MIDWEST CLIMATE AND SPECIALTY CROPS

Specialty crop leader views and priorities for Midwest Specialty Crops

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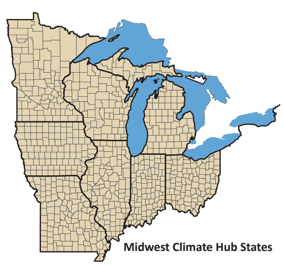

This research, North Central Fruit, Vegetable and Wine Growers' Assessment of Soil and Water Vulnerability Under Changing Climate Conditions and Extreme Weather Events funded by USDA-Agricultural Research Service (ARS) Midwest Climate Hub.

Midwest Climate and Specialty Crops
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Executive Summary

Specialty crop agriculture in the Midwest is an important and diverse industry, valued at $4.7 billion in 2012. The Midwest produces a wide variety of specialty crops including fruits, vegetables, greenhouse and nursery crops. The 2014 United States (US) Third National Climate Assessment reports that climate disruptions to agriculture have been increasing, and are projected to become more frequent and extreme. Increased variability in annual and intra-seasonal Midwest weather is already evident with heavier rainfall events and drought. Temperature and precipitation fluctuations are affecting frost dates, weed management, soil erosion, crop productivity, and pest and disease life cycles. This variability increases the uncertainty and risks associated with planting schedules, quantity and quality of crops harvested, timing of labor needs, and the entire value chain from product storage and processing to marketing.

While US agriculture has continually adapted to changing weather and climate conditions, the magnitude of future change is expected to pose increased challenges and new opportunities. The USDA-Agricultural Research Service (ARS) Midwest Climate Hub was established in 2014 to assemble research on climate, Midwest production systems, and soil and water resource vulnerabilities. This science-based information provides the foundation for development of decision support tools and information resources to assist farmers, crop advisors and other land managers. The Midwest Climate Hub is also engaged in building collaborative public and private partnerships to increase climate resilient systems of agriculture.

To develop a plan of work that responds to Midwest specialty crop needs, the Midwest Climate Hub, Michigan State University and The Ohio State University experiment station directors invited specialty crop leaders from Michigan and Ohio to share their views on the challenges and opportunities of climate change and to identify priority areas for programming. At an October 2014 meeting in Toledo, Ohio twenty-five specialty crop leaders, research and extension faculty from Michigan State University and The Ohio State University participated in a planning process using a concept mapping methodology. This core group identified 85 key issues associated with climate and their production systems by completing the statement: "One way a changing climate and extreme weather events affect fruit, vegetable and other specialty crop production in the upper Midwest is…" These statements were then rated for importance and grouped according to similarities. An additional 104 specialty crop growers were invited to rate and sort these statements into related groupings with 50 responses total (39% response rate) and 44 completed responses used in this analysis.

Multi-dimensional scaling and hierarchical cluster analysis produced a spatial map of the 85 statements and their importance ratings. Nine priority areas representing specialty crop leader views and priorities are presented below in ranked order:

1. Pest and disease;
2. Marketing and risk;
3. Water;
4. Climate and weather;
5. Farming as a livelihood;
6. Labor;
7. Changes in operations;
8. Changing opportunities and vulnerabilities; and
9. Production-consumer-research nexus.

These nine priority areas will be used by the Midwest Climate Hub and partners as a framework for developing decision support tools, extension and outreach efforts, research, and development of additional resources to strengthen the climate resilience of the specialty crop industry. These findings represent a snapshot of the views of Michigan and Ohio specialty crop leaders on these issues. It is recognized that specialty crops are grown in all Midwestern states and more information on growers and their value chain throughout the region is needed. Further, to achieve the shared goal of a climate resilient Midwest agricultural landscape with healthy soil and water resources will require strong institutional relationships and partnerships. This is just a beginning.

Next steps:

- Development of a stratified random sample survey of Midwest specialty crop growers to assess current practices; experiences, concerns, and risks associated with a variable climate; and resource needs to meet challenges and opportunities.
- Strengthen and build university and industry partnerships and institutional relationships to improve the resilience of Midwest production systems while protecting the integrity of soil and water resources.
- Utilize the nine priority areas identified by specialty crop leaders to develop a Midwest Climate Hub region-wide plan of work to frame action items, guide programming, and target investments.

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Midwest Climate and Specialty Crops
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Midwest agriculture and a changing climate

The Midwest is a region of intensive and diverse agriculture that includes corn-soybean, specialty crops, forage and grasslands, forests, and animal production systems. Almost 32 million acres, or 25% of Midwest cropland, is used to produce alfalfa, oats, tobacco, wheat, and a wide variety of annual and perennial specialty crops. In 2012, eight states in the Midwest region harvested approximately 850,000 acres of vegetables, 166,000 acres of orchards, and 344,000 acres of dry beans. During that same period, the value of specialty crops sold in the Midwest was $4.7 billion (e.g. vegetables, melons, potatoes, sweet potatoes, fruits, tree nuts, berries, nursery crops, greenhouse crops, floriculture, sod, cut Christmas trees, short rotation woody crops, and maple syrup).

Climate disruptions to agriculture have been increasing and are projected to become more frequent and extreme in this century. The Third National Climate Assessment (Hatfield et al. 2014) documents several key findings that are currently and in the future likely to affect the specialty crop industry in the Midwest. Climate induced changes are expected to lead to increased weed, disease, and insect pest pressures and to affect crop management decisions and productivity. Further, increasing extremes in precipitation are accelerating loss and degradation of critical soil and water resources and are challenging producers working in both rain-fed and irrigated agricultural systems to put in place innovative conservation strategies. Extreme weather events and a highly variable climate can lead to unexpected intra-seasonal variability in the timing of frost and temperatures at pollination as well as extremes in precipitation and water availability, which increase the risks and vulnerabilities associated with specialty crop production. Too much rain can lead to flooding, soil erosion, and off-field, off-farm losses of nitrogen, phosphorus and other nutrients, thereby affecting water quality. Additional moisture and humidity also create ideal conditions for increased weed, disease and insect stresses.

