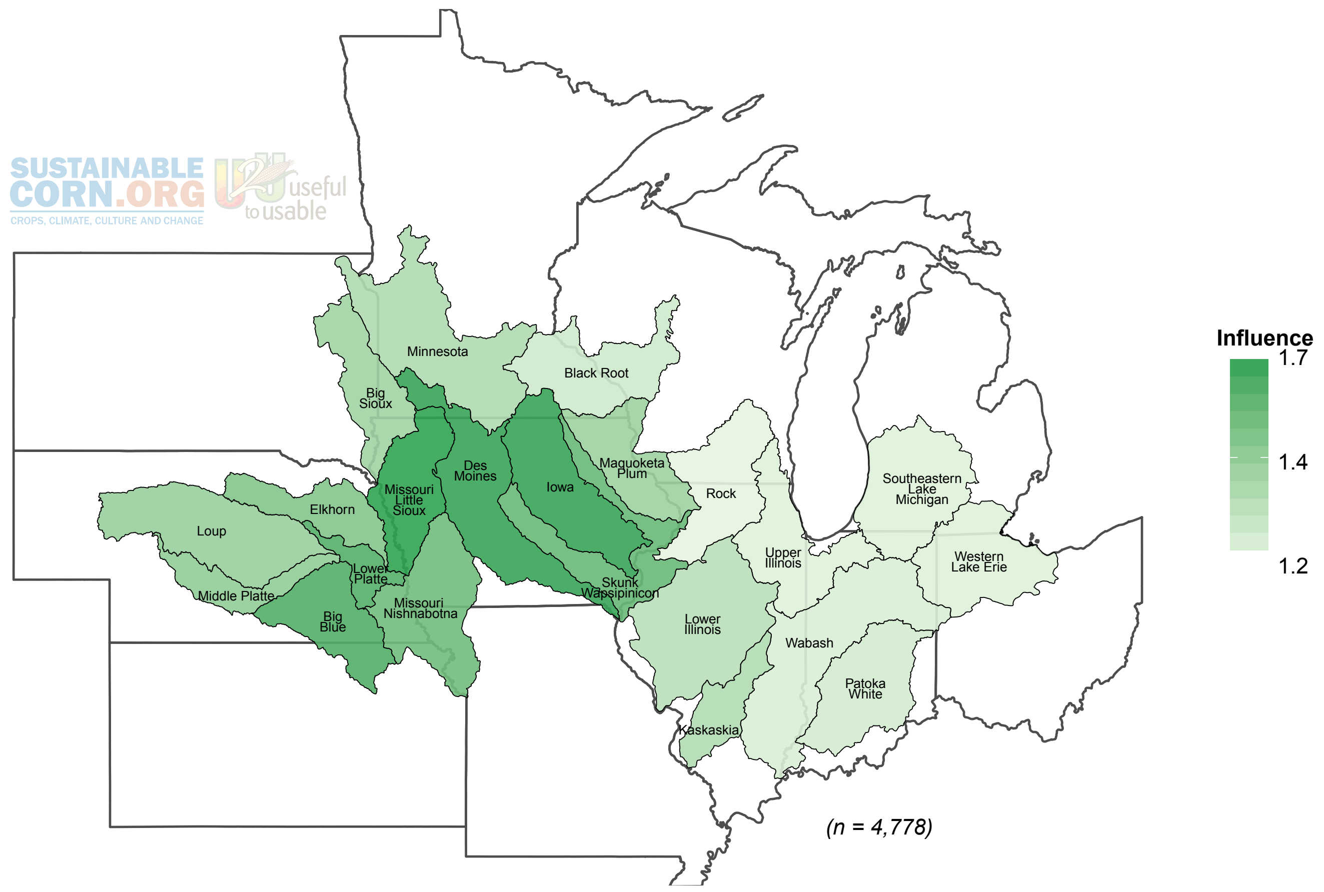

Map 39. Influence of state climatologist on decisions about agricultural practices and strategies, average.

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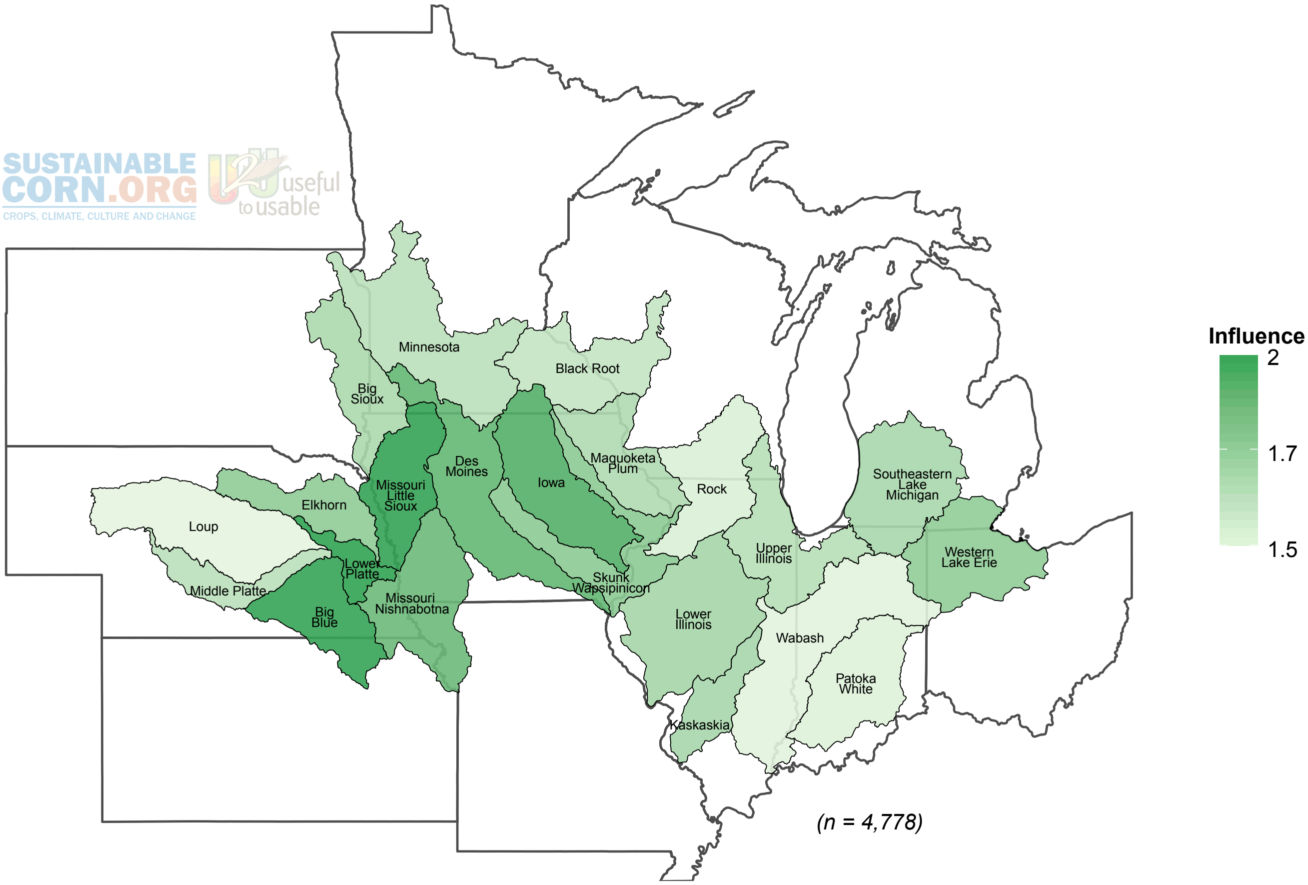

Map 40. Influence of University Extension on decisions about agricultural practices and strategies, average.

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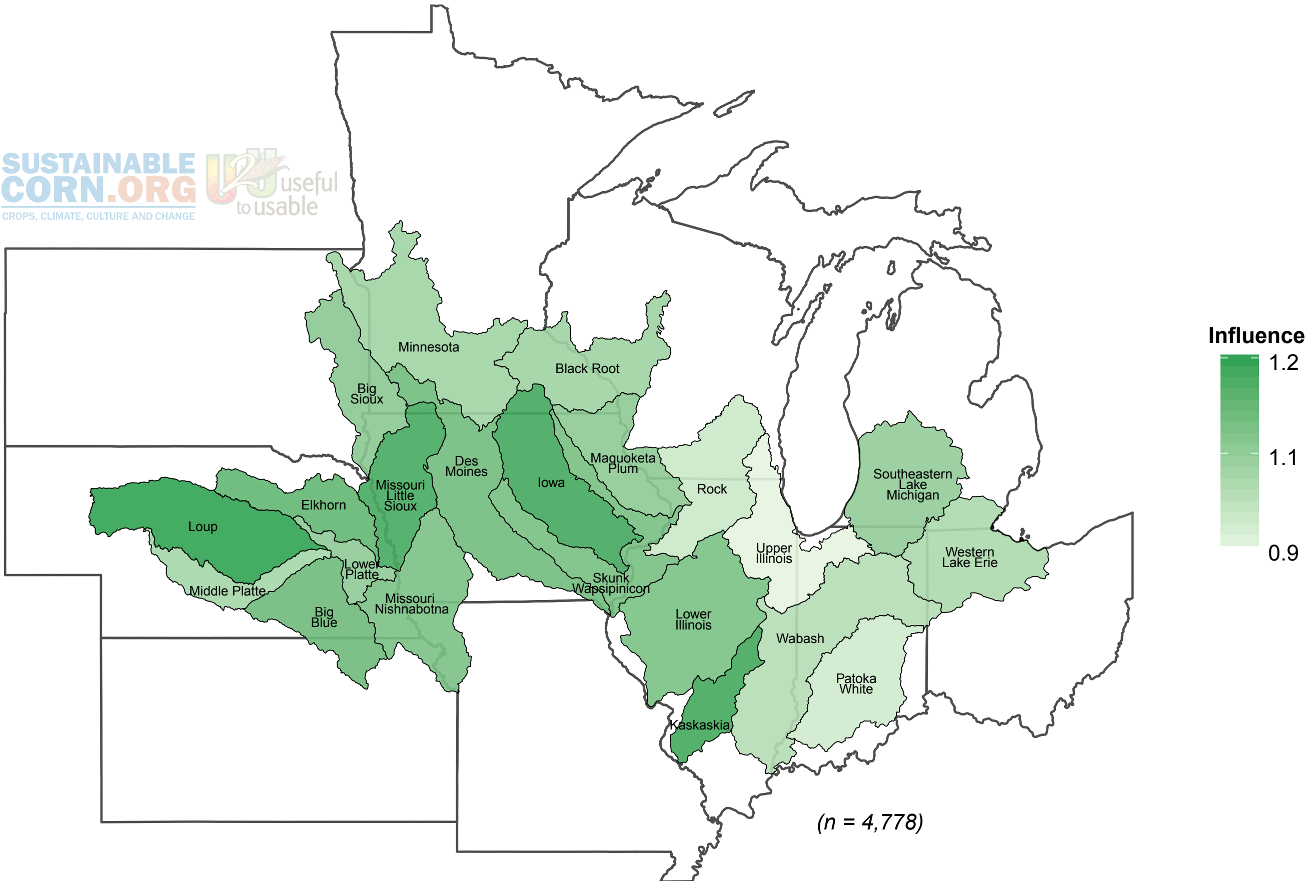

Map 41. Influence of conservation NGO staff on decisions about agricultural practices and strategies, average.

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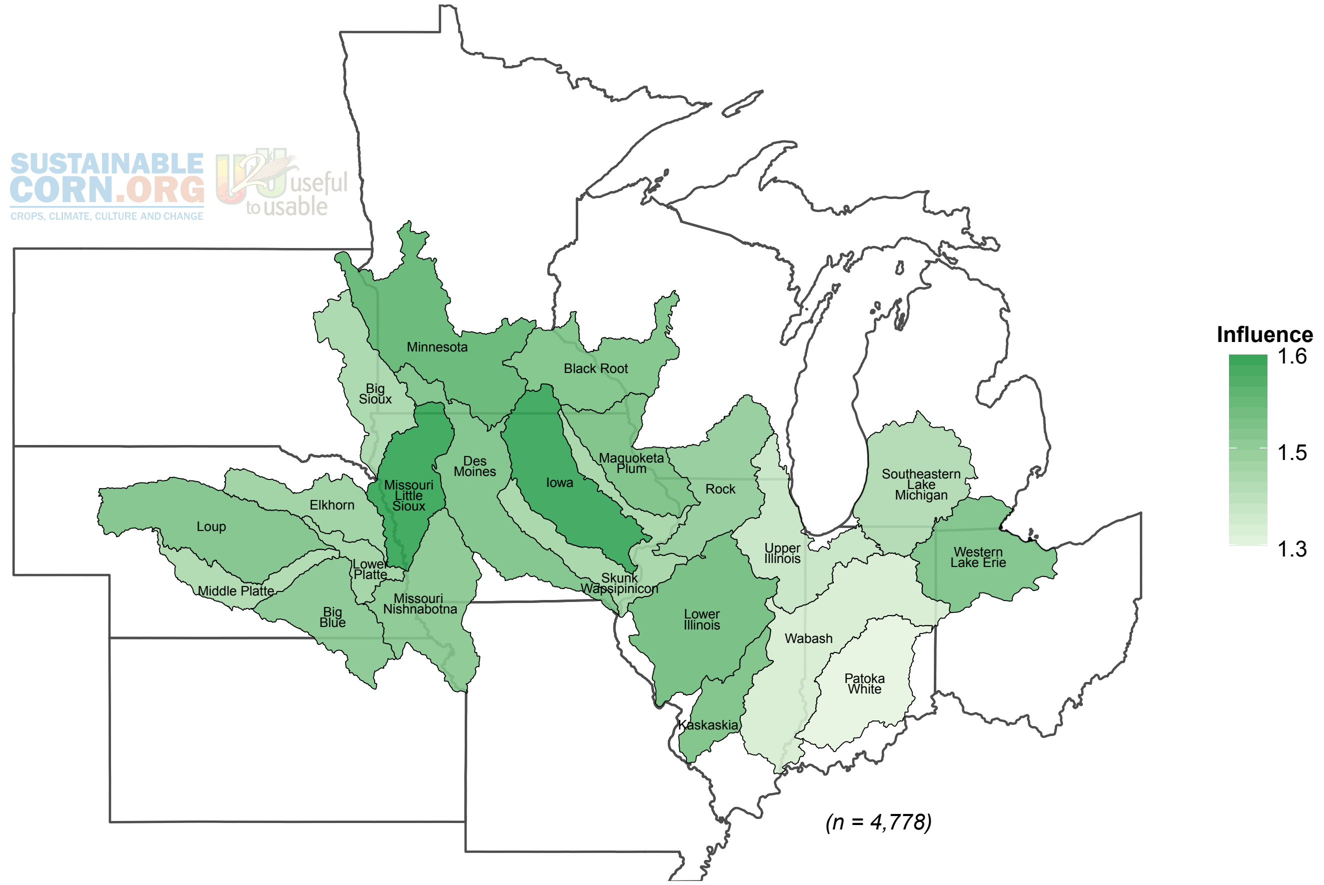

Map 42. Influence of state departments of agriculture on decisions about agricultural practices and strategies, average.

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6 Capacity

Changing climate conditions will have a number of potential impacts on agriculture. Farmers have differing adaptive capacities to adjust and moderate potential damages or take advantage of opportunities as conditions change. Farmer ability to cope is based on their current situation, access to data, information and technology and their confidence, ability and skills to turn data into useable information about how to best respond to weather-related threats. Further, perceptions about uncertainty, the vulnerably of their farm enterprise, and access to resources including crop insurance and other programs can also affect capacity to respond to perceived risks and hazards.

Five survey items measured farmers' self-rated capacity to cope with the potential impacts of climate change on a five-point agreement scale from strongly disagree (1) to strongly agree (5). The items were preceded by the text, "given what you believe to be true about the potential impacts of climate change on agriculture in the Corn Belt, please provide your opinions on the following statements."

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Table 7. Perceived capacity[1] to deal with the potential impact of climate change, percent agree or strongly agree (n = 4,778)

Watershed (HUC6)	Q19A[a]	Q19B[b]	Q19E[e]	Q19F[f]	Q19H[h]
Full Weighted Sample	48.4	45.0	30.9	32.6	27.2
Loup	50.0	41.6	23.4	18.2	26.6
Middle Platte	54.3	45.7	29.8	29.8	31.8
Elkhorn	50.0	39.6	31.7	30.5	25.0
Big Blue	49.7	44.9	29.7	30.8	26.5
Lower Platte	43.5	45.3	24.2	30.4	23.0
Big Sioux	45.9	42.1	31.7	28.4	26.8
Missouri-Little Sioux	45.3	44.8	29.6	33.2	29.2
Missouri-Nishnabotna	40.6	39.3	25.0	30.8	21.9
Minnesota	49.0	40.5	29.5	35.4	30.4
Des Moines	46.0	45.6	31.7	36.3	25.9
Iowa	49.6	42.7	29.4	31.1	22.2
Black Root	43.0	38.0	24.4	27.3	25.2
Skunk Wapsipinicon	45.5	48.5	30.0	33.5	27.5
Maquoketa Plum	42.4	37.7	31.0	32.2	26.7
Lower Illinois	48.4	49.2	28.7	35.3	23.4
Rock	42.5	37.8	24.7	24.7	27.4
Kaskaskia	40.6	39.1	26.9	30.0	22.3
Upper Illinois	44.9	41.9	29.9	27.4	22.7
Wabash	45.2	43.5	33.5	27.2	23.9
Patoka-White	35.3	33.8	24.4	21.4	18.4
Southeastern Lake Michigan	48.5	42.0	29.9	21.7	29.9
Western Lake Erie	40.6	35.4	27.6	32.3	21.7

[1]Measured by percent agreement (agree or strongly agree) on a 5-point scale.
[a]I have the knowledge and technical skill to deal with any weather-related threats to the viability of my farm operation.
[b]I have the financial capacity to deal with any weather-related threats to the viability of my farm operation.
[e]Climate change is not a big issue because human ingenuity will enable us to adapt to changes.
[f]Crop insurance and other programs will protect the viability of my farm operation regardless of weather.
[h]I am concerned that available best management practice technologies are not effective enough to protect the land I farm from the impacts of climate change.