The term "specialty crop" is defined in law as "fruits and vegetables, tree nuts, dried fruits, and horticulture and nursery crops (including floriculture)" (7 U.S.C. 1621). Midwestern U.S. specialty crops include apples, asparagus, green beans, blueberries, cabbage, carrots, sweet and tart cherries, cranberries, cucumbers, Christmas trees, grapes, greenhouse crops, nursery crops, onions, peaches, plums, peas, bell peppers, potatoes, pumpkins, raspberries, strawberries, sweet corn, tomatoes, tree nuts, and watermelon.

Too little precipitation can increase wind erosion of the soil, decrease soil moisture, and limit plant growth and the quality and quantity of fruit and vegetables. Thus, climate variability and uncertainty not only put agroecosystems, livelihoods and food security at risk but also the entire value chain of crop production, storage, transportation, processing, and marketing.

In the past, the U.S. agricultural sector has continually adapted to changing weather and climate conditions using a variety of strategies to assure continued growth and efficiency in production (Walthall et al. 2013). However, the magnitude of change projected is expected to challenge agriculture, including specialty crop growers, to successfully adapt. Agriculture is a major player in the Midwest's economy, with over $74 billion in crop sales from eight Midwestern States in 2012 including nearly $5 billion of specialty crop sales. There is great concern as to how climate change is affecting U.S. agricultural production systems and what resources can be mobilized to address this complex issue. In 2014, the U.S. Department of Agriculture (USDA) established seven climate "hubs" to address the regional impacts of a variable climate on agriculture and forestry. The Midwest Climate Hub, representing the states of Indiana, Illinois, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin is tasked with the assembly of research on climate and 1) Midwest production systems 2) soil and water resource vulnerabilities and 3) the identification of adaptation tools and information that will increase climate resilience of agricultural systems. Although there have been research investments on the impact of a changing climate on corn-soybean row crop production, the implications for specialty crop production systems are relatively unstudied. In developing the plan of work for the Midwest Climate Hub, the leadership recognized a lack of knowledge about Midwestern specialty crops, including grower perceptions of how climate change is impacting their production, challenges for processing and marketing systems, current adaptation strategies, and resources needed to prepare for future risks and opportunities.

A collaborative partnership was initiated in 2014 with the directors of the experiment stations at Michigan State University and The Ohio State University to begin a preliminary exploration to better understand the challenges and concerns of specialty crop growers in the region. The directors of the experiment stations and their staff identified a number of key leaders and researchers in the specialty crop industries of Michigan and Ohio. These individuals were invited to Toledo, Ohio in October 2014 to talk about changes in weather and climate, how these shifts were affecting them, and their perceptions and expectations of future challenges. This report details the processes used to gather preliminary data, identifies priority areas, and provides recommendations for the Midwest Climate Hub plan of work to support the specialty crop industry.

Concept mapping as a planning tool

In 2014, the USDA Agricultural Research Service (ARS) Midwest Climate Hub began the process of assessing specialty crop growers' perceived risks, opportunities and challenges associated with managing production systems and soil and water resources under increasing extreme weather events and changing climate patterns. The development of the plan of work for the Midwest Climate Hub is based in:

1) Assessments of social, economic, and biogeophysical data and syntheses of literature,

2) Development of partnerships and leadership among regional land grant universities (LGU) research and extension to strengthen current and increase future responsiveness to agricultural industry issues associated with productivity and soil and water management, and

3) Institutionalization of iterative exchanges and feedback loops among ARS, LGU, and the fruit, vegetable and specialty crop industries to increase agroecosystem climate resilience under changing conditions in ways that increase capacities to grow these North Central region industries while assuring long-term sustainability of soil and water resources.

A first step was to convene LGU and specialty crop leaders to discuss challenges and opportunities and use the planning tool of concept mapping as an analytic participatory process to identify challenges and concerns of specialty crop growers. The concept mapping process produced key themes and priorities which can be used to guide the development of a random sample survey of growers in the region in order to more fully represent the region's current practices, experiences and perceptions of climate challenges and opportunities in the specialty crop industry.

The directors and staff of the experiment stations at both Michigan State University and The Ohio State University identified a group of specialty crop leaders, researchers and extension faculty representing the wide variety of specialty crops in these states, including apples, cherries, nursery and greenhouse crops. These individuals were invited to begin a conversation around how the Midwest Climate Hub could support their needs and interests. A group of twenty-five people met in Toledo, Ohio, in 2014 for a two-day meeting to initiate a relationship with the new Midwest Climate Hub and identify priority program areas. The meeting encompassed three distinct activities: 1) the concept mapping participatory planning process (which is the focus of this report), 2) semi-structured discussions facilitated by Dr. Jerry Hatfield, Director of the Midwest Climate Hub and 3) a presentation on the Midwest climate by Dr. Jeff Andresen, Climatologist at Michigan State University.

The concept mapping methodology[i] is a participatory planning process which spatially maps the thoughts and knowledge of a particular group of people to create a common framework for planning and evaluation of issues that matter to that group. The process begins with the group brainstorming key ideas together, then individually rating each of the idea statements by degree of importance, followed by individual conceptual sorting of the statements into groups of similar concepts. A variation of this process was used at the Toledo meeting. The group brainstormed 85 statements, then rated and sorted the statements into similar groupings. The 25 attendees were also asked to invite five specialty crop growers in their personal network to rate and sort the brainstormed statements. [ii] A total of 129 people, including the first twenty-five participants and their invitees, were invited to participate in the concept mapping process over a two month period. Fifty rating and sorting packets were returned with 44 completed and used in the analysis that follows (a response rate of 39%).

Brainstorming, rating, and sorting. Participants first brainstormed climate challenges by completing the statement: “One way a changing climate and extreme weather events affect fruit, vegetable and other specialty crop production in the upper Midwest is…” The brainstormed statements were recorded on a large screen where the entire group could read them. Eighty-five statements were generated by those attending the meeting in person, with two additional statements on risk management and insurance added after the brainstorming session (see Appendix III for the list of 85 statements). All 44 participants rated the importance of each statement using a 1-5 Likert scale (1 = Not at all important; 2 = A little important; 3 = Moderately Important; 4 = Highly Important; 5 = Extremely important). Lastly, participants each sorted the 85 items into separate piles or groups based on perceptions of statement similarities. Some participants lumped statements together, others split the statements into many groupings. The smallest number of groups created by a participant was three; the largest was twenty-one.