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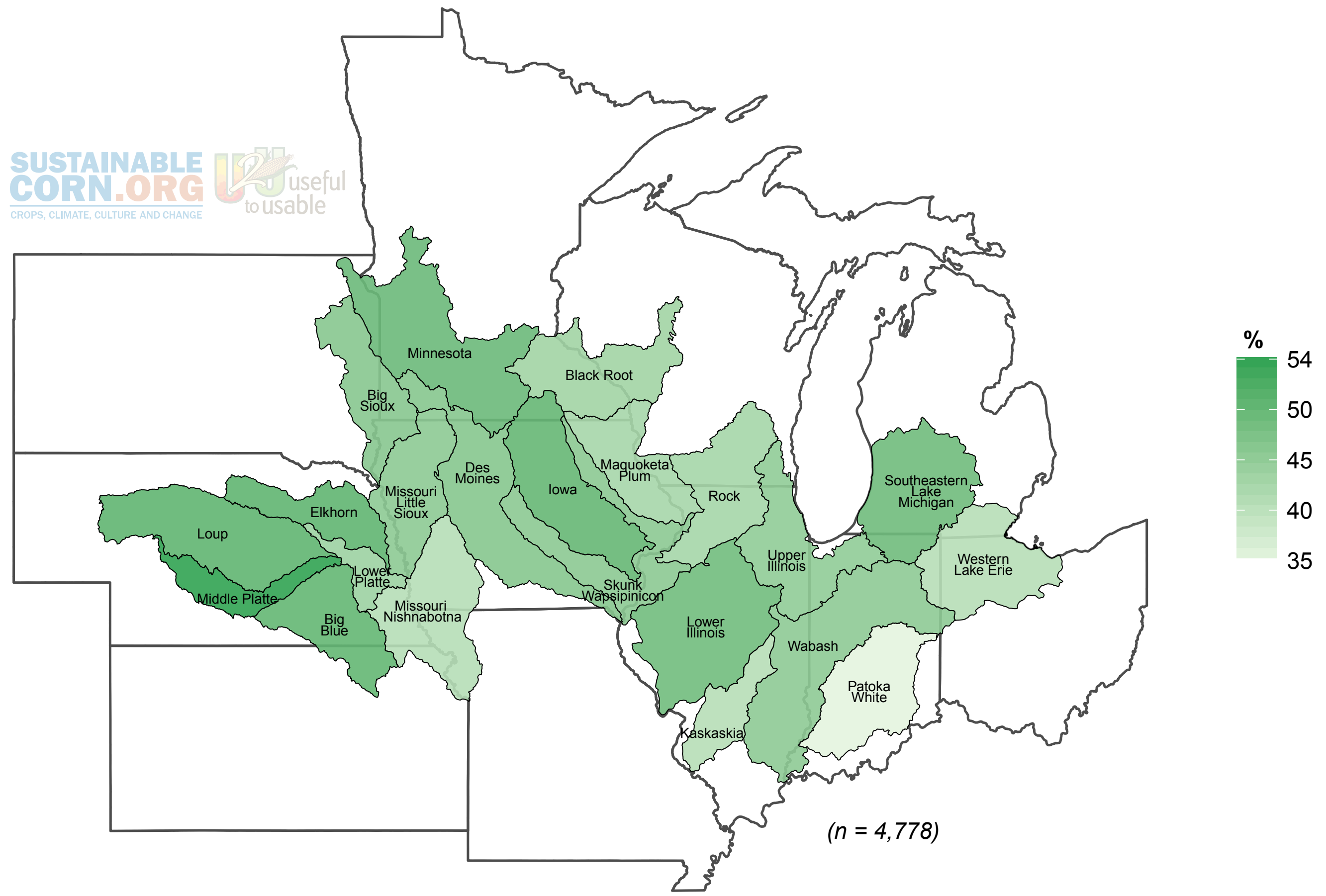

Map 43. Have the knowledge and technical skill to deal with any weather-related threats to the viability of my farm operation (Q19A), percent agree or strongly agree.

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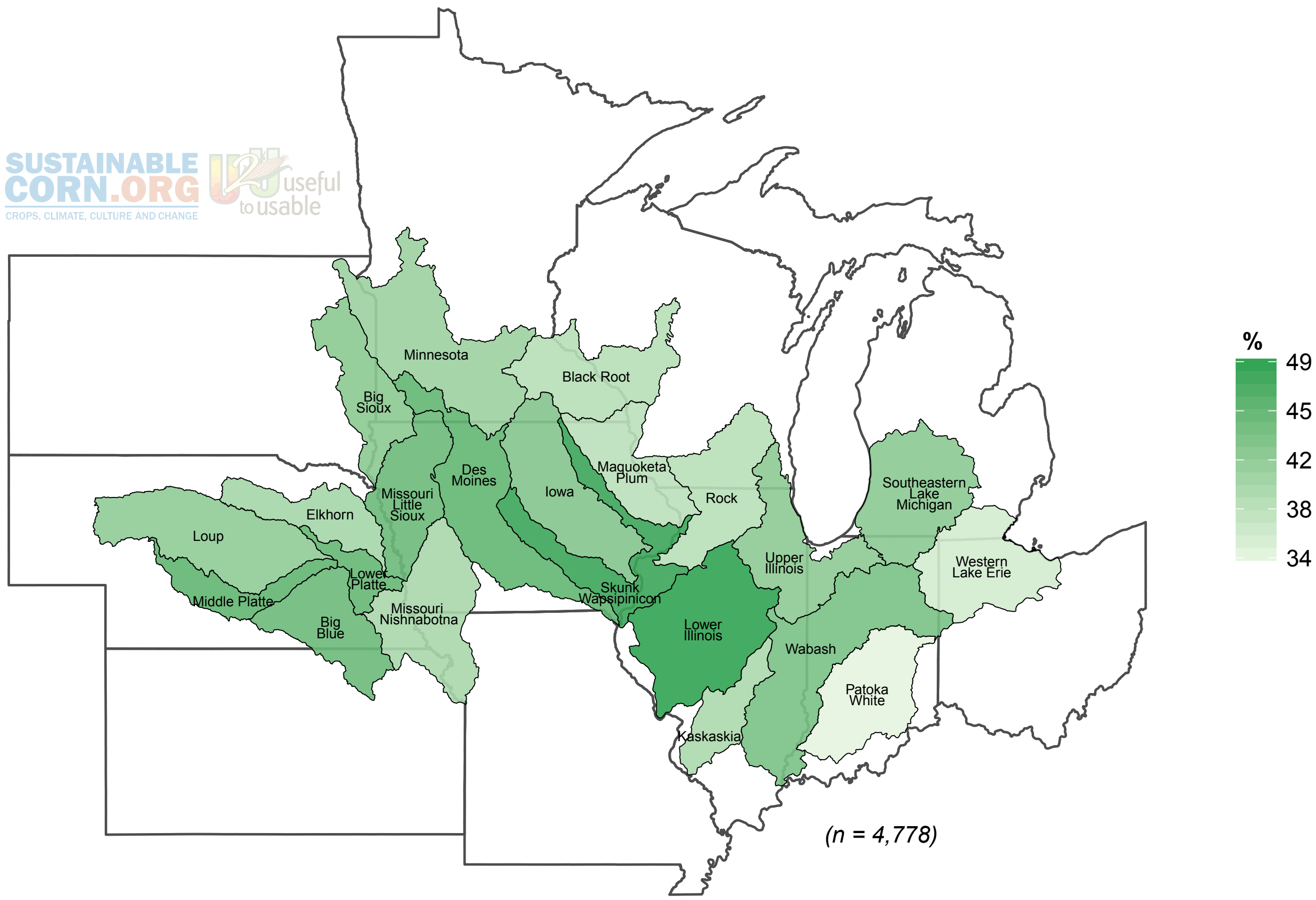

Map 44. Have the financial capacity to deal with any weather-related threats to the viability of my farm operation (Q19B), percent agree or strongly agree.

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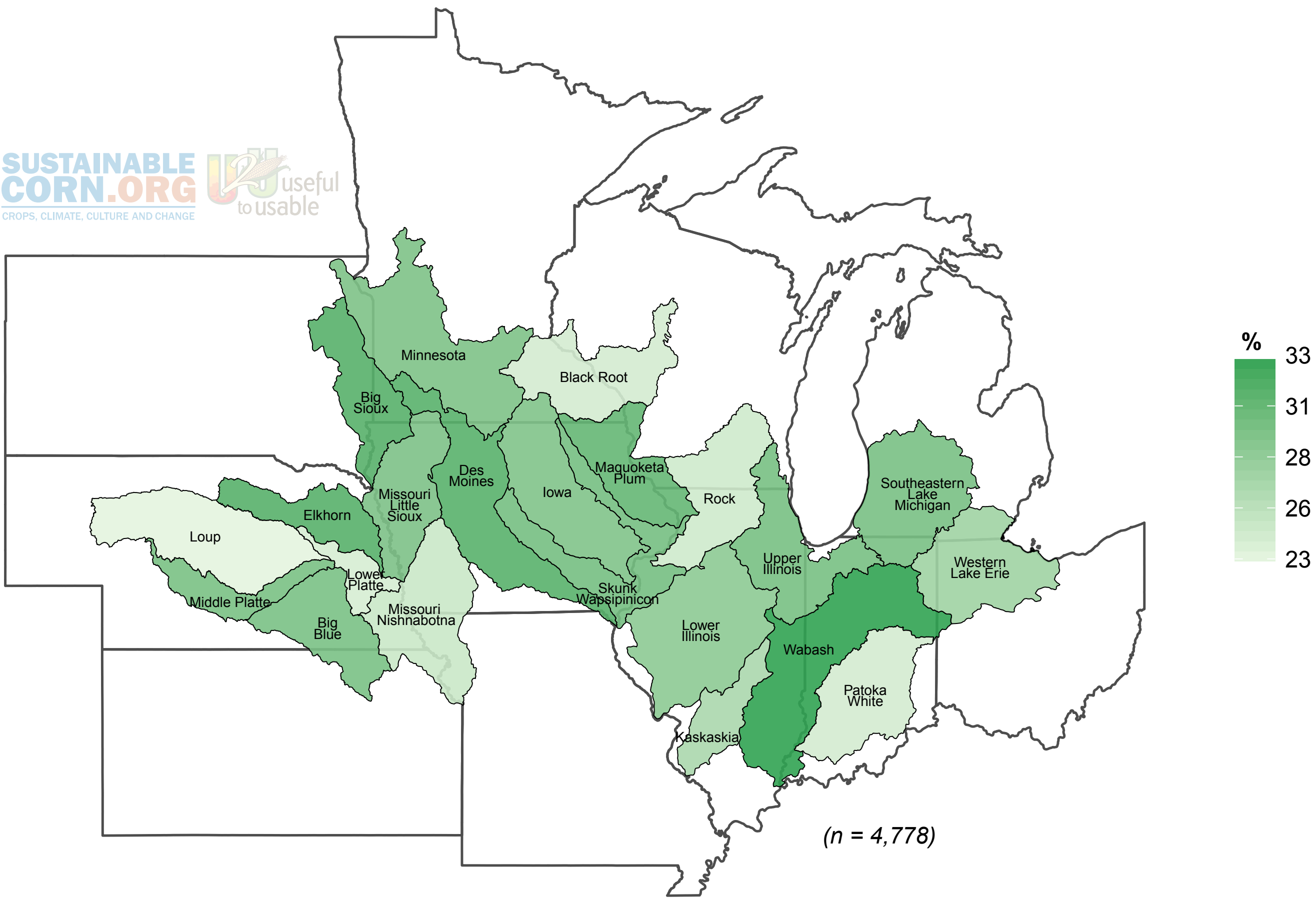

Map 45. Climate change is not a big issue because human ingenuity will enable us to adapt to changes (Q19E), percent agree or strongly agree.

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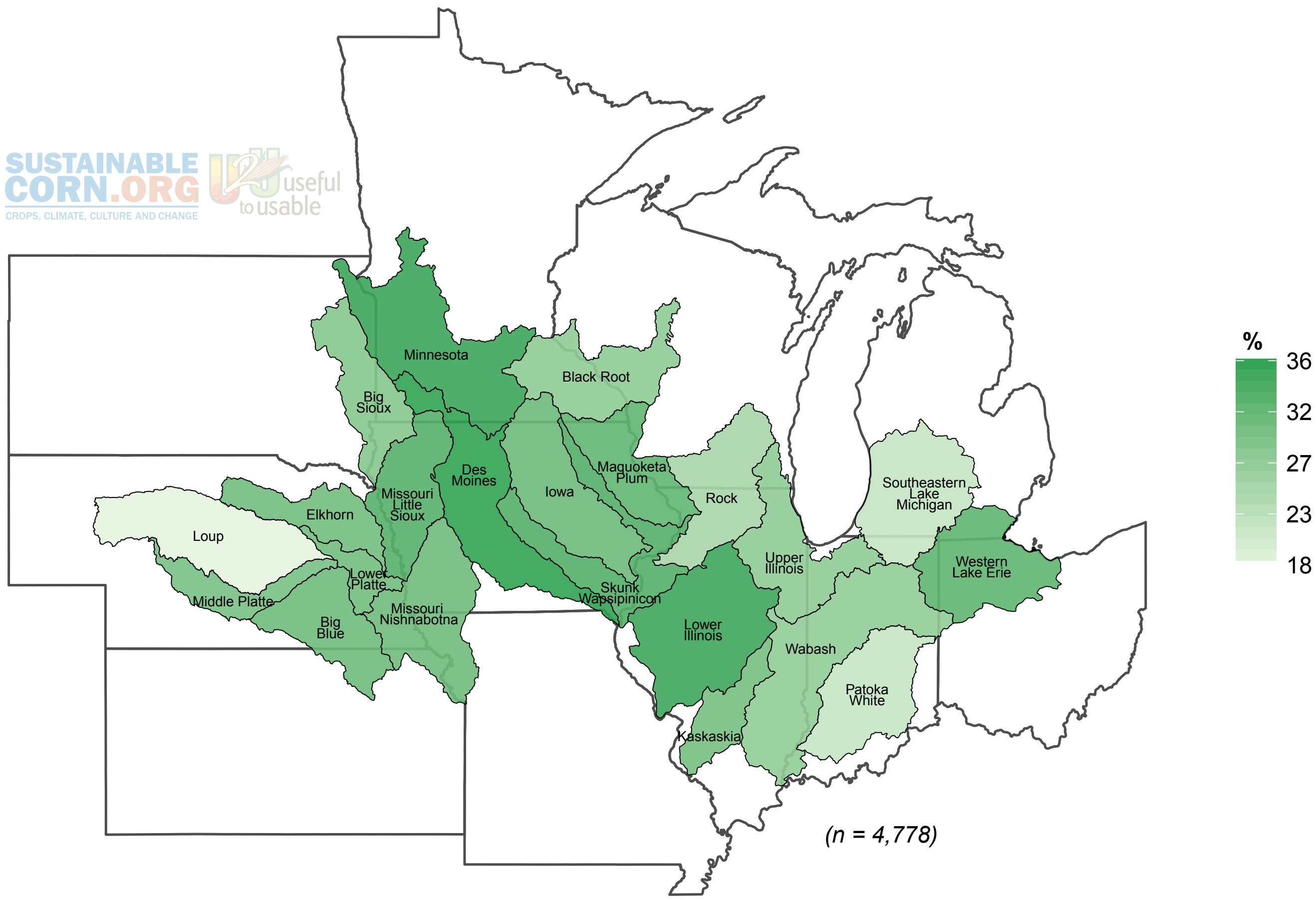

Map 46. Crop insurance and other programs will protect the viability of my farm operation regardless of weather (Q19F), percent agree or strongly agree.

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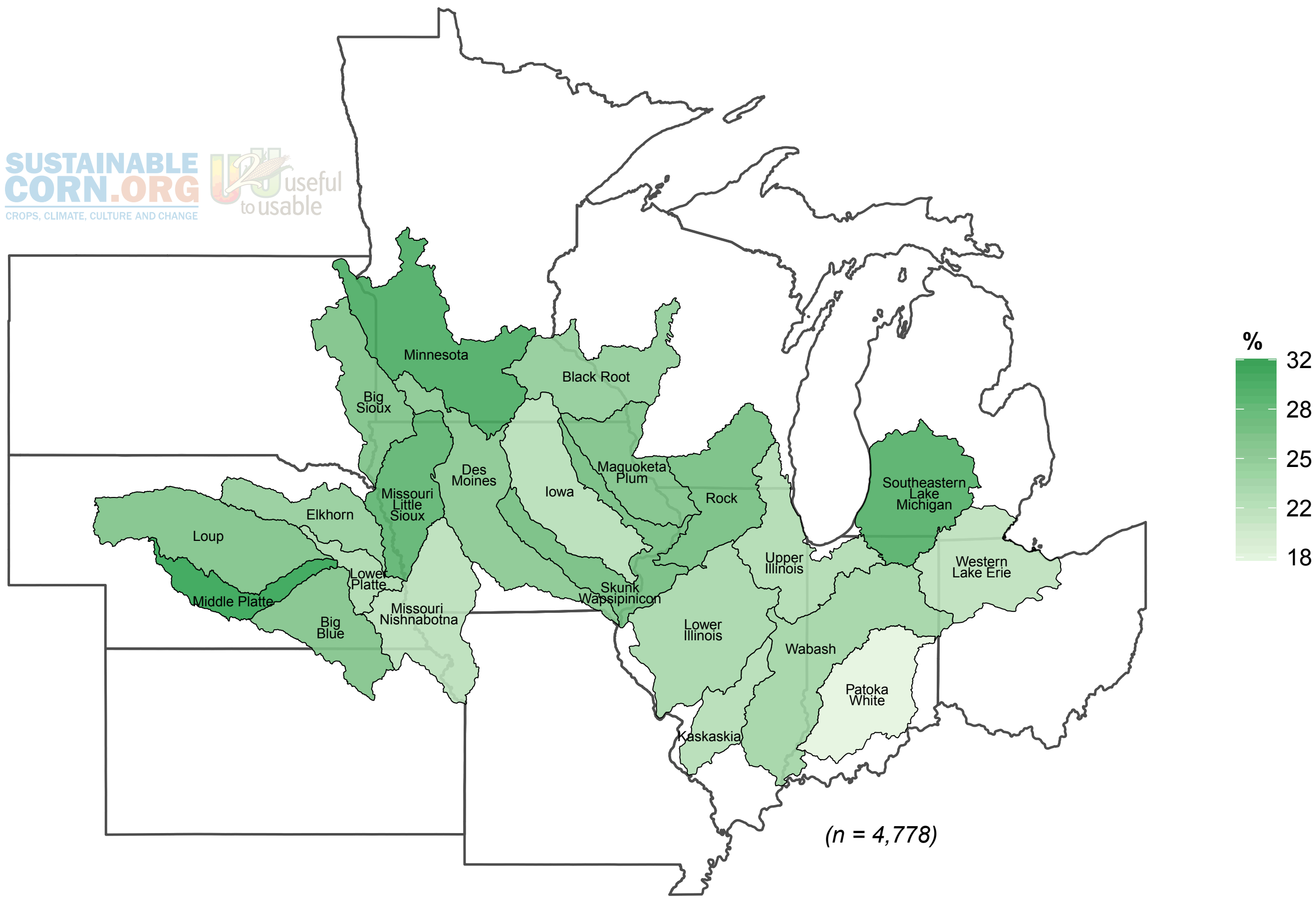

Map 47. I am concerned that available best management practice technologies are not effective enough to protect the land I farm from the impacts of climate change (Q19H), percent agree or strongly agree.