Midwest specialty crop map of climate challenges and opportunities

Multi-dimensional scaling of the data from the sorting process produced a “map” of the 85 statements (figure 1). Statements that are located close together on the map indicate that they were more likely to have been sorted into the same group. More distant statements on the map were more likely to not have been grouped together.

Clusters and priority ratings

Following the multidimensional scaling of the data, a hierarchical cluster analysis partitioned the mapped statements into clusters representing conceptual groupings. Then the average importance ratings were computed for each statement and each cluster and were overlaid on the spatial map. A nine cluster map, represented by the polygons in Figure 2, is the best

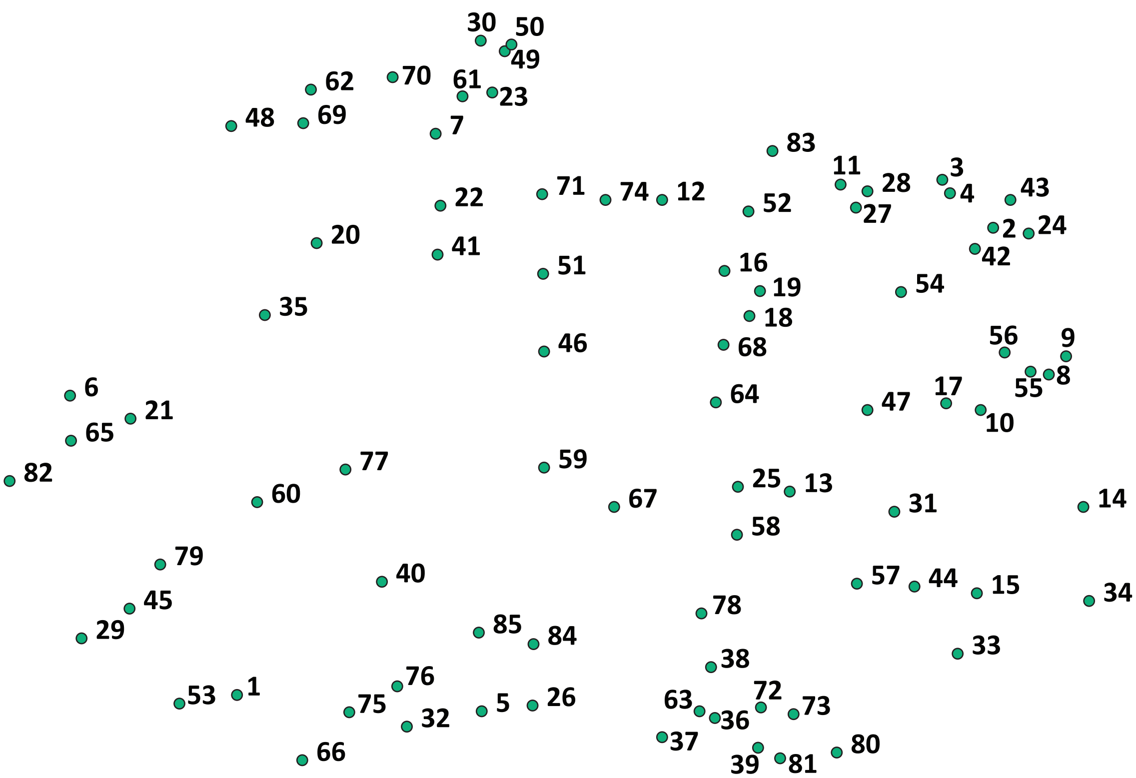

Figure 1. Spatial distribution of Midwest climate and specialty crop challenges and opportunities. (N = 44) (See Appendix III for statements which correspond to number.)

representation of the group's thinking and views.[iii] The cluster names were chosen subjectively by the researchers. Figure 2 displays the relative importance of the different clusters: for example, the five layers for cluster 1 indicate that a large number of items in that cluster were rated as highly important by several participants. The nine clusters are grouped into three tiers by relative importance to provide further visual clarity and analysis.

Climate Hub plan of work: clusters and priorities

The nine clusters (Figure 2; Table 1) identify distinct areas in which climate and agricultural programming, tool development and research would benefit specialty crop growers and their value chain. These are: pest and disease; marketing and risk; water; climate and weather; farming as a livelihood; labor; change in operations; changing opportunities and vulnerabilities; and production-consumer-research nexus. Appendices I, II, and III list the statements by cluster, by average rating, and by statement number, respectively. The nine clusters are grouped into three tiers based on their grand mean ratings and their spatial density. Note that all cluster grand means are in the highly to moderately important range (3.86 to 3.39) and within each cluster there are highly important statements that represent key priorities to the specialty crop industry.

Tier 1. Three of the highest rated clusters, pest and disease; marketing and risk; and water were placed in Tier 1. *Pest and disease*, consisting of 12 statements, was the most spatially dense and highly rated cluster with an overall grand mean rating of highly important (3.86). Within pest and disease, four statements were rated highly important (4) or higher: new invasive insect pests, diseases, and weeds (4.14); increased humidity increases fungal disease pressure (4.11), increase in bacterial diseases (4.09), and increased humidity increases bacterial disease pressure (4.07). The second most highly rated cluster was *marketing and risk* (3.86) containing eight statements. Four statements within this cluster were rated highly important (4) and above: increased need for financial