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7 Farm and Farmer Characteristics

Table 8. Respondents with at least a college education (a 4-year degree or higher), percent (n = 4,778)

Watershed (HUC6)	Percentage
Weighted Full Sample	24.5
Loup	27.6
Middle Platte	38.5
Elkhorn	24.5
Big Blue	25.7
Lower Platte	28.3
Big Sioux	19.4
Missouri-Little Sioux	27.2
Missouri-Nishnabotna	29.6
Minnesota	17.4
Des Moines	23.9
Iowa	26.5
Black Root	15.6
Skunk Wapsipinicon	29.7
Maquoketa Plum	22.0
Lower Illinois	29.3
Rock	20.6
Kaskaskia	29.3
Upper Illinois	28.9
Wabash	26.0
Patoka-White	27.5
Southeastern Lake Michigan	19.0
Western Lake Erie	17.1

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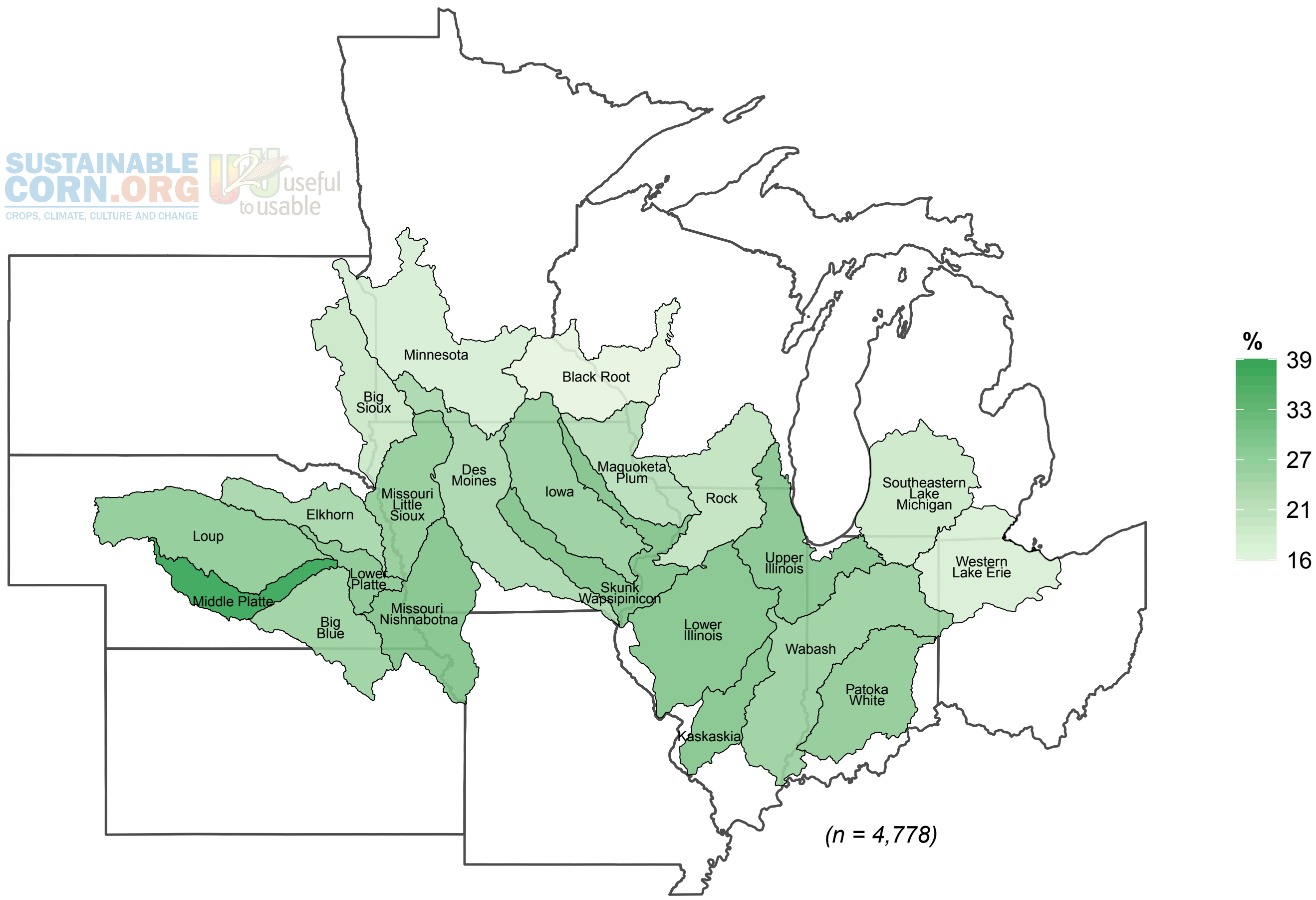

Map 48. Respondents with at least a college education (a 4-year degree or higher), percent.

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Table 9. Farmers who plan to retire in the next 5 years (2012–2016) (n = 4,778)

Watershed (HUC6)	Percentage
Weighted Full Sample	26.0
Loup	26.9
Middle Platte	26.4
Elkhorn	26.4
Big Blue	30.8
Lower Platte	29.1
Big Sioux	25.1
Missouri-Little Sioux	30.3
Missouri-Nishnabotna	30.7
Minnesota	22.0
Des Moines	23.3
Iowa	28.6
Black Root	21.9
Skunk Wapsipinicon	24.8
Maquoketa Plum	21.3
Lower Illinois	28.1
Rock	28.7
Kaskaskia	27.2
Upper Illinois	26.7
Wabash	26.4
Patoka-White	22.6
Southeastern Lake Michigan	24.4
Western Lake Erie	23.9

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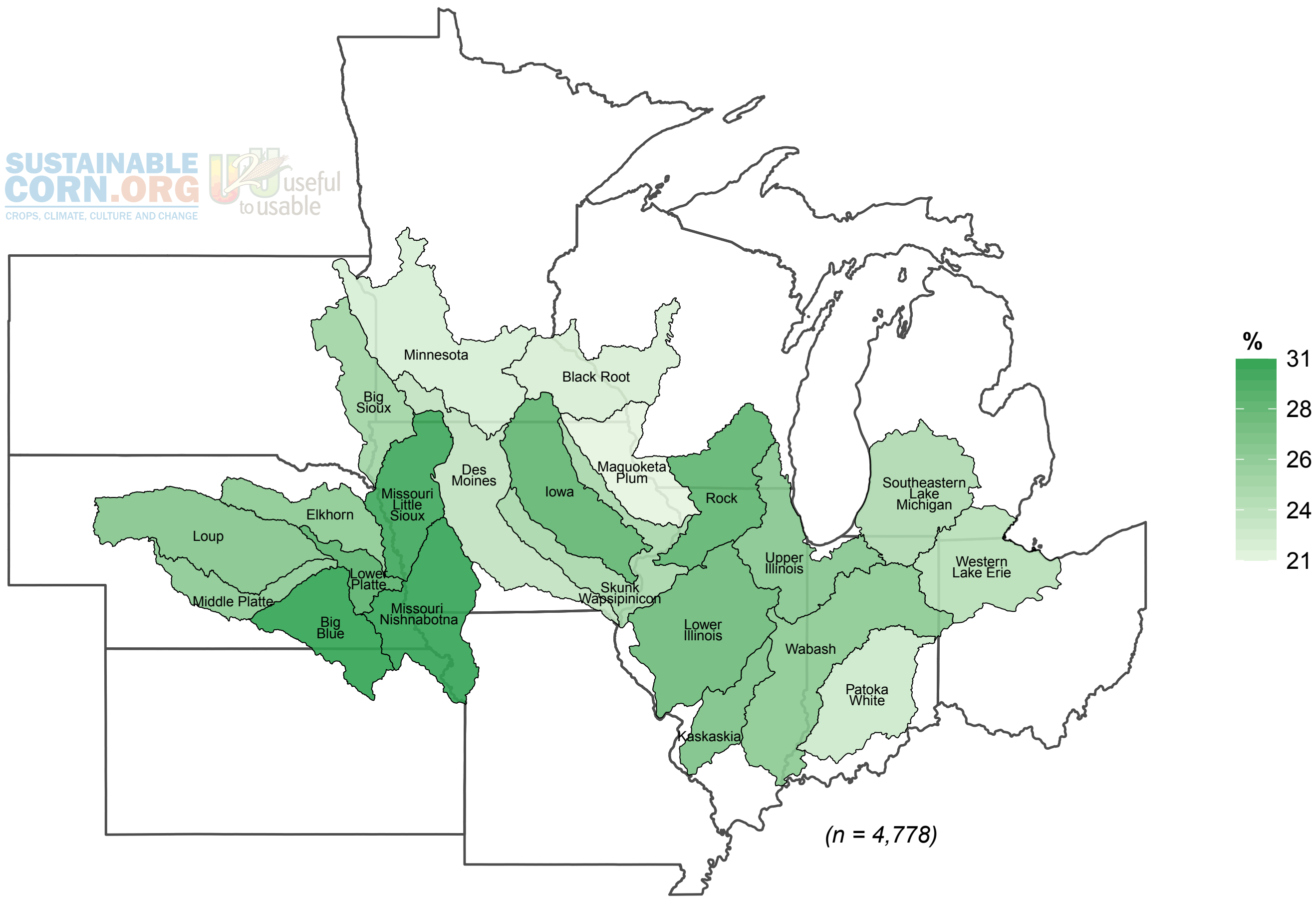

Map 49. Farmers who plan to retire in the next 5 years (2012–2016), percent.

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Table 10. Likelihood[1] that a family member will take over their farm operation when they retire, percent likely or very likely (n = 4,778)

Watershed (HUC6)	Percent likely or very likely
Weighted Full Sample	54.9
Loup	54.9
Middle Platte	48.3
Elkhorn	52.8
Big Blue	52.2
Lower Platte	54.7
Big Sioux	46.4
Missouri-Little Sioux	58.7
Missouri-Nishnabotna	59.3
Minnesota	52.1
Des Moines	56.7
Iowa	52.7
Black Root	54.8
Skunk Wapsipinicon	56.6
Maquoketa Plum	46.4
Lower Illinois	57.9
Rock	57.3
Kaskaskia	55.0
Upper Illinois	51.3
Wabash	54.3
Patoka-White	61.5
Southeastern Lake Michigan	54.4
Western Lake Erie	62.9

[1] Likelihood was measured on a 5-point scale: very unlikely, unlikely, uncertain, likely, very likely.

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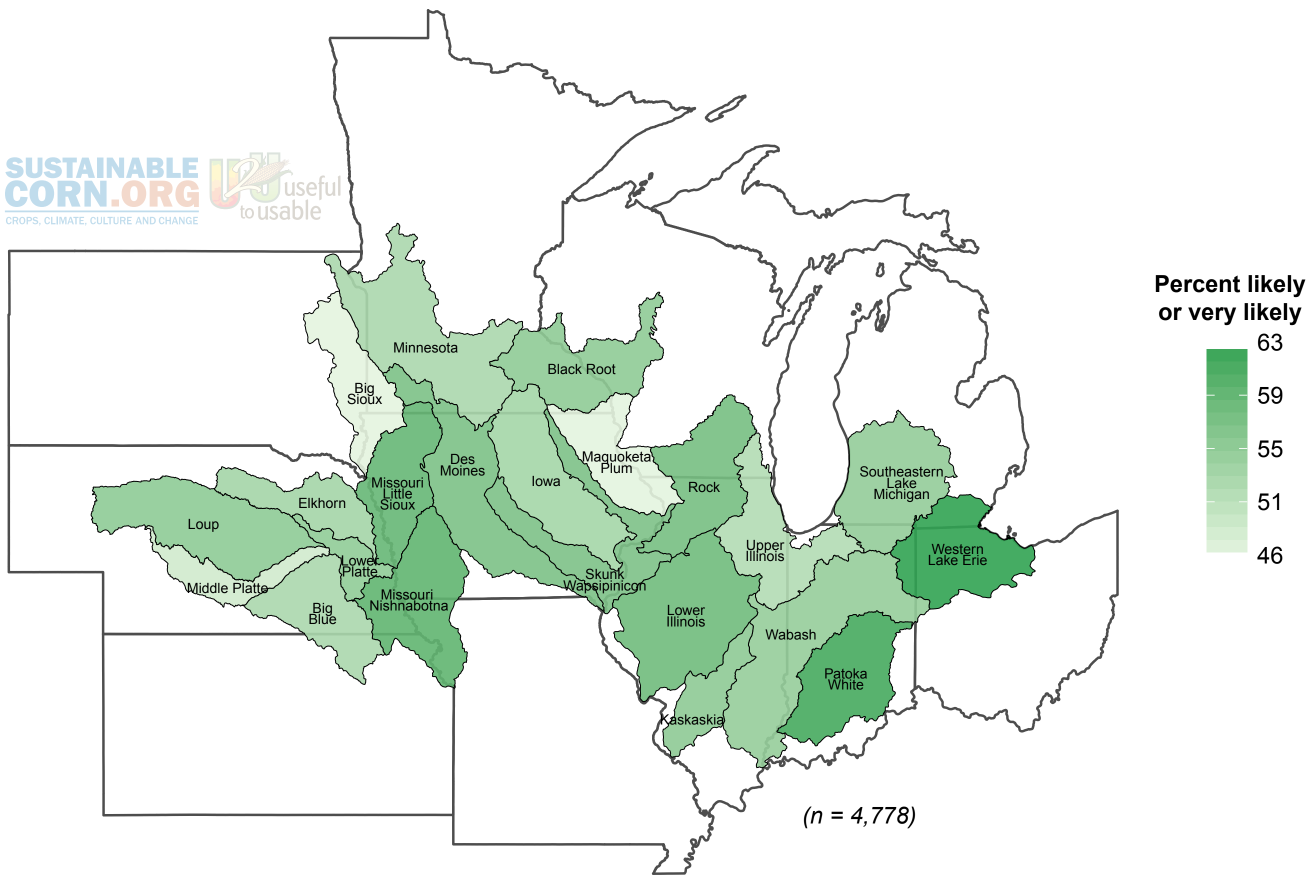

Map 50. Likelihood that a family member will take over the farm operation when they retire, percent likely or very likely.

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Table 11. Farm characteristics (averages)

Watershed (HUC6)	Land owned and rented (Acres)	Percent Rented	Percent Land Drained		Percent Land Irrigated		Percent HEL Land in Crops		Percent Land No-Till		Percent Land Cover Crops	
			Owned	Rented	Owned	Rented	Owned	Rented	Owned	Rented	Owned	Rented
Weighted Full Sample	1025	59.4	51.4	45.4	7.8	6.4	19.1	19.2	31.7	32.0	4.5	3.5
Loup	1759	41.1	3.8	2.5	55.5	52.2	29.6	26.2	42.4	42.0	4.4	3.6
Middle Platte	1251	58.1	5.3	4.3	78.0	73.6	18.1	14.5	31.6	26.1	5.9	2.6
Elkhorn	923	50.0	7.1	8.0	30.5	26.9	45.6	46.1	58.4	63.4	6.8	2.6
Big Blue	1005	56.0	7.0	5.4	56.7	54.8	24.4	23.8	59.5	58.7	2.5	2.1
Lower Platte	969	52.5	14.2	11.4	32.2	25.3	44.0	48.7	73.6	75.5	3.6	3.7
Big Sioux	854	56.2	32.4	27.9	2.8	2.5	11.2	11.6	10.8	10.6	1.8	2.1
Missouri-Little Sioux	836	59.0	48.9	47.9	3.8	3.7	25.2	24.7	29.7	30.5	1.1	1.6
Missouri-Nishnabotna	997	49.7	37.4	34.1	2.5	0.9	47.8	48.3	68.3	67.8	2.5	1.4
Minnesota	876	52.3	66.0	63.2	1.6	1.2	4.8	5.7	6.1	6.6	3.7	2.4
Des Moines	899	57.9	71.6	68.4	0.9	0.2	10.4	10.3	14.5	14.9	3.0	2.5
Iowa	808	54.1	75.7	67.5	0.6	0.3	22.0	22.6	28.1	27.6	3.2	2.0
Black Root	647	37.6	25.0	19.1	3.9	3.0	27.7	25.5	18.3	18.9	11.6	10.3
Skunk Wapsipinicon	769	51.5	68.5	58.7	0.8	0.6	29.3	31.6	28.7	29.1	4.2	2.2
Maquoketa Plum	663	36.5	45.3	40.3	0.5	0.1	43.1	43.8	32.4	36.1	10.0	6.2
Lower Illinois	1069	65.2	66.0	63.5	5.3	4.0	13.9	15.8	28.3	28.1	3.6	2.4
Rock	776	50.4	34.6	32.8	3.1	0.7	25.2	25.2	30.8	33.5	8.1	4.5
Kaskaskia	1021	62.9	32.1	30.2	0.4	0.5	18.4	18.9	28.2	27.1	5.2	3.5
Upper Illinois	944	66.0	69.1	68.9	5.8	2.7	5.8	8.5	28.2	28.0	7.7	4.4
Wabash	1093	58.7	62.9	53.7	0.8	1.0	10.7	11.8	40.0	38.0	7.0	4.4
Patoka-White	1079	56.0	64.8	55.6	1.3	0.4	15.2	16.2	54.4	56.6	9.6	8.8
Southeastern Lake Michigan	883	47.9	42.4	29.8	17.1	7.3	10.9	10.7	40.0	41.9	11.9	10.0
Western Lake Erie	850	55.3	80.2	68.2	0.5	0.5	7.9	7.6	52.9	53.8	9.2	7.6

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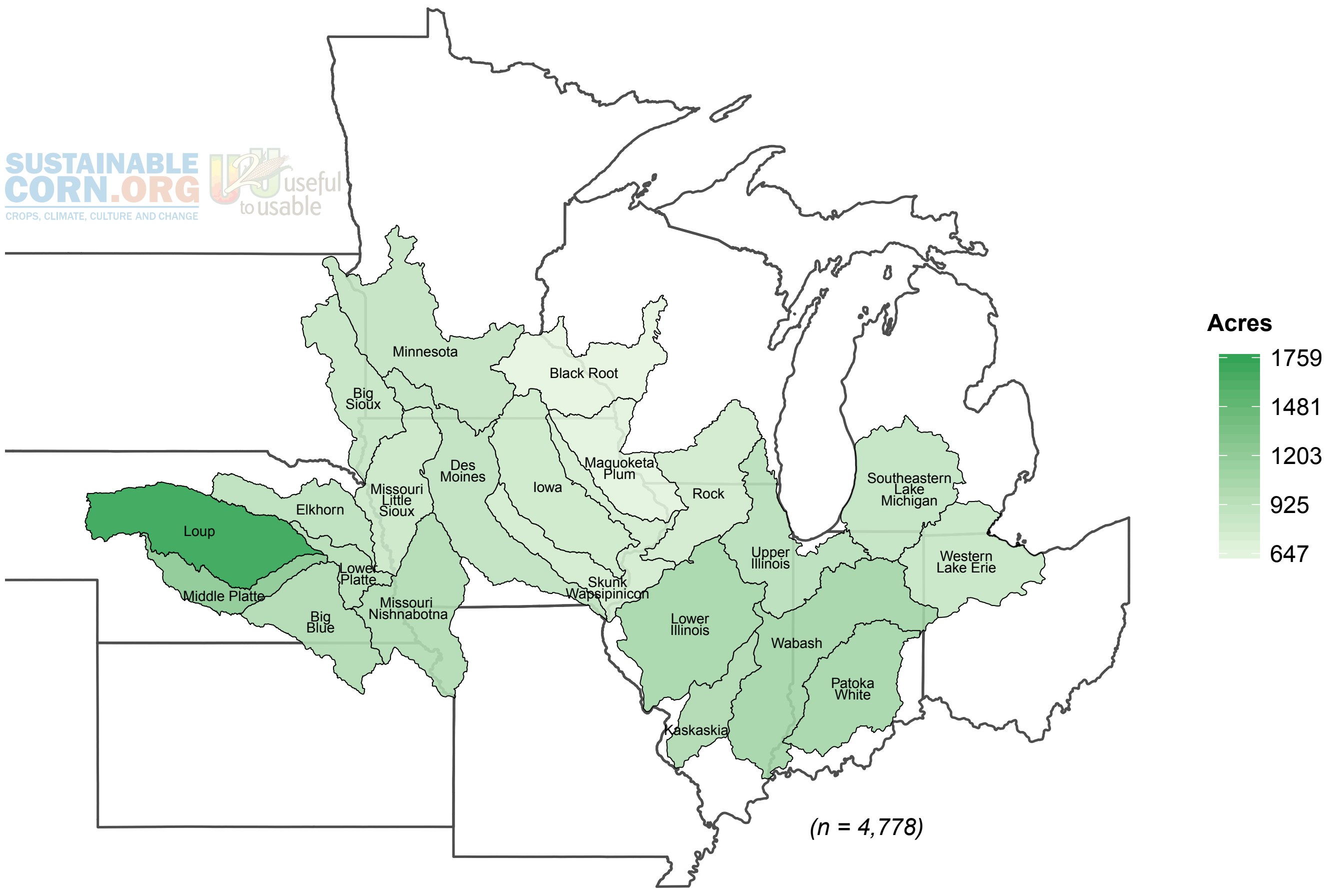

Map 51. Acres of land farmed by respondents (owned and rented).

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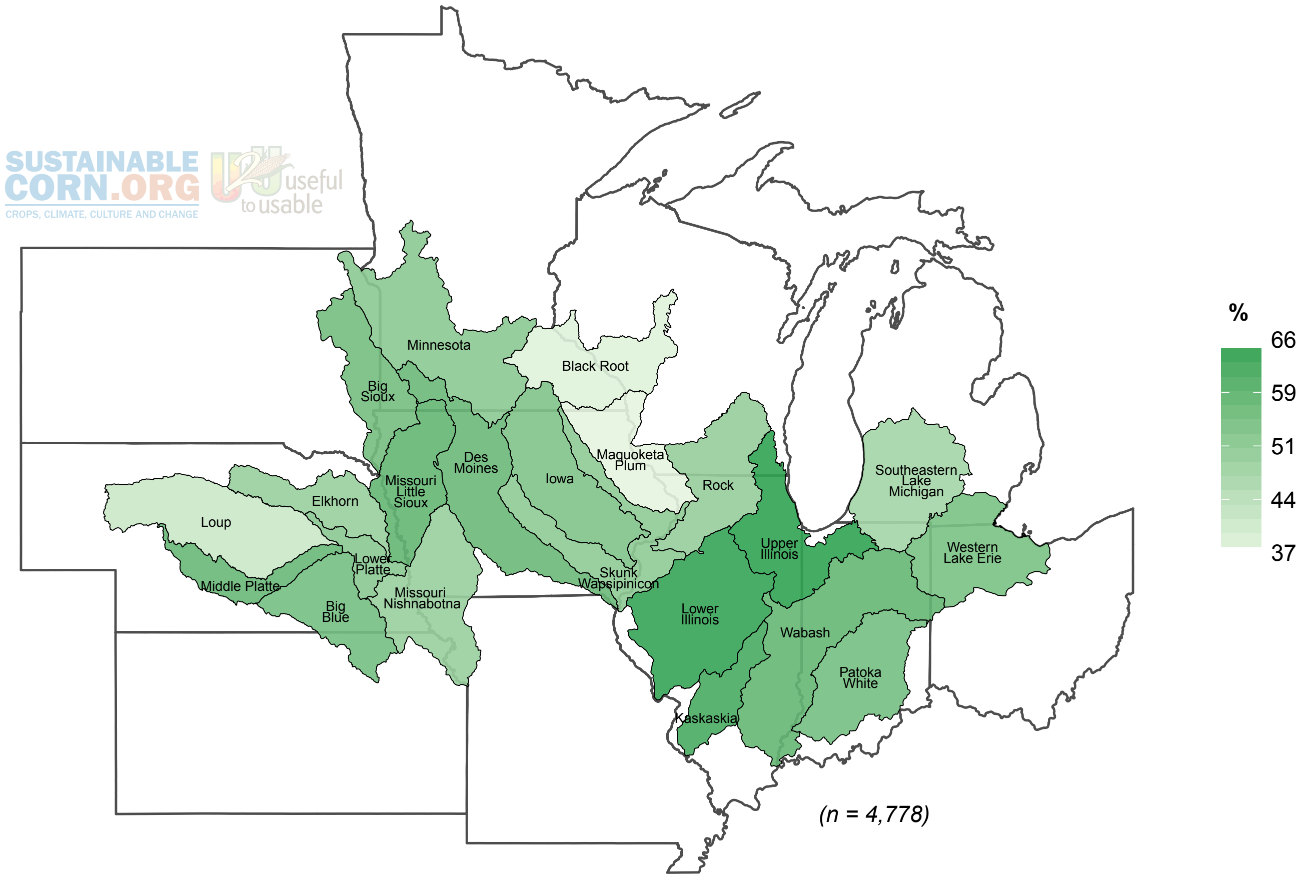

Map 52. Percentage of land farmed by respondents that is rented.

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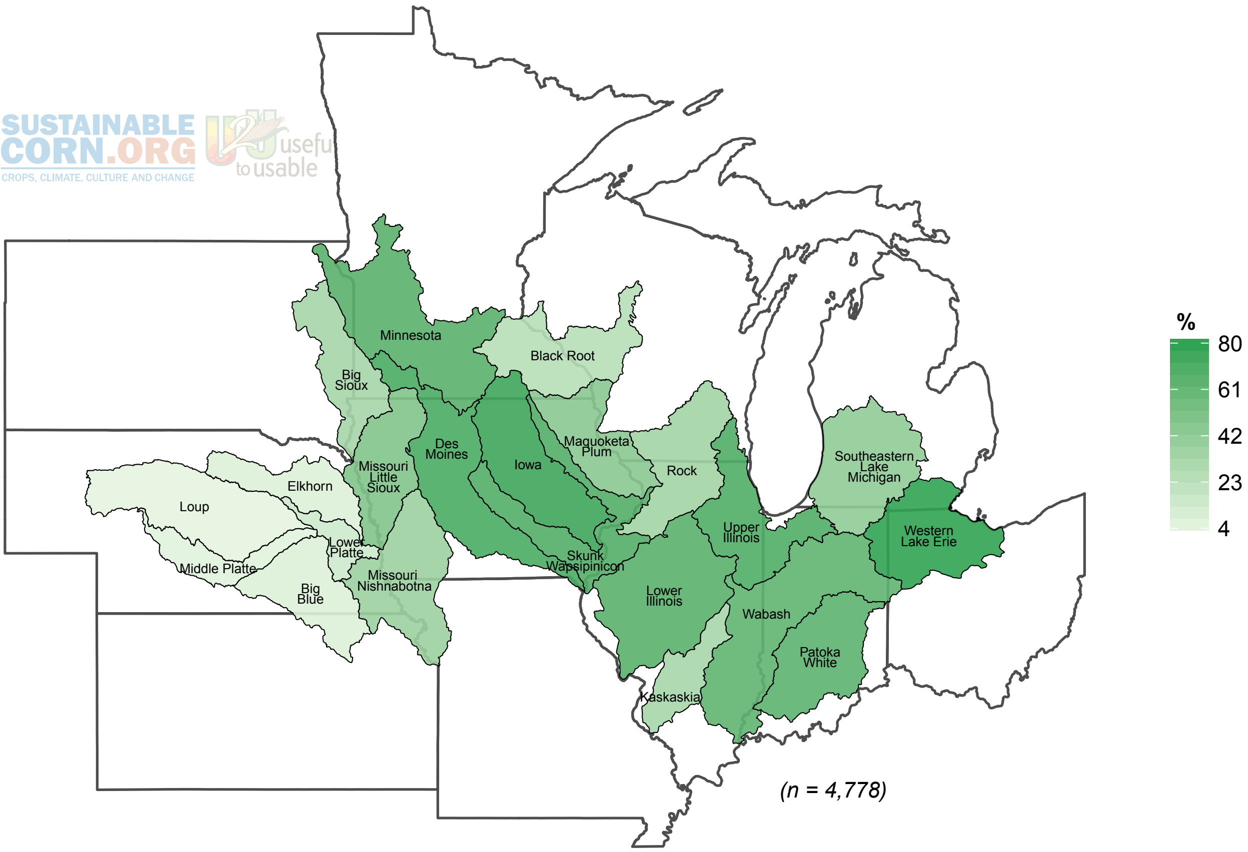

Map 53. In 2011, approximately what percentage of the owned land that you farmed was artificially drained through tile or other methods?

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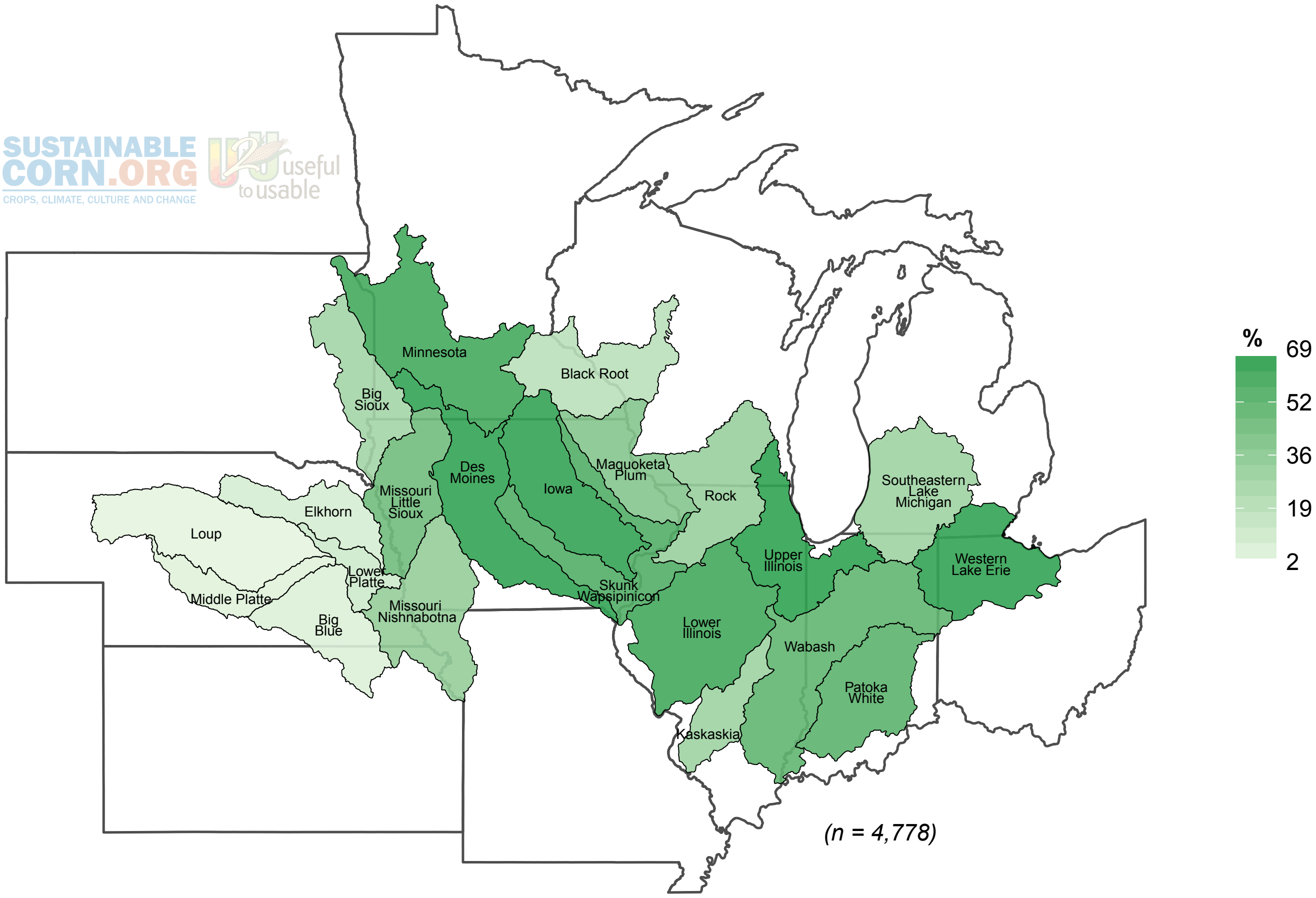

Map 54. In 2011, approximately what percentage of the rented land that you farmed was artificially drained through tile or other methods?

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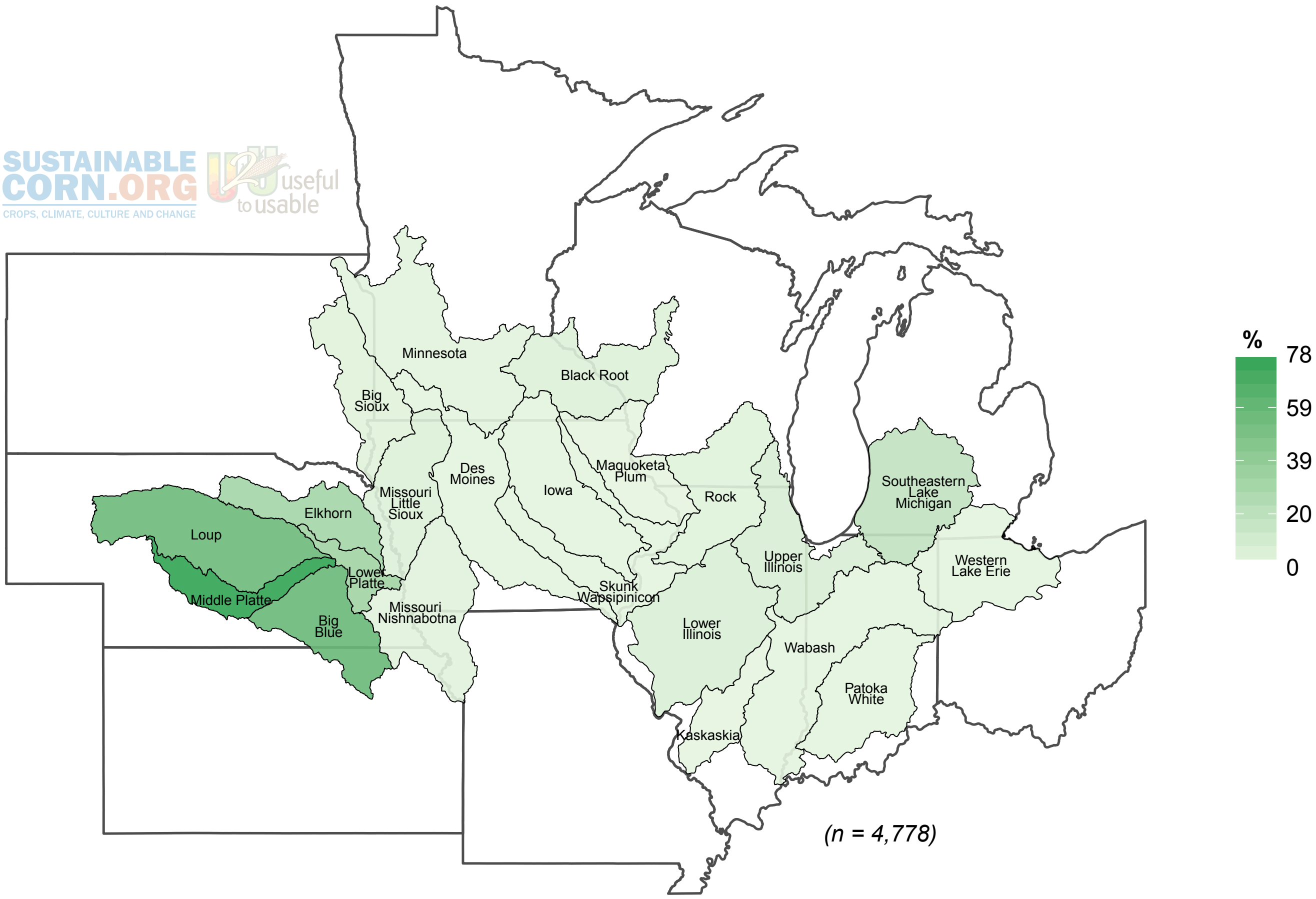

Map 55. In 2011, approximately what percentage of the <u>owned</u> land that you farmed was irrigated?

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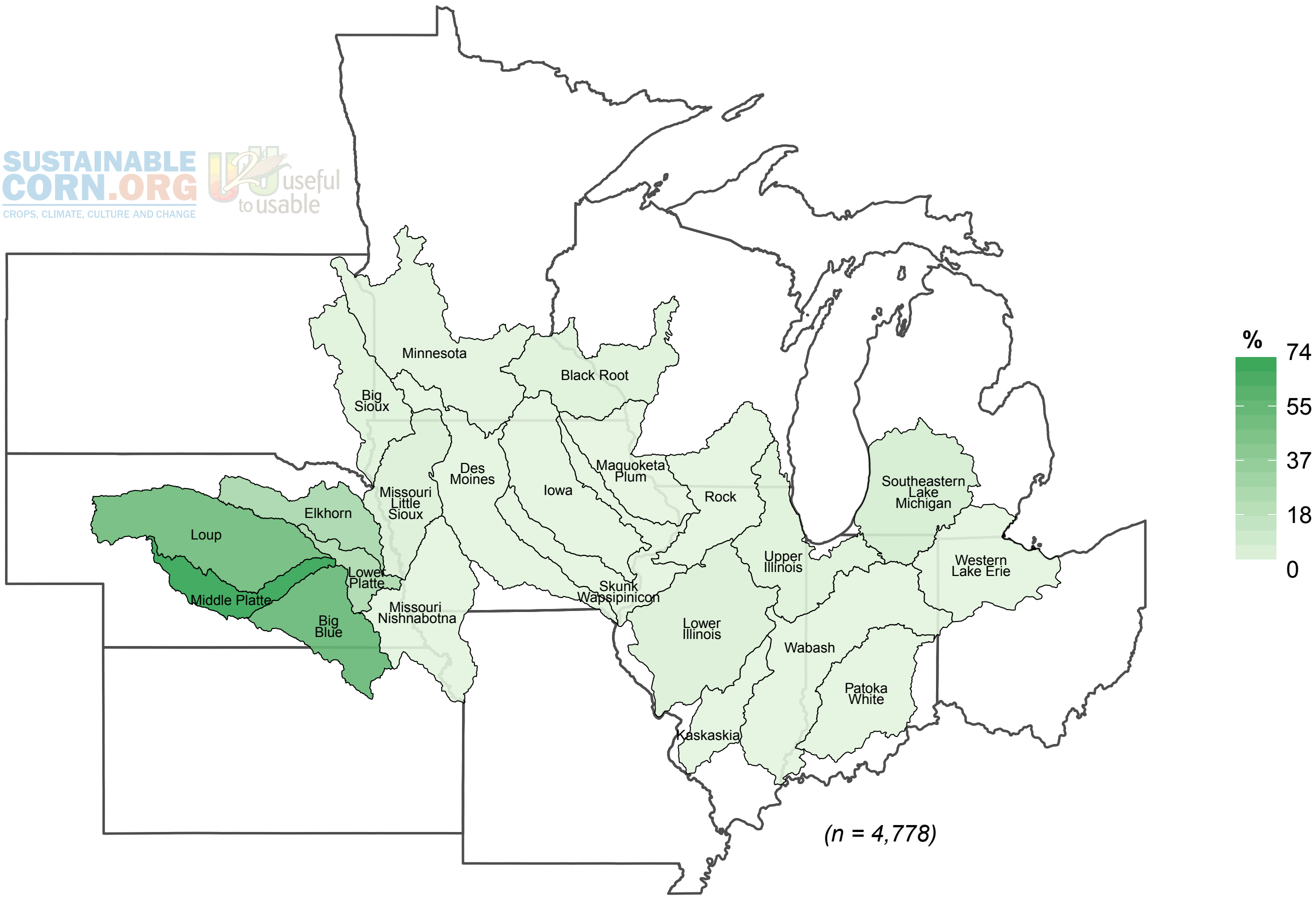

Map 56. In 2011, approximately what percentage of the rented land that you farmed was irrigated?