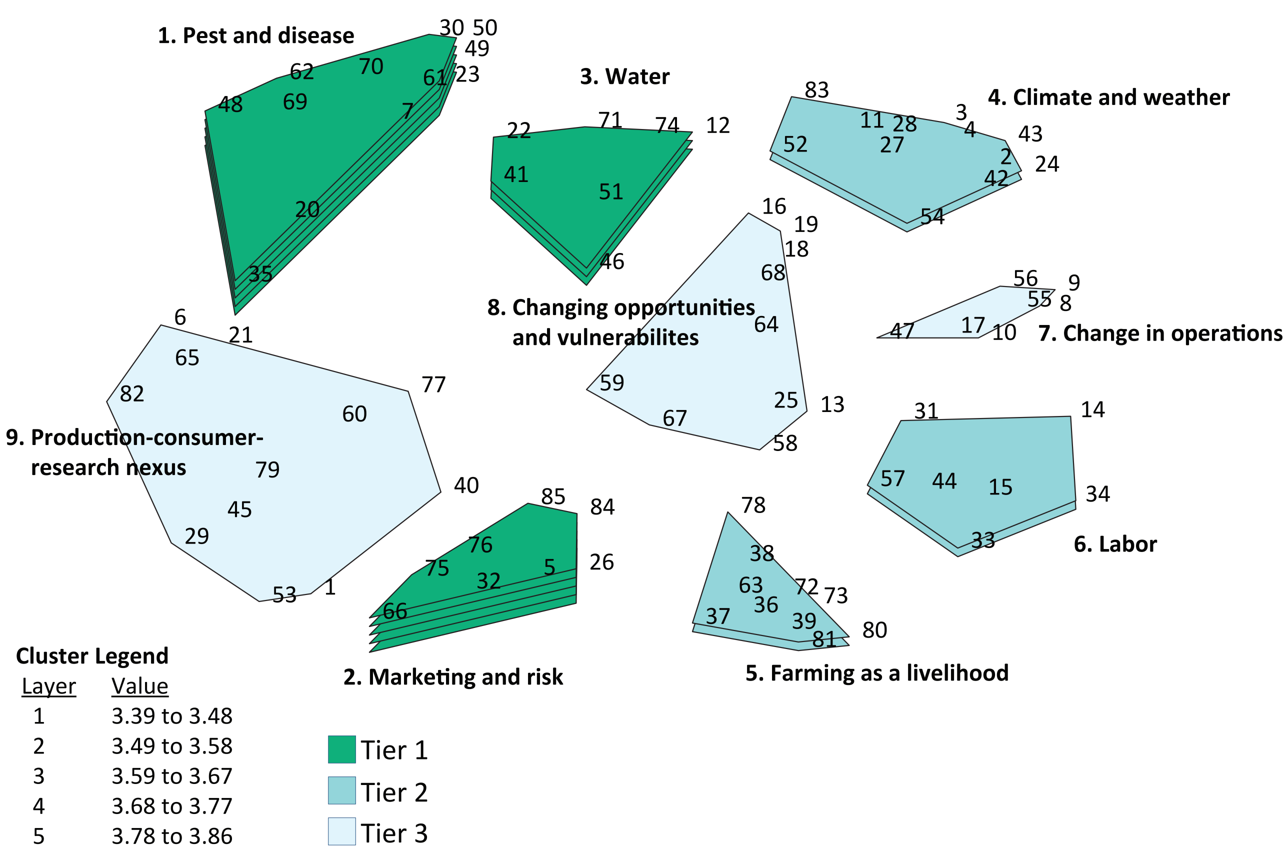

Figure 2. Nine cluster rating map generated from Midwest specialty crop leaders' brainstorming, rating and sorting process. (N = 44)

Table 1. Midwest specialty crop leaders' priority ratings of climate and specialty crop challenges and opportunities. "One way a changing climate and extreme weather events affect fruit, vegetable and other specialty crop production in the upper Midwest is…"

	Cluster Name	Grand Mean	Number of Statements	Top-Ranked Statement	Statement Rating
Tier 1	1. Pest and disease	3.86	12	23. New invasive insect pests, diseases, weeds	4.14
	2. Marketing and risk	3.86	8	84. Increased need for financial risk management tools for specialty crops	4.30
	3. Water	3.58	7	74. Increasing demand for water	4.05
Tier 2	4. Climate and weather	3.56	12	43. Fluctuations in spring temperature and fruit bud break	4.18
	5. Farming as a livelihood	3.51	10	36. Reduction in farm profitability	3.98
	6. Labor	3.49	7	15. Quantity variability	3.86
Tier 3	7. Change in operations	3.47	7	47. New opportunities for new approaches with varieties	3.61
	8. Changing opportunities and vulnerabilities	3.43	10	59. Increased risk in specialty crop cultivation in upper Midwest	3.89
	9. Production-consumer-research nexus	3.39	12	60. Increased need for more flexible risk management tools	4.16

risk management tools for specialty crops (4.30); economic unpredictability (4.27); increased need for specialty crop insurance (4.23); and production instability harms marketing and sales (4.00). The third most highly rated cluster was *water* (3.58) with seven statements. Three highly important rated statements within *water* were increasing demand for water (4.05); need for increased water resources-irrigation (3.93); and increased potential for nutrient runoff due to rainfall extremes (3.82).

Tier 2. Climate and weather; farming as a livelihood; and labor were the next highly rated clusters and were placed in Tier 2. *Climate and weather* (3.56) has twelve statements with three rated above highly important (4): fluctuations in spring temperature and fruit bud break (4.18); early spring warming and late frost for tree fruit (4.09); and excessive rainfall in spring affects planting dates (4.02). The next cluster in Tier 2, *farming as a livelihood*, consists of ten statements with reduction in farm profitability (3.98) and increased workforce instability (3.86) as the highest rated concerns in this cluster. *Labor* (3.49), the last cluster in Tier 2, has seven statements with top ranked statements quantity variability (3.86) and quality variability (3.80) as related to fruits and vegetables.

Tier 3. Although Tier 3 clusters are not rated as highly as those in Tiers 1 and 2, the clusters of change in operations; changing opportunities and vulnerabilities; and the production-consumer-research nexus are areas of priority interest for the specialty crop industry. *Change in operations* has a grand mean (3.47) halfway between highly important (4) and moderately important (3) and contains seven statements. The highest rated statement in this cluster was new opportunities for new approaches with varieties (3.61). The second cluster in Tier 3, with a grand mean similarly halfway between highly important and moderately important is *changing opportunities and vulnerabilities* (3.43) with ten statements. Two statements in this cluster that were rated highly important were increased risk in specialty crop cultivation in the upper Midwest (3.89) and opportunity to expand specialty crop production in the Midwest due to decreased production elsewhere (3.84); followed by new opportunities to grow new crops (3.66) and increased long-term storage problems for crops (3.43). The last cluster in Tier 3 is *production-consumer-research nexus* (3.39) with twelve statements. Although one of the lowest rated clusters, it has two statements within its grouping

Table 2. Top quartile (25%) Midwest specialty crop leaders' ranked statements. "One way a changing climate and extreme weather events affect fruit, vegetable and other specialty crop production in the upper Midwest is…"

Statement	Cluster	Mean Statement Rating
84. Increased need for financial risk management tools for specialty crops	Marketing and risk	4.30
26. Economic unpredictability	Marketing and risk	4.27
85. Increased need for specialty crop insurance	Marketing and risk	4.23
43. Fluctuations in spring temperature and fruit bud break	Climate and weather	4.18
60. Increased need for more flexible risk management tools	Production-consumer-research nexus	4.16
23. New invasive insect pests, diseases, weeds	Pest and disease	4.14
49. Increased humidity increases fungal disease pressure	Pest and disease	4.11
30. Increase in bacterial diseases	Pest and disease	4.09
2. Early spring warming and late frost for tree fruit	Climate and weather	4.09
50. Increased humidity increases bacterial disease pressure	Pest and disease	4.07
21. Need for increased extension expertise with specialty crops	Production-consumer-research nexus	4.07
74. Increasing demand for water	Water	4.05
4. Excessive rainfall in spring affects planting dates	Climate and weather	4.02
5. Production instability harms marketing and sales	Marketing and risk	4.00
7. Increases in variable and unpredictable pest pressures and outbreaks	Pest and disease	3.98
36. Reduction in farm profitability	Farming as a livelihood	3.98
62. Increased disease and pest resistance to available pesticides	Pest and disease	3.95
69. Reduced ability to respond to pests due to fewer pest management tools available from increased regulation	Pest and disease	3.95
12. Need for increased water resources (irrigation)	Water	3.93
59. Increased risk in specialty crop cultivation in upper Midwest	Changing opportunities and vulnerabilities	3.89
63. Increased workforce instability for those supporting specialty crops	Farming as a livelihood	3.86
15. Quantity variability	Labor	3.86

which are considered to be highly important: increased need for more flexible risk management tools (4.16) and need for increased extension expertise with specialty crops (4.07).

Top quartile statements. In addition to using the nine clusters to guide the Climate Hub plan of work, another way to think about priority setting is to examine the most highly rated statements of the entire list of 85. Table 2 shows the top quartile of statements by their rankings. An average rating of 4 or above indicates a highly important statement which participants agreed was a high priority; over half of the statements in the top quartile received an average rating of 4 and above. For further context, only three out of 85 statements had an average rating of less than moderately important (3), indicating that there was general agreement of the overall importance of the brainstormed ideas. The list of all 85 statements arranged by highest to lowest rating is in Appendix II.

Recommendations and next steps

Midwest Climate Hub plan of work. The results from the nine cluster concept map offer a parsimonious set of priority themes identified by leaders in Midwest specialty crop industries which can guide the Midwest Climate Hub in the development of a region-wide plan of work for specialty crops. These priority conceptual areas are a framework for the development of an instrument to conduct a random sample survey of Midwest specialty crop growers, their value chain, and the land grant universities which provide critical research and extension support. It will be important that the Midwest Climate Hub and partner universities understand the human-climate-agriculture-ecosystem relationships associated with specialty crop agricultural systems in order to develop the tools, resources, and research necessary to assure the climate resilience of the region.

Specialty crop growers and their value chain have been relatively understudied. This concept map is just a beginning. Much more is needed to be known about the highest priority areas that the specialty crop growers identified. Further, if the Midwest Climate Hub is to well serve this audience, it will need to also have information about 1) beliefs and awareness of changing climate conditions, 2) current strategies associated with managing water and soil resources, 3) anticipated risks and concerns for future productivity and agroecosystem resilience under changing climate conditions/extreme weather events, 4) perceptions of what kinds of adaptive management practices are needed in the future, 5) degree of willingness and capacity to continuously adapt as climate patterns change, 6) social relationships that influence decision making and risk assessments, 7) resources available that support/guide decision making, and 8) information and technological needs.

Lastly, the capacity of the Midwest Climate Hub to address even a few of the many challenges and opportunities identified by the Midwest specialty crop industry will be dependent upon individual and institutional relationships and partnerships built. How can the Climate Hub best identify leaders and build these partnerships? That is the challenge ahead.

Next steps:

- Development of a stratified random sample survey of Midwest specialty crop growers to assess perspectives; current practices; experiences, concerns, and risks associated with a variable climate; and resource needs to meet challenges and opportunities.

- Strengthen and build university and industry partnerships and institutional relationships to improve the resilience of Midwest production systems while protecting the integrity of soil and water resources.

- Utilize the nine priority areas identified by specialty crop leaders to develop a Midwest Climate Hub region-wide plan of work to frame action items, guide programming, and target investments.

References

Hatfield, J., G. Takle, R. Grotjahn, P. Holden, R. C. Izaurralde, T. Mader, E. Marshall, and D. Liverman, 2014: Ch. 6: Agriculture. *Climate Change Impacts in the United States: The Third National Climate Assessment,* J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 150-174. doi:10.7930/J02Z13FR.

Kane, M., Trochim, W.M.K. *Concept Mapping for Planning and Evaluation.* Thousand Oaks: Sage Publications, 2007. Print.

Walthall, C.L., J. Hatfield, P. Backlund, L. Lengnick, E. Marshall, M. Walsh, S. Adkins, M. Aillery, E.A. Ainsworth, C. Ammann, C.J. Anderson, I. Bartomeus, L.H. Baumgard, F. Booker, B. Bradley, D.M. Blumenthal, J. Bunce, K. Burkey, S.M. Dabney, J.A. Delgado, J. Dukes, A. Funk, K. Garrett, M. Glenn, D.A. Grantz, D. Goodrich, S. Hu, R.C. Izaurralde, R.A.C. Jones, S-H. Kim, A.D.B. Leaky, K. Lewers, T.L. Mader, A. McClung, J. Morgan, D.J. Muth, M. Nearing, D.M. Oosterhuis, D. Ort, C. Parmesan, W.T. Pettigrew, W. Polley, R. Rader, C. Rice, M. Rivington, E. Rosskopf, W.A. Salas, L.E. Sollenberger, R. Srygley, C. Stöckle, E.S. Takle, D. Timlin, J.W. White, R. Winfree, L. Wright-Morton, L.H. Ziska. 2012. *Climate Change and Agriculture in the United States: Effects and Adaptation*. USDA Technical Bulletin 1935. Washington, DC. 186 pages.