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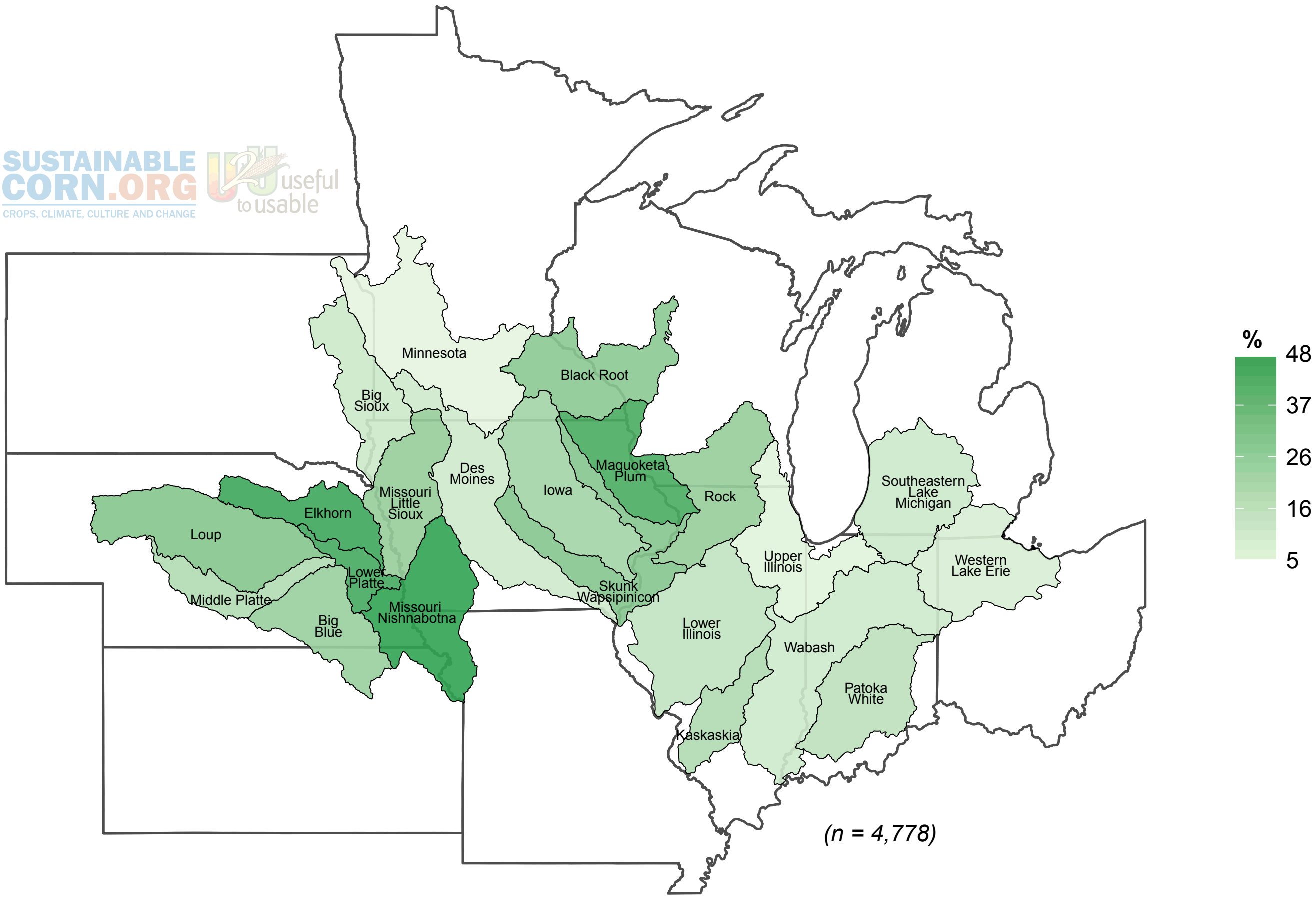

Map 57. In 2011, approximately what percentage of the <u>owned</u> land that you farmed was highly erodible land (HEL) that was planted to crops?

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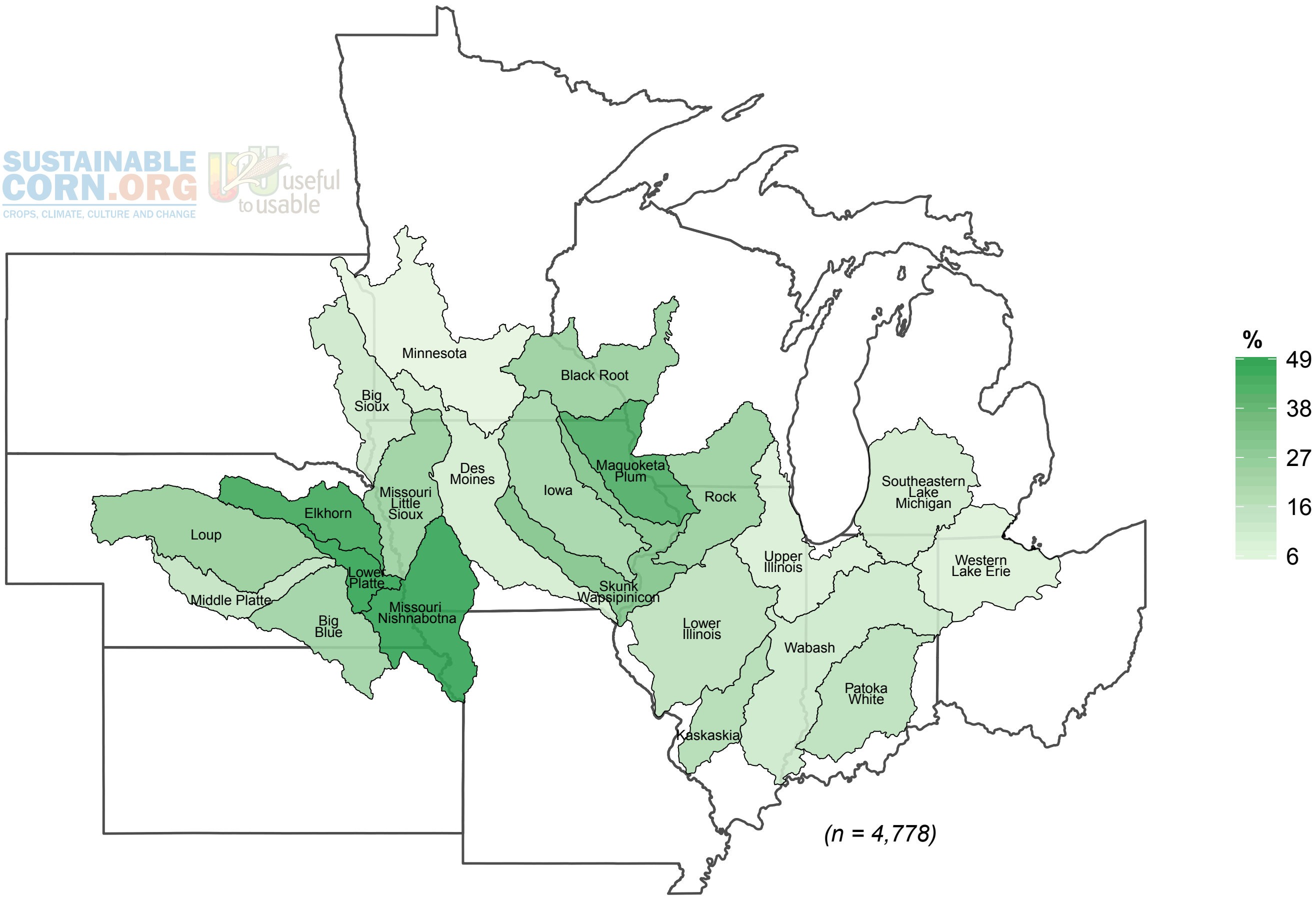

Map 58. In 2011, approximately what percentage of the rented land that you farmed was highly erodible land (HEL) that was planted to crops?

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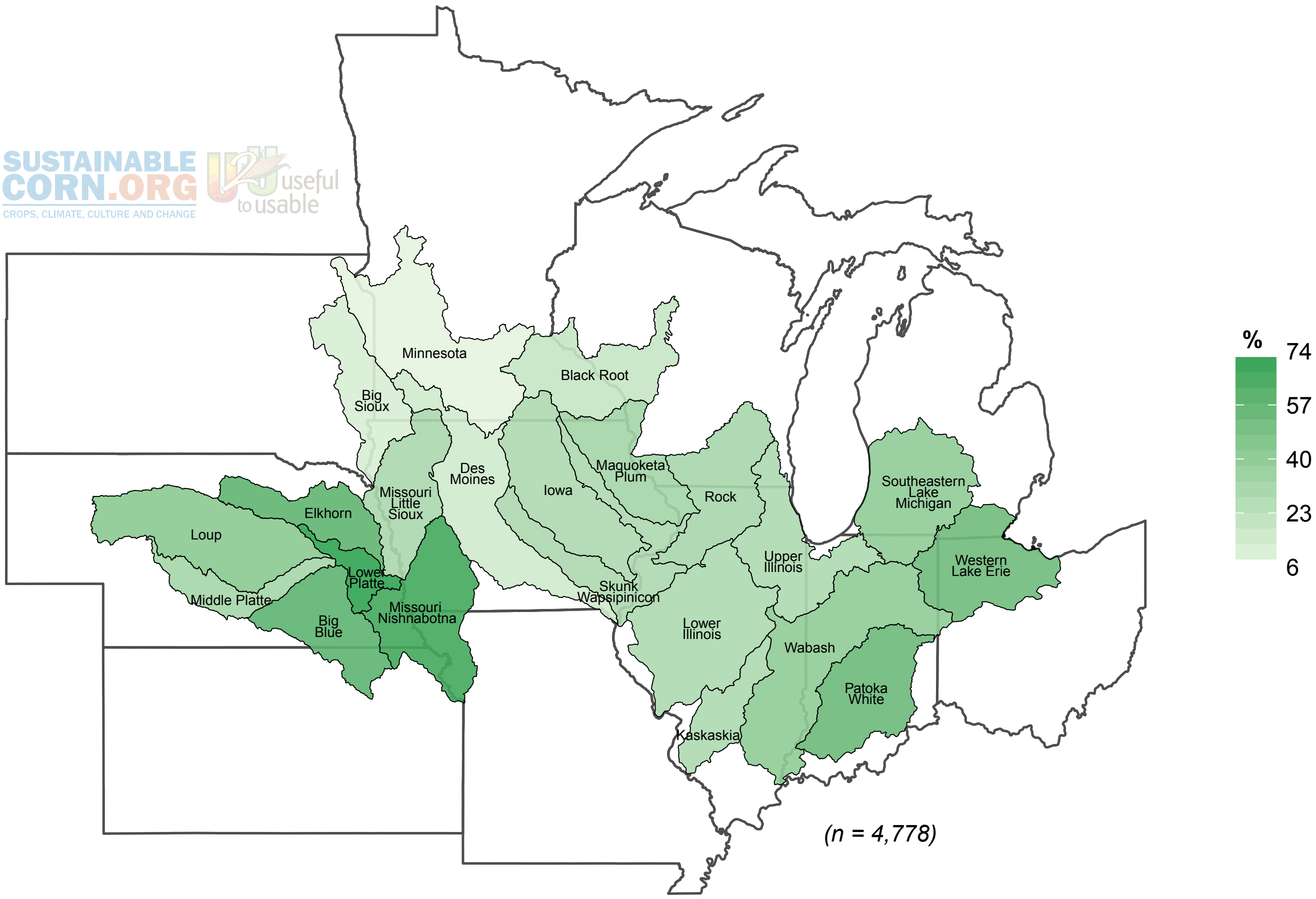

Map 59. In 2011, approximately what percentage of the <u>owned</u> land that you farmed was in no-till?

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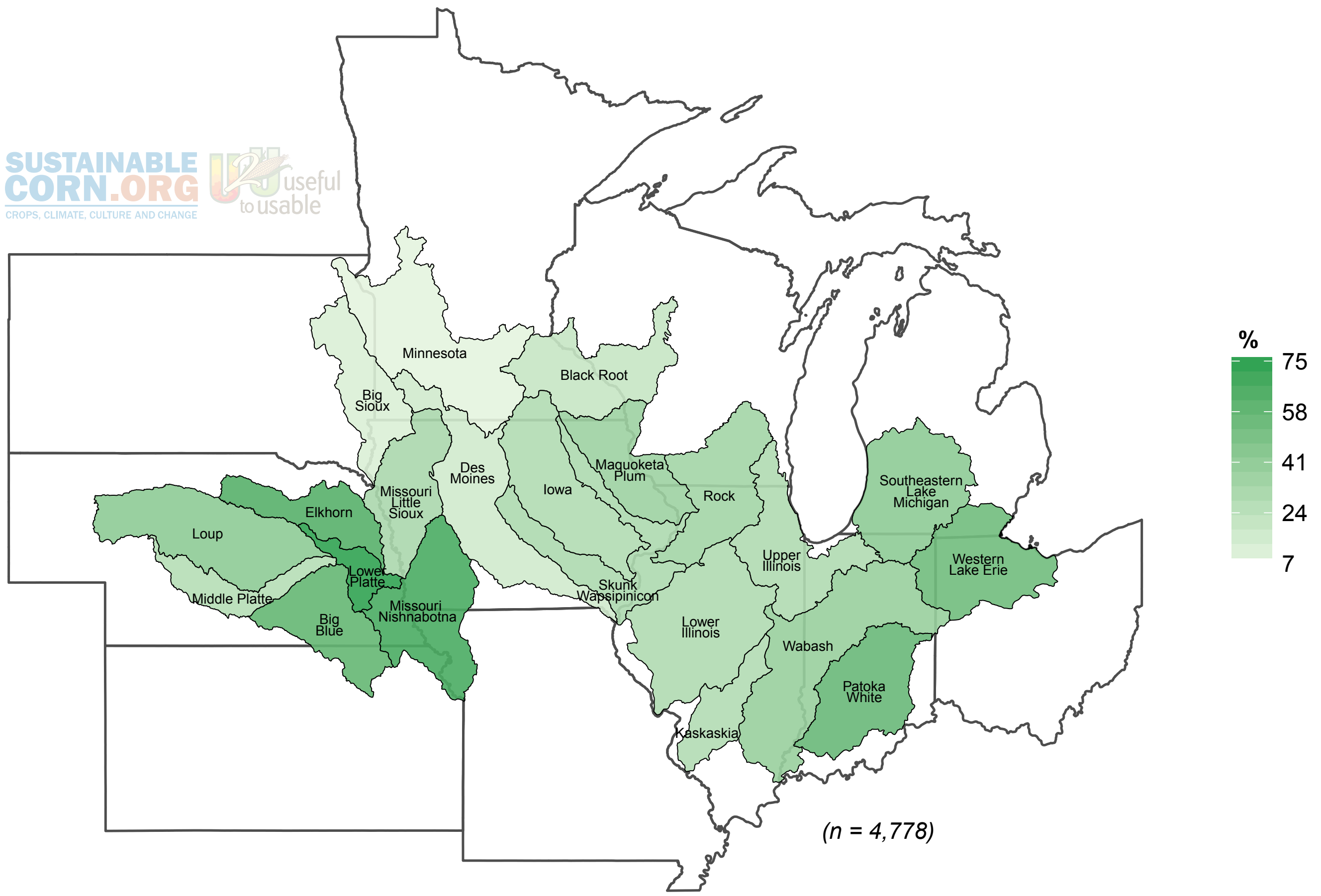

Map 60. In 2011, approximately what percentage of the rented land that you farmed was in no-till?

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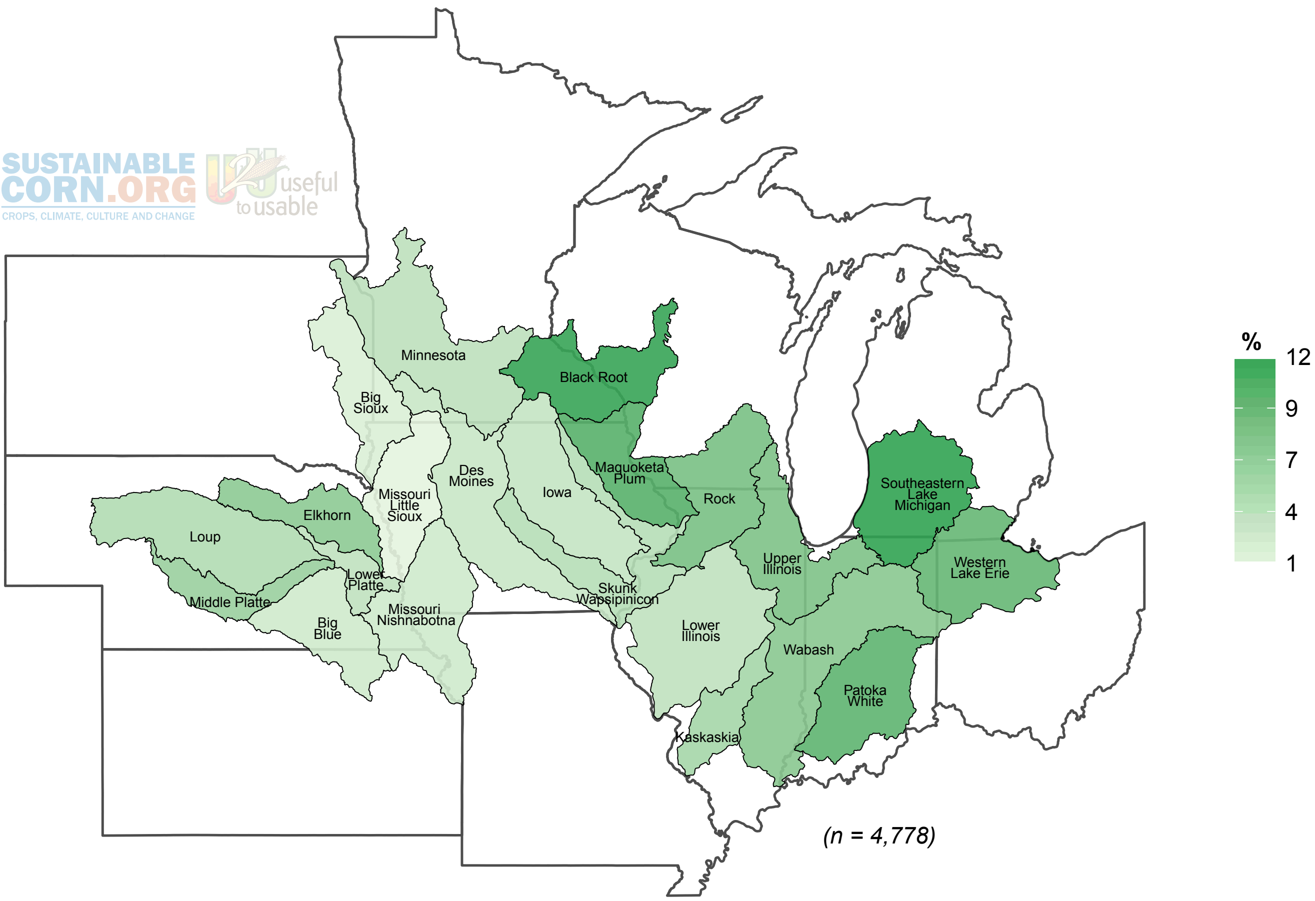

Map 61. In 2011, approximately what percentage of the owned land that you farmed was in cover crops?