End Notes

[i]Concept mapping methodology based on Kane and Trochim (2007)

[ii]Iowa State University Institutional Review Board approval IRB ID 14-453

[iii]There are many possible ways to group, or "cluster" the items once they have been mapped – in other words, Figure 2 could have five, or six, or thirteen polygons instead of the nine shown. In advising on how to choose the number of clusters, Kane and Trochim (2007) use the metaphor of forests and trees: from a 10,000 foot level, the broad landscape of a forest is clear, but from a closer level, the detail of individual trees is easier to discern. Both can offer valuable insights. The same is true in establishing few or many clusters. The goals of the group determine the ideal number of clusters for a map: whether they wish to identify a few broad themes from the data or several specific ones.

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Appendix I: Statements sorted by tier and cluster
N = 44

		"One way a changing climate and extreme weather events affect fruit, vegetable and other specialty crop production in the upper Midwest is…"	Average Rating
Tier 1			
1.	***Pest and disease***		***3.86***
	23	New invasive insect pests, diseases, weeds	4.14
	49	Increased humidity increases fungal disease pressure	4.11
	30	Increase in bacterial diseases	4.09
	50	Increased humidity increases bacterial disease pressure	4.07
	7	Increases in variable and unpredictable pest pressures and outbreaks	3.98
	62	Increased disease and pest resistance to available pesticides	3.95
	69	Reduced ability to respond to pests due to fewer pest management tools available from increased regulation	3.95
	61	Increased potential for pest/pathogen over-wintering	3.84
	48	Dramatic increase in amount of pesticides applied	3.75
	35	Lack of accurate forecasting of weather changes	3.7
	70	Increased pesticide use increases pesticide runoff	3.39
	20	Drought affects landscape demands for water from municipal sources	3.30
2.	***Marketing and risk***		***3.86***
	84	Increased need for financial risk management tools for specialty crops	4.30
	26	Economic unpredictability	4.27
	85	Increased need for specialty crop insurance	4.23
	5	Production instability harms marketing and sales	4.00
	32	Unpredictability in marketing	3.77
	75	Disruptions in supply chains	3.73
	66	Mismatch between crop availability and consumer demand	3.43
	76	Changes in market entry and exit dates overall	3.18
3.	***Water***		***3.58***
	74	Increasing demand for water	4.05
	12	Need for increased water resources (irrigation)	3.93
	71	Increased potential for nutrient runoff due to rainfall extremes	3.82
	22	Increased need for water capture and storage in compromised watersheds	3.61
	46	Straining supply of broadly adapted improved genetics	3.41
	41	Change in feedback loops in biological systems	3.25
	51	Need to account for increased carbon dioxide concentrations	3.00

	"One way a changing climate and extreme weather events affect fruit, vegetable and other specialty crop production in the upper Midwest is…"	Average Rating
Tier 2		
4.	***Climate and weather***	***3.56***
43	Fluctuations in spring temperature and fruit bud break	4.18
2	Early spring warming and late frost for tree fruit	4.09
4	Excessive rainfall in spring affects planting dates	4.02
83	Impacts of pollinators and pollination timing	3.73
42	Fluctuations in bud break (ex: maple syrup)	3.70
3	Fluctuating weather for over-wintering nursery crops	3.59
11	Increased dry periods for fruit and vegetable production	3.50
24	Warmer climate extends growing season	3.39
54	Decrease in workable field days for crop protection	3.34
28	More discrete microclimates	3.30
52	Increased ozone could limit crop production in new ways	3.05
27	Fluctuations in temperature affect aquaculture survival rates	2.86
5.	***Farming as a livelihood***	***3.51***
36	Reduction in farm profitability	3.98
63	Increased workforce instability for those supporting specialty crops	3.86
37	Loss of farms	3.52
39	Reduction of potential to pass farm down within family	3.50
38	Land use out of agriculture	3.45
72	Increase in farmer stress	3.43
78	Challenges economic sustainability of small scale production	3.43
80	Loss of farmer experience poses challenges as difficulty of farming increases	3.36
73	Increase in farm family stress	3.34
81	Loss of farmer experience as farmers age out	3.23
6.	***Labor***	**3.49**
15	Quantity variability	3.86
14	Quality variability	3.80
34	Changes in timing of labor needs	3.70
33	Poor crop quality impacts migrant labor earning capacity	3.41
44	Increased difficulty for farming	3.36
57	Changes in scheduling of processing	3.30
31	Increased temperatures encourage overconfidence in growers	3.02

		“One way a changing climate and extreme weather events affect fruit, vegetable and other specialty crop production in the upper Midwest is…”	Average Rating
Tier 3			
7.		***Change in operations***	***3.47***
	47	New opportunities for new approaches with varieties	3.61
	55	Decrease in workable field days for harvest field operations	3.59
	10	Difficulty in changing perennial crops	3.57
	8	Changes in cropping systems	3.55
	56	Decrease in workable field days for planting	3.45
	9	Changes in annual crops	3.27
	17	Migration of production systems northward	3.25
8.		***Changing opportunities and vulnerabilities***	***3.43***
	59	Increased risk in specialty crop cultivation in upper Midwest	3.89
	67	Opportunity to expand specialty crop production in Midwest due to decreased production elsewhere	3.84
	25	New opportunities to grow new crops	3.66
	64	Increased long-term storage problems for crops	3.43
	16	Expanded area of production because weather is wetter and warmer	3.39
	68	Increased need for enhanced greenhouse systems	3.39
	18	Increasing opportunity for semi-protected cultivation (ex: high tunnels)	3.23
	58	Changes in scheduling of fresh market crops	3.16
	19	Increasing demand for semi-protected cultivation (ex: high tunnels)	3.14
	13	Increased variability in processing quality (wheat, sugarbeets, others)	3.14
9.		***Production-consumer-research nexus***	***3.39***
	60	Increased need for more flexible risk management tools	4.16
	21	Need for increased extension expertise with specialty crops	4.07
	82	Need for changes in delivery of information from research community	3.64
	79	Increased food safety concerns with produce	3.45
	53	Fluctuation affects consumer food prices	3.43
	77	More opportunities for small scale production	3.41
	65	Increased demand for managing large datasets to model production variables	3.27
	40	Increased population pressure	3.27
	1	Changes in public’s purchasing preferences	3.18
	6	Climate considerations add additional complexity for land grant universities for resource allocation	3.16
	29	Consumer education is needed regarding expectations for fruit/vegetable appearance	2.93
	45	Consumers purchase more drought tolerant landscape plants	2.68