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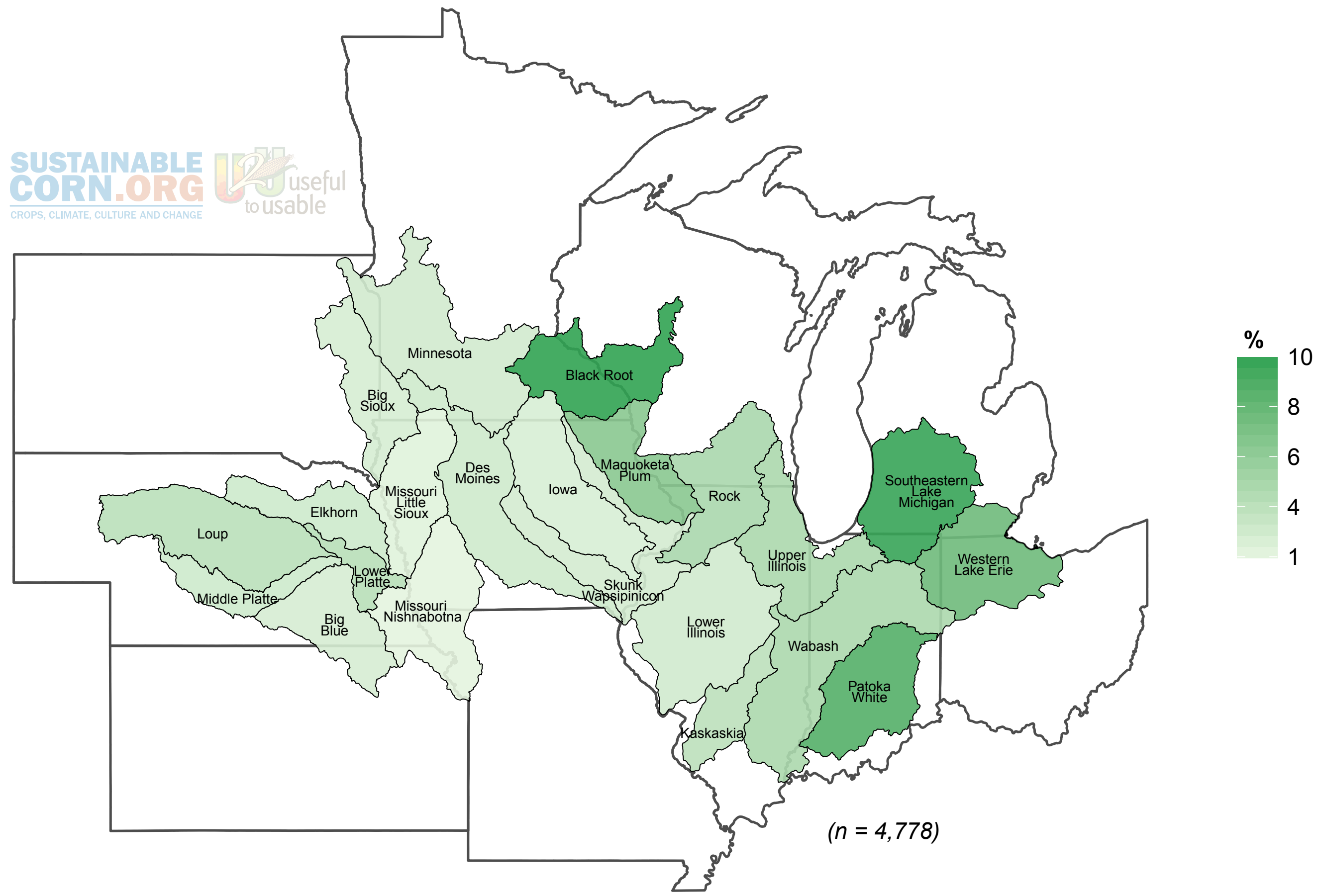

Map 62. In 2011, approximately what percentage of the rented land that you farmed was in cover crops?

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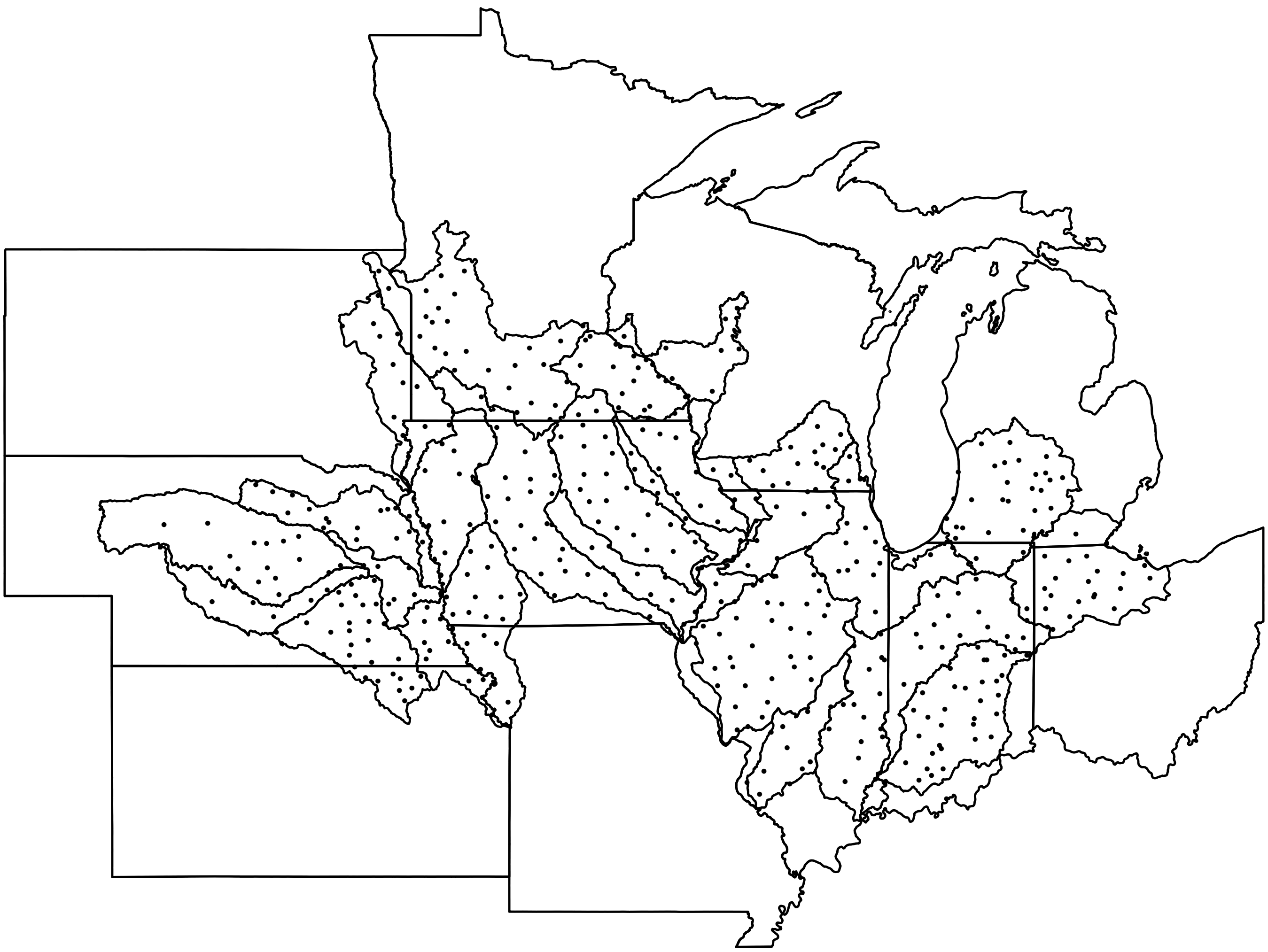
8 Weather

In this section weather variables that were constructed to supplement the survey data are presented. The construction of these weather variables is discussed, then summaries of these variables by watershed are presented.

Weather Variable Definitions

The weather variables were constructed from the National Weather Service (NWS) Cooperative Observer (COOP) data archive, which includes daily values of minimum temperature, maximum temperature, precipitation, and snowfall. The data archive constructed for the CSCAP-U2U survey includes all available data from January 1, 1971 through December 31, 2011. Data were downloaded from the Iowa Environmental Mesonet (http://mesonet.agron.iastate.edu/).



Map 63. Locations of the National Weather Service Cooperative Observer Network (NWS COOP) stations in the HUC6 watersheds included in the CSCAP-U2U survey.

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Several of the weather variables were based on station-specific percentiles computed from this historical record. Daily percentiles are month-specific; for example, the 99th percentile of daily precipitation for June was defined by combining all daily precipitation for June across all 41 years. Seasonal or monthly summaries (percentiles, means, standard deviations) were computed from the record of 41 seasonal or monthly totals.

Below we define the weather variables included in this report:

Seasonal Precipitation

Seasonal precipitation was computed as the total precipitation for April 1 through September 30. The empirical cumulative distribution (CDF), often based on 41 values for a station, was computed to yield a percentile rank for each year. The percentile rank for a year is a rank divided by the total number of years, or the percentage of years with as much or less precipitation than the chosen year. A value of 50% would indicate the median seasonal precipitation and that half of all years would have as much or less precipitation than the selected year. In this report, we include this median value and the average of these percentages for the five-year period from 2007-2011.

Daily Precipitation Extremes

Heavy precipitation events are counted as any days when the daily precipitation exceeded the 99th percentile of daily precipitation for a given month. The 99th percentile was defined separately for each station and each month. As an example, the 99th percentile for May precipitation is found by assembling all daily precipitation in May from 1971–2011 for a particular station. Then the 99th percentile of this empirical distribution of about 31x41=1271 values is found. We consider the proportion of days with precipitation exceeding the 99th percentile for the five-year period 2007–2011. Note that one would expect this to be about 0.01 by chance.

Cumulative Drought Index

The U.S. Drought Monitor (http://droughtmonitor.unl.edu/) is a subjective analysis of drought conditions produced weekly. Table 12 highlights the drought severity categories used in this product.

Table 12. Drought monitor categories

Category	Name	Possible Impacts
None		
D0	Abnormally dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered
D1	Moderate drought	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested
D2	Severe drought	Crop or pasture losses likely; water shortages common; water restrictions imposed
D3	Extreme drought	Major crop/pasture losses; widespread water shortages or restrictions
D4	Exceptional drought	Exceptional and widespread crop/pasture; losses; shortages of water in reservoirs, streams and wells creating water emergencies

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Since the Drought Monitor is produced weekly, the archive can be used to identify areas with prolonged drought conditions. To quantify long-term drought exposure, we constructed a variable $d_{i,t}$ defined for location i in week t, with

$$d_{i,t} = \begin{cases} 0 & \text{if location } i \text{ is not in a drought area in week } t \\ 1 & \text{if location } i \text{ is in D0 in week } t \\ 2 & \text{if location } i \text{ is in D1 in week } t \\ 3 & \text{if location } i \text{ is in D2 in week } t \\ 4 & \text{if location } i \text{ is in D3 in week } t \\ 5 & \text{if location } i \text{ is in D4 in week } t \end{cases}$$

This variable not only reflects whether a location is in drought conditions, but also takes on increasingly large values for more severe drought conditions.

To obtain watershed-level summaries, we took the median of the summed $d_{i,t}$ values over the last five years for each watershed. This cumulative drought index reflects both the length of drought conditions as well as the severity of prolonged drought conditions.

Aridity Index

The aridity index is a composite weather index that has been linked with crop yield. The index combines standardized precipitation and maximum temperature anomalies. Let $T_{i,j}$ be the average maximum temperature and $P_{i,j}$ be the total precipitation in month i of year j. Then $T'_{i,j}$ and $P'_{i,j}$ are the standardized maximum temperature and precipitation anomalies in month i and year j.

$$T'_{i,j} = \frac{T_{i,j} - \overline{T}_i}{s_{T,i}}$$

$$P'_{i,j} = \frac{P_{i,j} - \overline{P}_i}{s_{P,i}}$$

The aridity index is defined as the difference in the standardized anomalies

$$A_{i,j} = T'_{i,j} - P'_{i,j}$$

Thus, a hot and dry month will have a positive index value while a cool and wet month will have a negative index value.

Heat Stress Degree Days

Accumulated heat stress degree days (SDD) is one weather variable that characterizes the cumulative impact of hot weather. SDD are computed as the sum of maximum temperatures over some threshold, with 86°F (30°C)often used for corn. If $T_{m,t}$ is the maximum temperature on day t, the season SDD are

$$SDD = \sum_{t=1}^{n} I\,(T_{m,t} > 86)(T_{m,t} - 86)$$

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To characterize recent trends in heat stress, we compute a standardized SDD for each station i and year j

$$z_{i,j} = \frac{\mathrm{SDD}_{i,j} - \overline{x}_i}{s_i},$$

where $\overline{x}_i$ and s_i are the 41-year average and standard deviation at station i. In this report we consider the average of these standardized values over the last five years. To aggregate to the watershed-level, the median of this measure for all stations within a watershed was calculated.

Table 13. Median seasonal April to September precipitation from 1971–2011, percentile rank of seasonal precipitation from 2007–2011, and average percentage of extreme daily April to September precipitation for 2007–2011

Watershed (HUC6)	Median Seasonal Precipitation	Seasonal Precipitation Percentile Rank	Extreme Daily Precipitation Frequency
Loup	19.1	75.8	0.013
Middle Platte	17.8	81.2	0.015
Elkhorn	19.6	69.8	0.011
Big Blue	20.7	63.4	0.012
Lower Platte	20.2	67.1	0.011
Big Sioux	18.8	60.5	0.010
Missouri-Little Sioux	21.8	67.8	0.013
Missouri-Nishnabotna	24.1	67.5	0.011
Minnesota	20.1	46.3	0.010
Des Moines	23.6	65.4	0.015
Iowa	24.2	73.4	0.013
Black Root	23.0	52.7	0.011
Skunk Wapsipinicon	23.9	73.2	0.018
Maquoketa Plum	24.5	75.1	0.016
Lower Illinois	22.2	64.4	0.013
Rock	23.2	66.8	0.015
Kaskaskia	22.3	66.3	0.010
Upper Illinois	23.0	69.3	0.013
Wabash	23.4	63.4	0.011
Patoka-White	24.7	60.0	0.013
Southeastern Lake Michigan	20.7	66.1	0.013
Western Lake Erie	21.4	56.6	0.013

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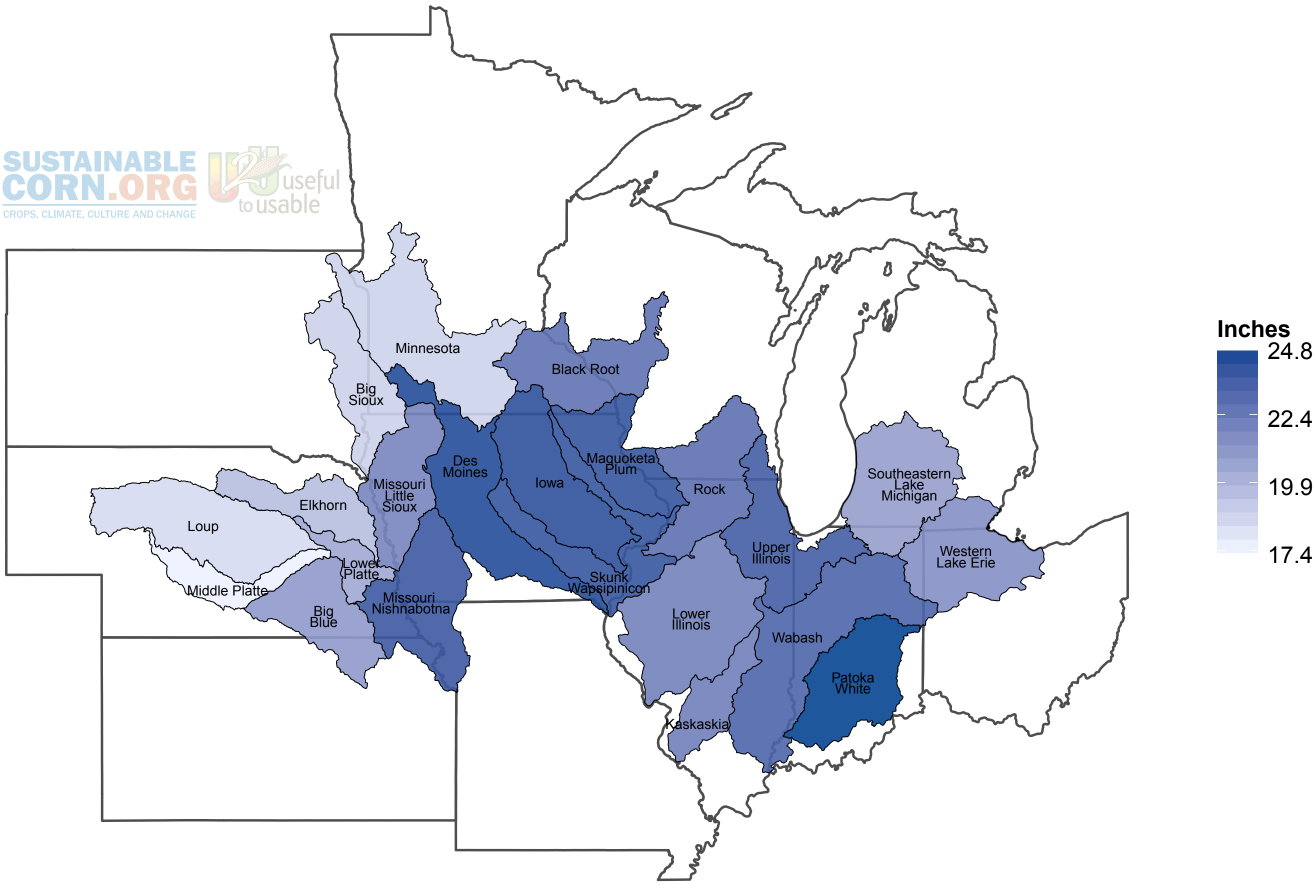

Map 64. Median total April to September precipitation from 1971–2011.