Appendix II: Statements sorted by rating (high to low)
N = 44

Statement Number	"One way a changing climate and extreme weather events affect fruit, vegetable and other specialty crop production in the upper Midwest is…"	Average Rating	Cluster Number
84	Increased need for financial risk management tools for specialty crops	4.30	2
26	Economic unpredictability	4.27	2
85	Increased need for specialty crop insurance	4.23	2
43	Fluctuations in spring temperature and fruit bud break	4.18	4
60	Increased need for more flexible risk management tools	4.16	9
23	New invasive insect pests, diseases, weeds	4.14	1
49	Increased humidity increases fungal disease pressure	4.11	1
2	Early spring warming and late frost for tree fruit	4.09	4
30	Increase in bacterial diseases	4.09	1
21	Need for increased extension expertise with specialty crops	4.07	9
50	Increased humidity increases bacterial disease pressure	4.07	1
74	Increasing demand for water	4.05	3
4	Excessive rainfall in spring affects planting dates	4.02	4
5	Production instability harms marketing and sales	4.00	2
7	Increases in variable and unpredictable pest pressures and outbreaks	3.98	1
36	Reduction in farm profitability	3.98	5
62	Increased disease and pest resistance to available pesticides	3.95	1
69	Reduced ability to respond to pests due to fewer pest management tools available from increased regulation	3.95	1
12	Need for increased water resources (irrigation)	3.93	3
59	Increased risk in specialty crop cultivation in upper Midwest	3.89	8
15	Quantity variability	3.86	6
63	Increased workforce instability for those supporting specialty crops	3.86	5
61	Increased potential for pest/pathogen over-wintering	3.84	1
67	Opportunity to expand specialty crop production in Midwest due to decreased production elsewhere	3.84	8
71	Increased potential for nutrient runoff due to rainfall extremes	3.82	3
14	Quality variability	3.80	6
32	Unpredictability in marketing	3.77	2
48	Dramatic increase in amount of pesticides applied	3.75	1
75	Disruptions in supply chains	3.73	2
83	Impacts of pollinators and pollination timing	3.73	4
34	Changes in timing of labor needs	3.70	6
35	Lack of accurate forecasting of weather changes	3.70	1
42	Fluctuations in bud break (ex: maple syrup)	3.70	4
25	New opportunities to grow new crops	3.66	8
82	Need for changes in delivery of information from research community	3.64	9

Statement Number	"One way a changing climate and extreme weather events affect fruit, vegetable and other specialty crop production in the upper Midwest is…"	Average Rating	Cluster Number
22	Increased need for water capture and storage in compromised watersheds	3.61	3
47	New opportunities for new approaches with varieties	3.61	7
3	Fluctuating weather for over-wintering nursery crops	3.59	4
55	Decrease in workable field days for harvest field operations	3.59	7
10	Difficulty in changing perennial crops	3.57	7
8	Changes in cropping systems	3.55	7
37	Loss of farms	3.52	5
11	Increased dry periods for fruit and vegetable production	3.50	4
39	Reduction of potential to pass farm down within family	3.50	5
38	Land use out of agriculture	3.45	5
56	Decrease in workable field days for planting	3.45	7
79	Increased food safety concerns with produce	3.45	9
53	Fluctuation affects consumer food prices	3.43	9
64	Increased long-term storage problems for crops	3.43	8
66	Mismatch between crop availability and consumer demand	3.43	2
72	Increase in farmer stress	3.43	5
78	Challenges economic sustainability of small scale production	3.43	5
33	Poor crop quality impacts migrant labor earning capacity	3.41	6
46	Straining supply of broadly adapted improved genetics	3.41	3
77	More opportunities for small scale production	3.41	9
16	Expanded area of production because weather is wetter and warmer	3.39	8
24	Warmer climate extends growing season	3.39	4
68	Increased need for enhanced greenhouse systems	3.39	8
70	Increased pesticide use increases pesticide runoff	3.39	1
44	Increased difficulty for farming	3.36	6
80	Loss of farmer experience poses challenges as difficulty of farming increases	3.36	5
54	Decrease in workable field days for crop protection	3.34	4
73	Increase in farm family stress	3.34	5
20	Drought affects landscape demands for water from municipal sources	3.30	1
28	More discrete microclimates	3.30	4
57	Changes in scheduling of processing	3.30	6
9	Changes in annual crops	3.27	7
40	Increased population pressure	3.27	9
65	Increased demand for managing large datasets to model production variables	3.27	9
17	Migration of production systems northward	3.25	7
41	Change in feedback loops in biological systems	3.25	3
18	Increasing opportunity for semi-protected cultivation (ex: high tunnels)	3.23	8
81	Loss of farmer experience as farmers age out	3.23	5

Statement Number	"One way a changing climate and extreme weather events affect fruit, vegetable and other specialty crop production in the upper Midwest is…"	Average Rating	Cluster Number
1	Changes in public's purchasing preferences	3.18	9
76	Changes in market entry and exit dates overall	3.18	2
6	Climate considerations add additional complexity for land grant universities for resource allocation	3.16	9
58	Changes in scheduling of fresh market crops	3.16	8
13	Increased variability in processing quality (wheat, sugarbeets, others)	3.14	8
19	Increasing demand for semi-protected cultivation (ex: high tunnels)	3.14	8
52	Increased ozone could limit crop production in new ways	3.05	4
31	Increased temperatures encourage overconfidence in growers	3.02	6
51	Need to account for increased carbon dioxide concentrations	3.00	3
29	Consumer education is needed regarding expectations for fruit/vegetable appearance	2.93	9
27	Fluctuations in temperature affect aquaculture survival rates	2.86	4
45	Consumers purchase more drought tolerant landscape plants	2.68	9