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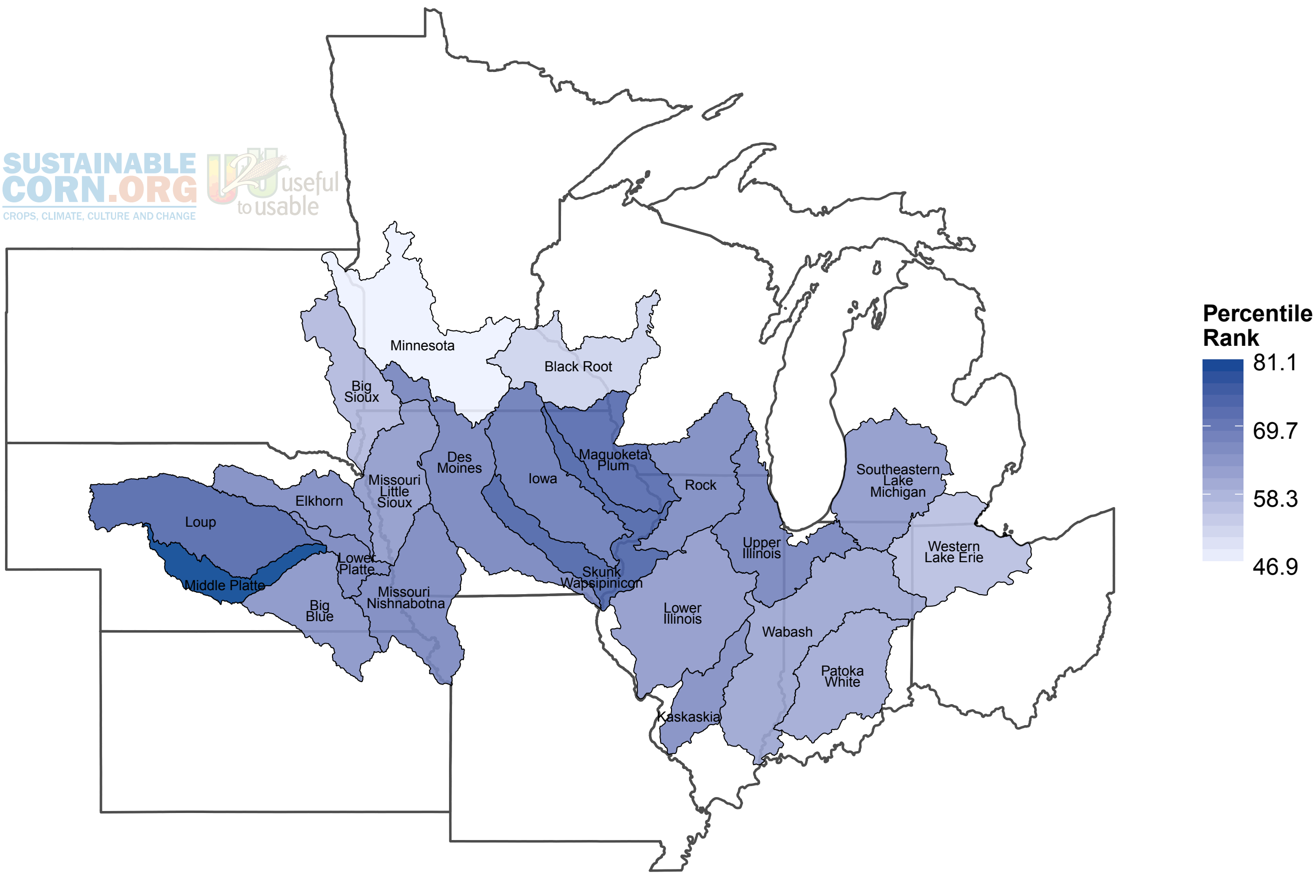

Map 65. Percentile rank of total April to September precipitation for 2007–2011 (compared to all data from 1971–2011).

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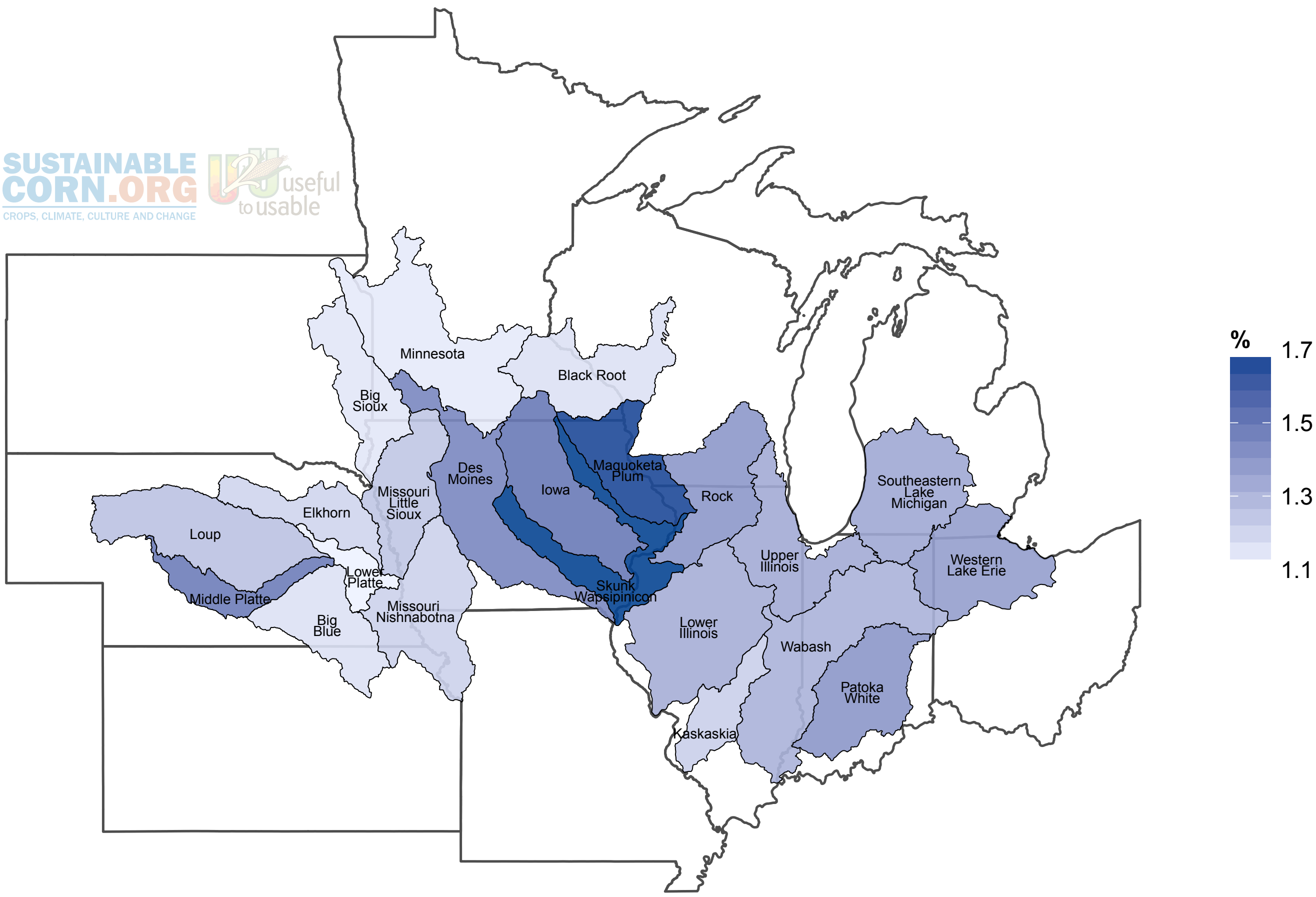

Map 66. Average percentage of extreme daily April to September precipitation from 2007–2011.

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Table 14. Median cumulative drought index, aridity index, and standardized annual heat stress degree days from 2007–2011

Watershed (HUC6)	Cumulative Drought Index	Average Aridity Index	Annual Heat Stress Degree Days
Loup	39	-0.74	-0.87
Middle Platte	40	-0.82	-0.89
Elkhorn	27	-0.56	-0.88
Big Blue	61	-0.55	-0.67
Lower Platte	57	-0.56	-0.79
Big Sioux	78	-0.43	-0.60
Missouri-Little Sioux	58	-0.42	-0.70
Missouri-Nishnabotna	35	-0.53	-0.59
Minnesota	121	-0.07	-0.42
Des Moines	48	-0.50	-0.61
Iowa	21	-0.52	-0.55
Black Root	160	-0.18	-0.32
Skunk Wapsipinicon	35	-0.48	-0.36
Maquoketa Plum	2	-0.52	-0.35
Lower Illinois	64	-0.24	-0.16
Rock	10	-0.26	-0.29
Kaskaskia	60	-0.10	0.20
Upper Illinois	11	-0.23	-0.19
Wabash	60	0.05	0.08
Patoka-White	108	0.13	0.36
Southeastern Lake Michigan	28	0.01	-0.08
Western Lake Erie	60	0.08	0.19

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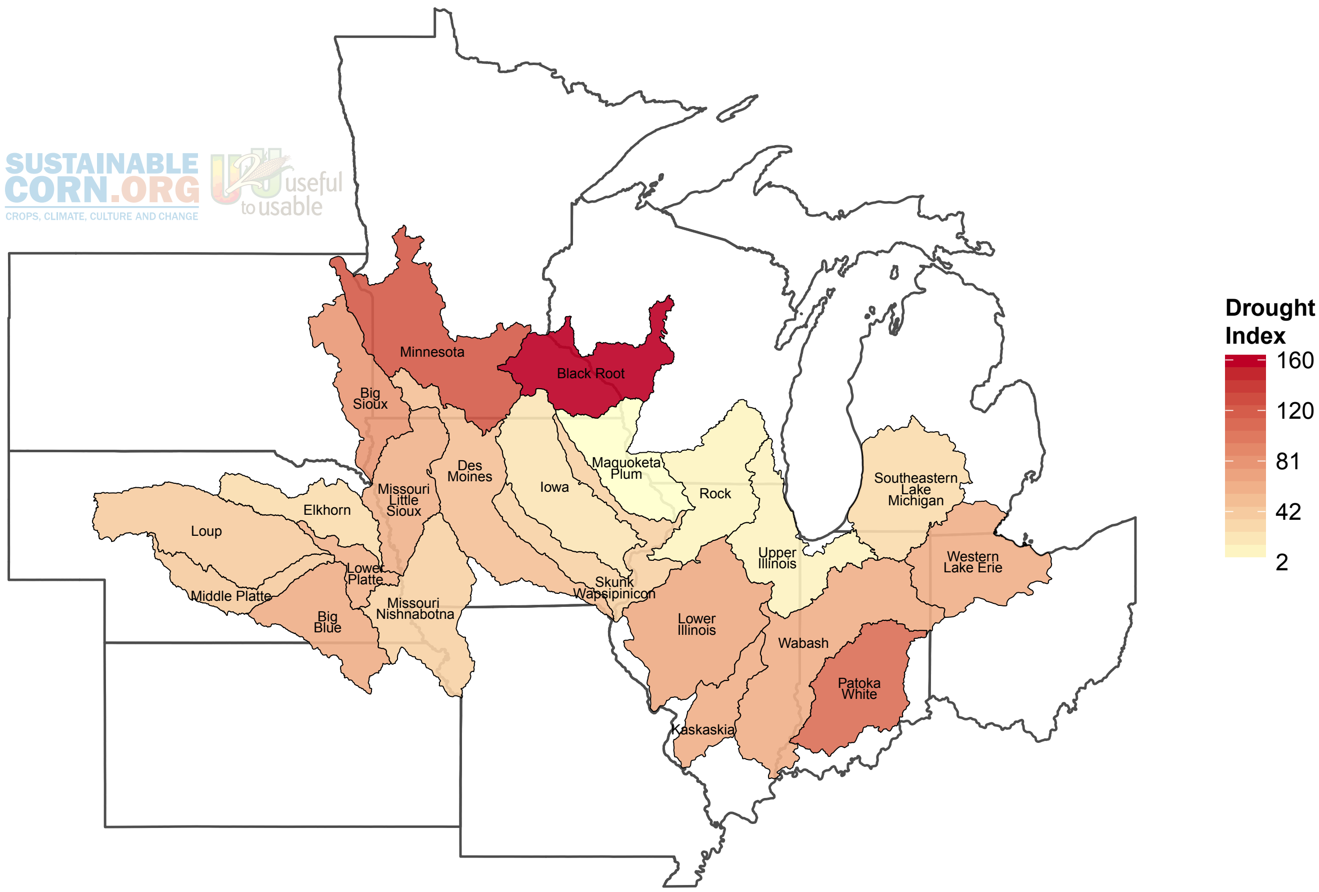

Map 67. Median cumulative drought index for 2007–2011.

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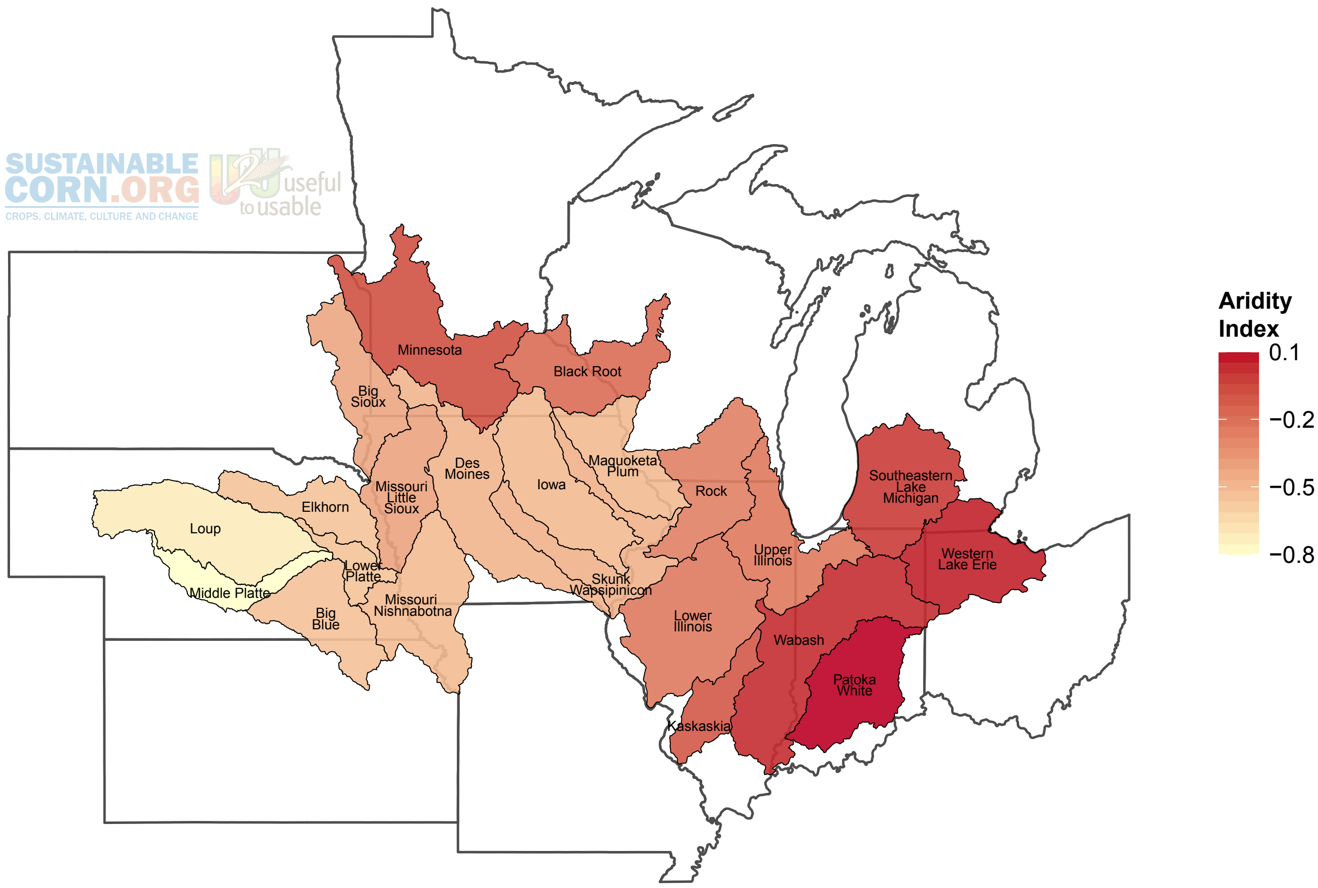

Map 68. Median aridity index for April to September from 2007–2011.

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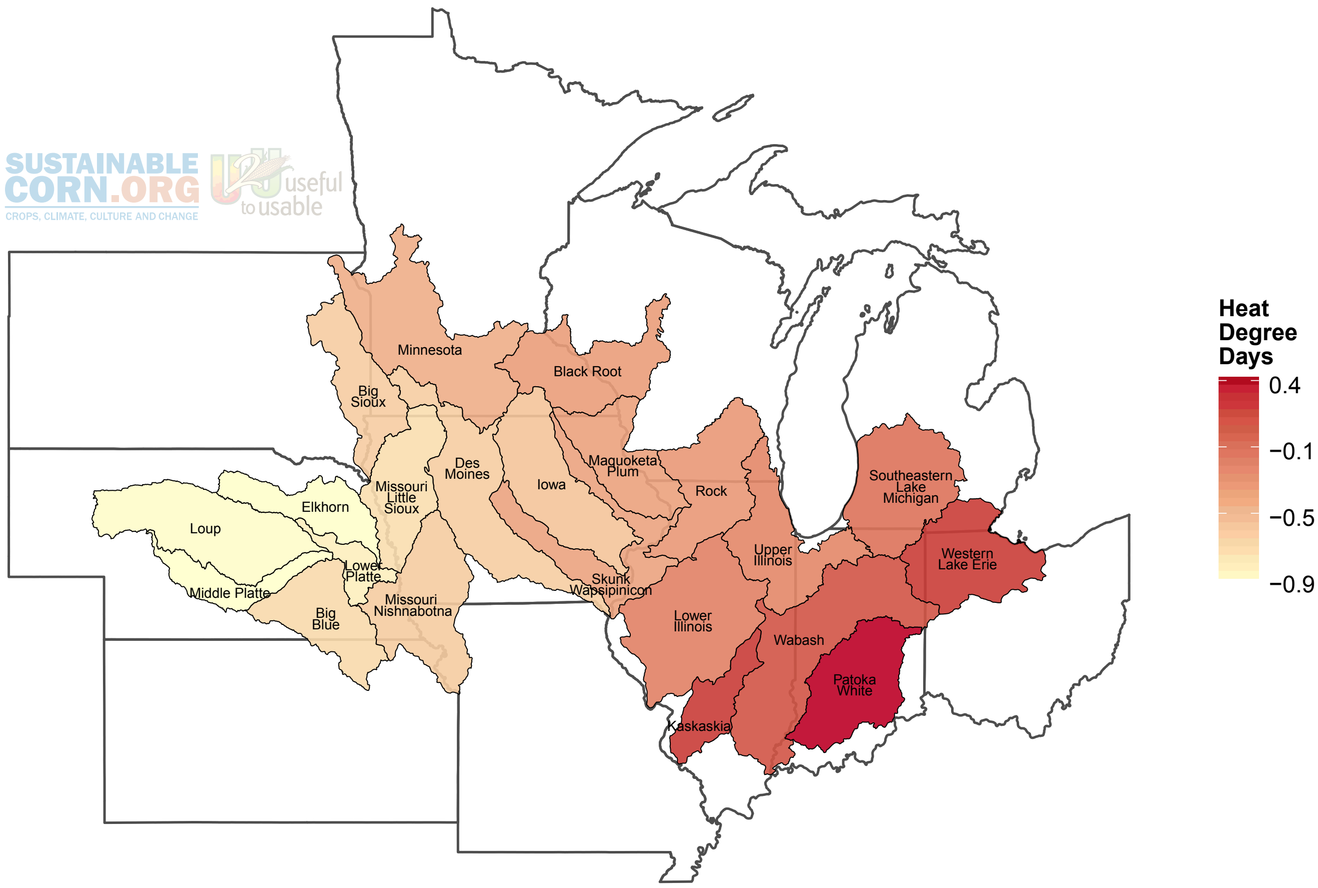

Map 69. Median standardized annual heat stress degree days from 2007–2011.

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9 Marginal Soils

The characteristics of soils affect their ability to grow crops to meet human needs for food, fiber, and fuels and their capacity to regulate the ecosystem (nutrient filtration, retention, and cycling; carbon retention and sequestration; and regulation of the water balance). The USDA Natural Resources Conservation Service (NRCS) has developed a land capability classification system (see Table 15) based on the land's ability to grow crops and pasture plants.

Map 60 shows the percent of non-irrigated marginal lands by county utilizing the NRCS soil capability classes 4–8. These are marginal lands with those soil classes having severe limitations which restrict type of plants and require very careful management for growing conditions (class 4) to limitations that preclude using the land for commercial plant production (class 8). Data for each county were obtained from the Soil Survey Geographic (SSURGO) database and the percent of marginal lands for each county was computed by summing the capability acreages for classes 4–8 for each county and creating a proportion of all acres in the county.

Table 15. Land capability classification and definitions. Source: U.S. Department of Agriculture, Natural Resources Conservation Service (2012)

Capability Classification	Definition
1	Soils have slight limitations that restrict their use.
2	Soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.
3	Soils have severe limitations that reduce the choice of plants or require special conservation practices, or both.
4	Soils have very severe limitations that restrict the choice of plants or require very careful management, or both.
5	Soils have little or no hazard of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
6	Soils have severe limitations that make them generally unsuited to cultivation and that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
7	Soils have very severe limitations that make them unsuited to cultivation and that restrict their use mainly to grazing, forestland, or wildlife.
8	Soils and miscellaneous areas have limitations that preclude their use for commercial plant production and limit their use to recreation, wildlife, or water supply or for aesthetic purposes.

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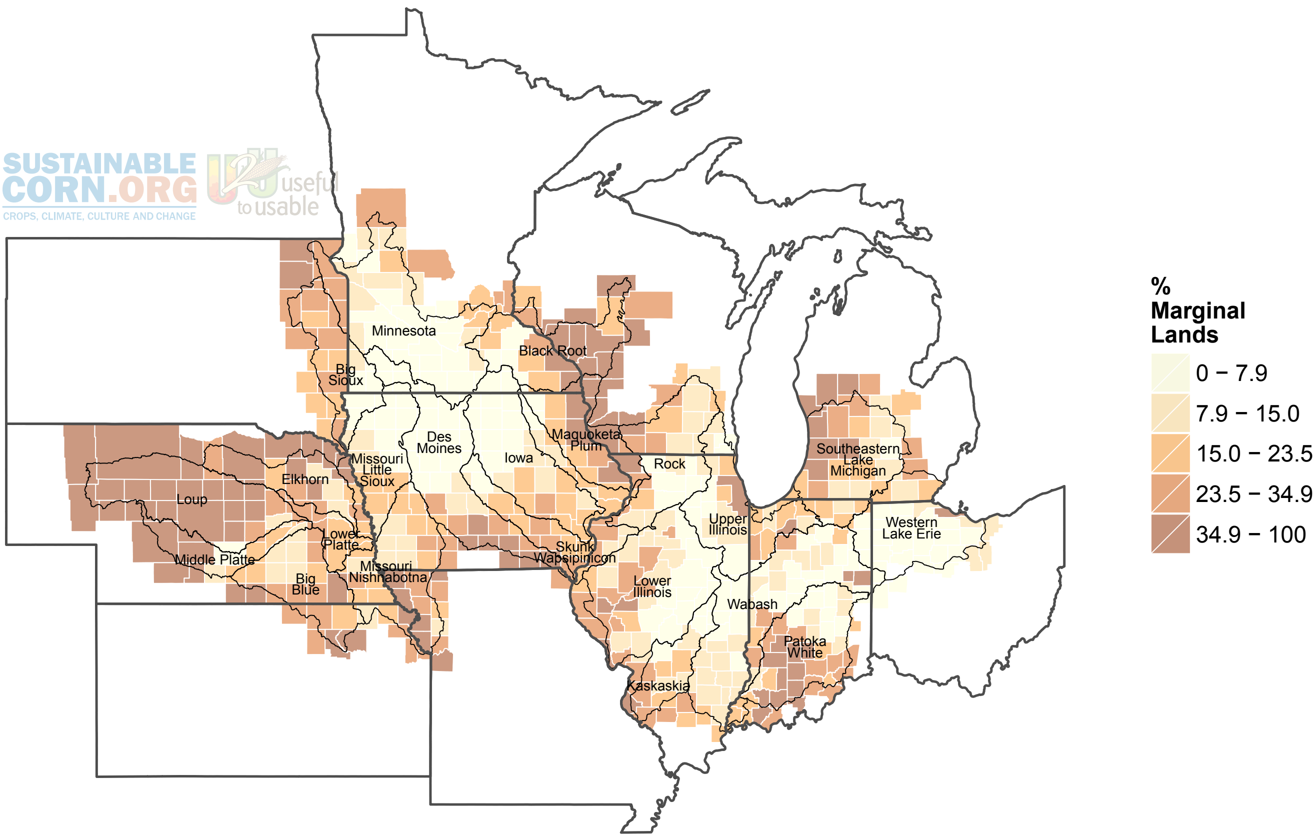

Map 70. Percentage of non-irrigated marginal lands (in soil capability classes 4–8), by county.

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Appendix A. Farmer Sample Selection

A.1 Background

This survey was a collaborative effort between the Climate and Corn-based Cropping Systems CAP (CSCAP) and the Useful-to-Usable (U2U) project. The original sampling plan for both the CSCAP and U2U projects called for state-level selection of random samples of farmers in several Corn Belt states. Once the project teams decided to pool resources, the possibility of using hydrological, ecological, or other criteria to stratify the Corn Belt study area was explored. We stratified by watershed because: 1) agricultural systems are influenced by ecological conditions that vary by hydrological unit; 2) the impacts of climate change are predicted to be in large part hydrological; and, 3) the National Agricultural Statistics Service (NASS) could sample by HUC6 watershed.

We limited our geographic scope to "major crop areas" for corn and soybeans as defined by the USDA (USDA 1994). Corn Belt counties that comprise the "major crop areas" for corn and soybeans span 25 HUC6 watersheds. These watersheds represent nearly 65 percent of all corn acres and 55 percent of soybean acres in the U.S.

A.2 Watershed selection

There are 25 HUC6 watersheds that comprise the area that USDA defines as "major crop areas" for corn and soybeans (USDA 1994). These watersheds cover some or all of 11 states:

Illinois	Missouri
Indiana	Nebraska
Iowa	Ohio
Kansas	South Dakota
Michigan	Wisconsin
Minnesota	

Initial calculations were conducted to determine the number of farms that must be surveyed in order to have a representative sample from which to generalize to the population of each watershed 1) at the 95% confidence level assuming a margin of error of 2.5% and 2) assuming a 40% response rate. It was estimated that approximately 900 farmers per watershed would need to be surveyed, depending on the population of farms within each watershed. Thus, the combined initial survey budget would cover only 16 watersheds. It was therefore necessary to develop decision criteria to determine which watersheds would be included/excluded. Between the two projects we were able to secure additional funding which allowed us to survey 22 watersheds.

Two main criteria were identified for determining watershed selection within the major crop areas:

(1) the proportion of total cropland that is planted to corn/soybeans within a HUC6 watershed; and

(2) the proportion of total cropland that is irrigated.

The 25 proposed HUC6 watersheds were ranked according to the two criteria. Fifteen watersheds were then selected: 1) the top ten watersheds based on corn/soybean production intensity, and 2) the top five watersheds based on irrigation acreage. All data on cropland and acreage were taken from the 2007 Census of Agriculture (NASS 2009).

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The top 15 watersheds, in ranked order by criteria are:

- Top ten by percent of cropland planted to corn and soy:
    1. 071300 — Lower Illinois
    2. 102300 — Missouri–Little Sioux
    3. 051201 — Wabash
    4. 071200 — Upper Illinois
    5. 070802 — Iowa
    6. 071402 — Kaskaskia
    7. 051202 — Patoka–White
    8. 070801 — Upper Mississippi Skunk Wapsipinicon
    9. 071000 — Des Moines
    10. 102002 — Lower Platte

- Top five by percent of cropland irrigated:
    11. 102001 — Middle Platte
    12. 102100 — Loup
    13. 102702 — Big Blue
    14. 102200 — Elkhorn
    15. 040500[1] — Southeastern Lake Michigan

[1]Because watershed 102002 was ranked 10th in corn and soy and 5th in irrigated acres, 040500 was selected as the fifth intensively irrigated watershed.

Selection of the next watersheds for inclusion followed a less rigid logic. Climatological, ecological, political, and other reasons were all considered and discussed, and decisions were made through team consensus. The following was the order proposed for inclusion of additional watersheds as funding became available.

- Next 10 watersheds by key selection criteria:
    16. 041000 — Western Lake Erie
    17. 070200 — Minnesota
    18. 070600 — Upper Mississippi Maquoketa Plum
    19. 102400 — Missouri–Nishnabotna
    20. 070900 — Rock
    21. 101702 — Big Sioux
    22. 070400 — Upper Mississippi Black Root

Detailed explanations of the ordering process were:

16. Watershed 041000 in Indiana, Michigan, and Ohio. This watershed was designated 16 because 1) it is the easternmost watershed and expands the east-west gradient substantially, 2) it is a critical

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watershed for the CSCAP project because watershed groups and research sites are located within it, and 3) it is a major crop production watershed (9th in the region in total corn and soybean acres).

17. Watershed 070200 in Iowa, Minnesota, and South Dakota. This watershed was included at 17 because 1) it is the northernmost watershed, expanding the north-south gradient substantially, 2) it comprises parts of two ecoregions that would otherwise not be covered sufficiently, and 3) it is a major crop production area (3rd in the region in total acres of corn and soybeans).

18. Watershed 070600 in Iowa, Illinois, Minnesota, and Wisconsin. This watershed was included at 18 because 1) it contains a unique ecological zone, the driftless area, 2) it is a critical watershed for the CSCAP project because watershed groups and are located within it, 3) it is a priority area for Iowa NRCS, and 4) it has substantial corn and soybean acreage (18th in total acres).

19. Watershed 102400 in Iowa, Kansas, Missouri, and Nebraska. This watershed was included at 19 because 1) it contains a unique ecological zone, the loess hills area, which is ecologically sensitive/ highly erosive, 2) it is a priority area for Iowa NRCS, and 3) it has substantial corn and soybean acreage (6th in total acres).

20. Watershed 070900 in Illinois, Wisconsin. This watershed was included at 20 because 1) it contains an ecological zone that would not otherwise be represented, 2) it stretches the north-south gradient in the center of the Corn Belt, and 3) it has substantial corn and soybean acreage (10th in total acres).

21. Watershed 101702 in Iowa, Minnesota, Nebraska, and South Dakota. This watershed was included at 21 because 1) it extends the northwestern boundary of our survey zone, 2) it expands coverage of an ecoregion that is present in only one other watershed, and 3) it may be the site of a watershed group.

22. Watershed 070400 in Minnesota, Wisconsin. This watershed was included at 22 because 1) it contains a major portion of the driftless ecological zone, 2) it stretches the north gradient toward the center of the Corn Belt, and 3) it may be the site of a watershed group.

The 22 watersheds are represented in Map 71.

A.3 Farmer sample selection

The potential sample frame was the population of farmers in the study area. The sample was drawn from the National Agricultural Statistics Service (NASS) “Master List,” which is the most comprehensive and up-to-date list of U.S. farmers available.

The USDA defines a farm as “as any place from which $1,000 or more of agricultural products (crops and livestock) were sold or normally would have been sold during the year under consideration” (Hoppe and Banker 2010, 1). This low revenue threshold necessitates inclusion of “farms” that do not contribute substantial amounts of income (if any) to household income nor do they produce a significant percentage of grain. For example, farms categorized as retirement and residential/lifestyle represent 18.4 and 45.1 percent of farms, respectively, yet together produce only 5.8 percent of overall sales. Further, 98 percent of farms in these two categories on average generate less than $100,000 in gross sales annually (Hoppe and Banker 2010, 8). A simple random sample of the overall farm population would be largely comprised of retirement and residential/lifestyle farmers and would not be representative of the farms that produce the bulk of the U.S. grain crop.

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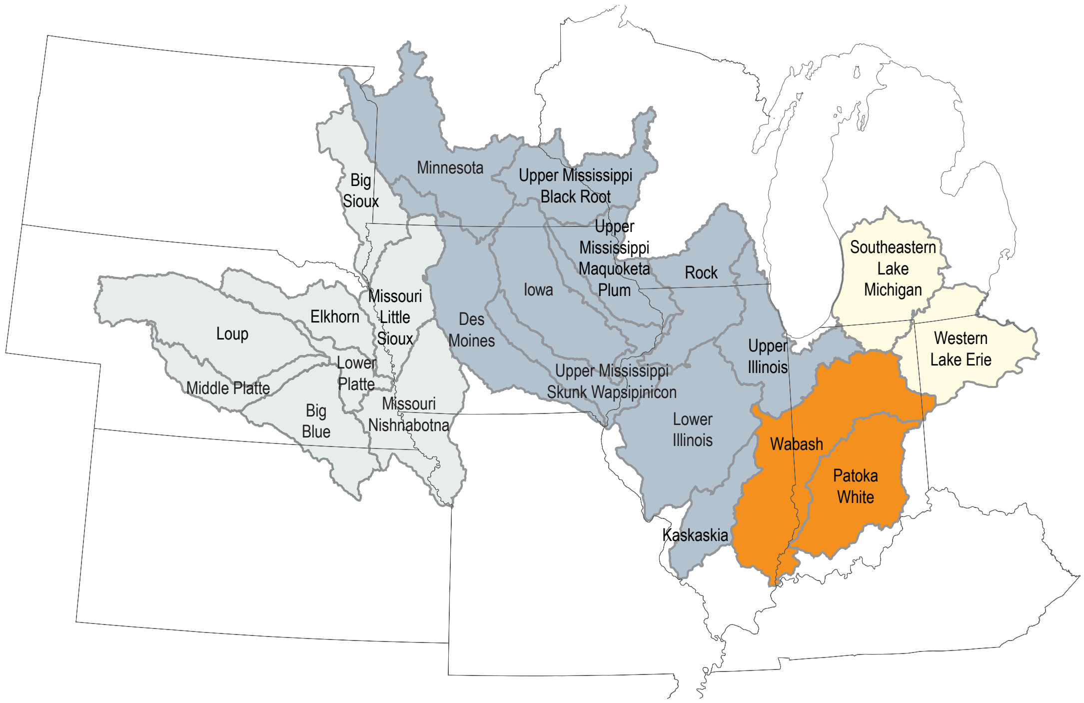

Map 71. Study watersheds.

Thus the challenge that the project faced was to define the population of farmers of interest. Given that our project focuses on long-term sustainability of corn (and soybean) production, our sampling approach is designed to allow us to generalize to farmers who produce a substantial proportion of corn (and soybean) acres in the Corn Belt.

A.4 Farmer selection criteria

The primary selection criteria were 1) farm size and, 2) amount of corn production.

To ensure that our sample was representative of farmers who produce substantial amounts of corn, the following thresholds were used to select farmers into the sample frame:

1) A Calculated Farm Value Sales of $100,000 or more, which would capture medium-sales farms and above. While these farms represent fewer than 17 percent of all farms nationally, they generate of 90 percent of overall value of sales (Hoppe and Banker 2010, 8).

2) A minimum of 80 acres of corn production. Setting 80 acres as the minimum threshold will ensure that the farmers in the sample produce a substantial amount of corn.

The NASS master list sampling frame was used to identify operations in the 11 states that met these two criteria. There were a total of 103,126 farms within the 22-watershed sample area (Map 71) that meet these two criteria. The number of farms that met the criteria within each watershed ranged from 1,454 to 8,881 and those farms represented between 11 percent and 44 percent of the total number of farms in the watersheds (Table 16). Calculations were conducted to determine the number of farms that must be surveyed in order to have a representative sample from which to generalize to the population of each watershed 1) at the 95% confidence level assuming a margin of error of 2.5% and 2) assuming

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Table 16. Sample size context and calculation

	HUC 6 Watershed	States	Farms in major crop area watersheds	Corn farms > $100K/ 80ac corn	Sample pop as percentage of all farms	Mailed (eligible)	Returned	Percent Response
1	071300	IL	22,862	7,955	35%	895	244	27.3%
2	102300	IA MN NE	12,571	5,341	42%	892	223	25.0%
3	051201	IL IN OH	31,868	7,899	25%	875	239	27.3
4	071200	IL IN WI	13,622	3,578	26%	837	234	28.0%
5	070802	IA MN	23,063	7,686	33%	895	248	27.7%
6	071402	IL	9,508	2,378	25%	801	197	24.6%
7	051202	IN	19,264	3,048	16%	804	201	25.0%
8	070801	IA IL MN	17,386	5,652	33%	880	233	26.5%
9	071000	IA MN	22,112	7,444	34%	890	259	29.1%
10	102002	NE	4,689	1,454	31%	753	161	21.4%
11	102001	NE	3,722	1,539	41%	760	151	19.9%
12	102100	NE	5,862	1,954	33%	795	154	19.4%
13	102702	KS NE	9,929	4,136	42%	877	185	21.%
14	102200	NE	6,693	2,923	44%	846	164	19.4%
15	040500	IN MI	26,079	2,986	11%	794	231	29.1%
16	041000	IN MI OH	25,857	4,698	18%	861	254	29.5%
17	070200	IA MN SD	23,520	8,881	38%	896	237	26.5%
18	070600	IA IL MN WI	17,301	4,688	27%	874	255	29.2%
19	102400	IA KS MO NE	19,223	5,558	29%	887	224	25.3%
20	070900	IL WI	21,737	5,040	23%	877	259	29.5%
21	101702	IA MN NE SD	10,652	4,230	40%	850	183	21.5%
22	070400	MN WI	20,509	4,058	20%	868	242	27.9%
		Totals	395,461	103,126	33%	18,707	4,778	25.5%

a 40% response rate. It was estimated that an average of approximately 875 farmers per watershed would need to be surveyed. A random sample of farmers was drawn from each watershed.

Once the stratified sample was drawn, the list was crosschecked with a NASS "do not contact" list. It was determined that some names were on that list, and these were removed from the sample. The survey was mailed to 18,813 farmers. A total of 106 of those were deemed ineligible, for a final sample size of 18,707.

A.5 Response rate and non-response bias analysis

Of the 18,707 selected farmers, 4,778 responded to the survey resulting in an overall unweighted response rate of 26%. To facilitate tests for non-response bias, NASS provided data for 28 variables measuring farm enterprise (e.g., farm size, crops and livestock produced) and farmer (e.g., age, sex)

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characteristics for both respondents and non-respondents. Statistical tests at the watershed level detected no meaningful differences between respondents and non-respondents, indicating that our sample is representative of the target population and statistics calculated for respondents will lead to unbiased estimates of the population parameters of interest.

A.6 Sampling weights

Because our random sample of farmers is stratified by watershed, it was necessary to assess potential differences in response probability between watersheds prior to calculating statistics for the region as a whole. Response rates differed between watersheds, ranging from 19% to 29%. In addition, selection probabilities within each watershed differed due to variation in the ratio of the sample size drawn to the overall population of farmers in each watershed. Because watershed-level sample sizes were calculated to assure generalizability at the 95% confidence level with a margin of error of 2.5%, selection probability ranged from 10% (sample size of 923 out of 8881 farmers) to 52% (sample size of 763 out of 1454 farmers). Thus, it was necessary to calculate sampling weights that account for differences in both probability of selection and response at the watershed level by

$$w_{i,h} = \frac{1/n_h^*}{1/N_h} = \frac{N_h}{n_h^*} \tag{1}$$

where N_h is the population size of watershed h, and is the number of respondents in watershed h. The resulting weights are applied in the regional-level analyses that are discussed by Arbuckle et al. (2013).

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