Appendix III: Statement ratings sorted by statement number
N = 44

Statement Number	"One way a changing climate and extreme weather events affect fruit, vegetable and other specialty crop production in the upper Midwest is…"	Average Rating	Cluster Number
1	Changes in public's purchasing preferences	3.18	9
2	Early spring warming and late frost for tree fruit	4.09	4
3	Fluctuating weather for over-wintering nursery crops	3.59	4
4	Excessive rainfall in spring affects planting dates	4.02	4
5	Production instability harms marketing and sales	4.00	2
6	Climate considerations add additional complexity for land grant universities for resource allocation	3.16	9
7	Increases in variable and unpredictable pest pressures and outbreaks	3.98	1
8	Changes in cropping systems	3.55	7
9	Changes in annual crops	3.27	7
10	Difficulty in changing perennial crops	3.57	7
11	Increased dry periods for fruit and vegetable production	3.50	4
12	Need for increased water resources (irrigation)	3.93	3
13	Increased variability in processing quality (wheat, sugarbeets, others)	3.14	8
14	Quality variability	3.80	6
15	Quantity variability	3.86	6
16	Expanded area of production because weather is wetter and warmer	3.39	8
17	Migration of production systems northward	3.25	7
18	Increasing opportunity for semi-protected cultivation (ex: high tunnels)	3.23	8
19	Increasing demand for semi-protected cultivation (ex: high tunnels)	3.14	8
20	Drought affects landscape demands for water from municipal sources	3.30	1
21	Need for increased extension expertise with specialty crops	4.07	9
22	Increased need for water capture and storage in compromised watersheds	3.61	3
23	New invasive insect pests, diseases, weeds	4.14	1
24	Warmer climate extends growing season	3.39	4
25	New opportunities to grow new crops	3.66	8
26	Economic unpredictability	4.27	2
27	Fluctuations in temperature affect aquaculture survival rates	2.86	4
28	More discrete microclimates	3.30	4
29	Consumer education is needed regarding expectations for fruit/vegetable appearance	2.93	9
30	Increase in bacterial diseases	4.09	1
31	Increased temperatures encourage overconfidence in growers	3.02	6
32	Unpredictability in marketing	3.77	2
33	Poor crop quality impacts migrant labor earning capacity	3.41	6
34	Changes in timing of labor needs	3.70	6
35	Lack of accurate forecasting of weather changes	3.70	1

Statement Number	"One way a changing climate and extreme weather events affect fruit, vegetable and other specialty crop production in the upper Midwest is…"	Average Rating	Cluster Number
36	Reduction in farm profitability	3.98	5
37	Loss of farms	3.52	5
38	Land use out of agriculture	3.45	5
39	Reduction of potential to pass farm down within family	3.50	5
40	Increased population pressure	3.27	9
41	Change in feedback loops in biological systems	3.25	3
42	Fluctuations in bud break (ex: maple syrup)	3.70	4
43	Fluctuations in spring temperature and fruit bud break	4.18	4
44	Increased difficulty for farming	3.36	6
45	Consumers purchase more drought tolerant landscape plants	2.68	9
46	Straining supply of broadly adapted improved genetics	3.41	3
47	New opportunities for new approaches with varieties	3.61	7
48	Dramatic increase in amount of pesticides applied	3.75	1
49	Increased humidity increases fungal disease pressure	4.11	1
50	Increased humidity increases bacterial disease pressure	4.07	1
51	Need to account for increased carbon dioxide concentrations	3.00	3
52	Increased ozone could limit crop production in new ways	3.05	4
53	Fluctuation affects consumer food prices	3.43	9
54	Decrease in workable field days for crop protection	3.34	4
55	Decrease in workable field days for harvest field operations	3.59	7
56	Decrease in workable field days for planting	3.45	7
57	Changes in scheduling of processing	3.30	6
58	Changes in scheduling of fresh market crops	3.16	8
59	Increased risk in specialty crop cultivation in upper Midwest	3.89	8
60	Increased need for more flexible risk management tools	4.16	9
61	Increased potential for pest/pathogen over-wintering	3.84	1
62	Increased disease and pest resistance to available pesticides	3.95	1
63	Increased workforce instability for those supporting specialty crops	3.86	5
64	Increased long-term storage problems for crops	3.43	8
65	Increased demand for managing large datasets to model production variables	3.27	9
66	Mismatch between crop availability and consumer demand	3.43	2
67	Opportunity to expand specialty crop production in Midwest due to decreased production elsewhere	3.84	8
68	Increased need for enhanced greenhouse systems	3.39	8
69	Reduced ability to respond to pests due to fewer pest management tools available from increased regulation	3.95	1
70	Increased pesticide use increases pesticide runoff	3.39	1
71	Increased potential for nutrient runoff due to rainfall extremes	3.82	3

Statement Number	"One way a changing climate and extreme weather events affect fruit, vegetable and other specialty crop production in the upper Midwest is…"	Average Rating	Cluster Number
72	Increase in farmer stress	3.43	5
73	Increase in farm family stress	3.34	5
74	Increasing demand for water	4.05	3
75	Disruptions in supply chains	3.73	2
76	Changes in market entry and exit dates overall	3.18	2
77	More opportunities for small scale production	3.41	9
78	Challenges economic sustainability of small scale production	3.43	5
79	Increased food safety concerns with produce	3.45	9
80	Loss of farmer experience poses challenges as difficulty of farming increases	3.36	5
81	Loss of farmer experience as farmers age out	3.23	5
82	Need for changes in delivery of information from research community	3.64	9
83	Impacts of pollinators and pollination timing	3.73	4
84	Increased need for financial risk management tools for specialty crops	4.30	2
85	Increased need for specialty crop insurance	4.23	2