Case Study:

The Future Projected Wisconsin Crop Suitability Tool (v1.0)

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In 2023, the U.S. Department of Agriculture (USDA) released an updated Plant Hardiness Zone Map (PHZM), jointly developed by USDA's Agricultural Research Service and Oregon State University's PRISM Climate Group. These maps—widely used by growers, seed companies, crop insurance providers and agricultural planners—help determine which plants are most suitable for specific growing locations based on historical climate data. Compared to the 2012 version, the 2023 PHZM offers improved accuracy and detail, using data from over 13,000 weather stations (up from nearly 8,000) and offering resolution down to ¼ square mile. While the PHZM is a key tool in determining crop insurance standards and guiding agricultural research, it relies on historical 30-year averages of annual minimum temperatures. **In a rapidly changing climate, this historical approach does not fully capture current or future conditions.** This mismatch presents growing risks for farmers, especially those whose livelihoods depend on reliable crop production and long-term planning.

To address this gap, *Clean Wisconsin* and the *Savanna Institute* partnered—in collaboration with the University of Wisconsin-Madison's Department of Atmospheric and Oceanic Sciences, the *Wisconsin Initiative on Climate Change Impacts* (WICCI), the *Daybreak Fund* and the *Platform for Agriculture & Climate Transformation* (PACT)—to develop the **Future Projected Wisconsin Crop Suitability Tool (v1.0).** This ArcGIS-based online tool models how climate change is projected on average to affect the **long-term suitability of 34 crops** (11 of Wisconsin's key commodity crops, and 23 emerging, high-value crops with climate resilience potential: 13 emerging tree crops, 5 perennial row crops and 5 hardy annual row crops.)

Using county-level average temperature and precipitation data from WICCI, national geo-referenced datasets on soil characteristics and expert-reviewed, crop-specific growing requirements, we cross-analyzed *ideal*, *suitable* and *unsuitable* conditions for each crop under "current" (1991-2020) and average, future projected (2030, 2050) climate conditions for two emission scenarios: *moderate* (RCP4.5) and *extreme* (RCP8.5) global emissions. Our interactive maps offer resolution down to 10 x 10 meters (0.002 acre).

Constraints in data availability and project scope limited our ability to account for days of extreme weather and temperature, and many of the climate variables impacting crop productivity thresholds are not yet scientifically quantified.

To fill the known gaps in extreme climate data and to enhance usability of the Tool (v1.0), we created supplementary crop info sheets for each of the 34 crops analyzed. These info sheets, rigorously reviewed by crop experts, detail specific crop threshold data—

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minimum and maximum ranges for ideal productivity, beyond which crop yields are expected to decline. This data is presented for each month of the year to aid users using the Tool (v1.0) to cross-reference average projected suitability and known climate extremes during key months of the year when these extremes can pose significant risks to crop establishment, bud development, fruiting, harvesting, etc.

Despite these data constraints, the **Future Projected Wisconsin Crop Suitability Tool (v1.0)** provides Wisconsin with a baseline tool—an important first step in the development of science-based, decision-support tools that integrate the best available data for farmers, land managers, technical service providers, and state agencies to:

- Better understand the climate risks to our crop commodities 25 years into the future,
- Identify high-value alternative crops that will thrive under future projected conditions,
- Identify strategic areas for technical agricultural support, and
- Inform strategic planning for advancing resilient rural economic development in Wisconsin.

Both the online-interactive ArcGIS tool and methodology report can be found in the NCS Toolkit.

The following excerpt demonstrates the power and potential of this science-based tool, highlighting the suitability of eight crops: two annual crop commodities (corn, soybeans), one perennial crop commodity (blueberries), one emerging winter-annual oil crop (winter camelina), one emerging herbaceous perennial row crop (Kernza® intermediate wheatgrass), and three emerging woody perennial crops (hybrid hazelnut, aronia and elderberry) under average current and future projected climate conditions.

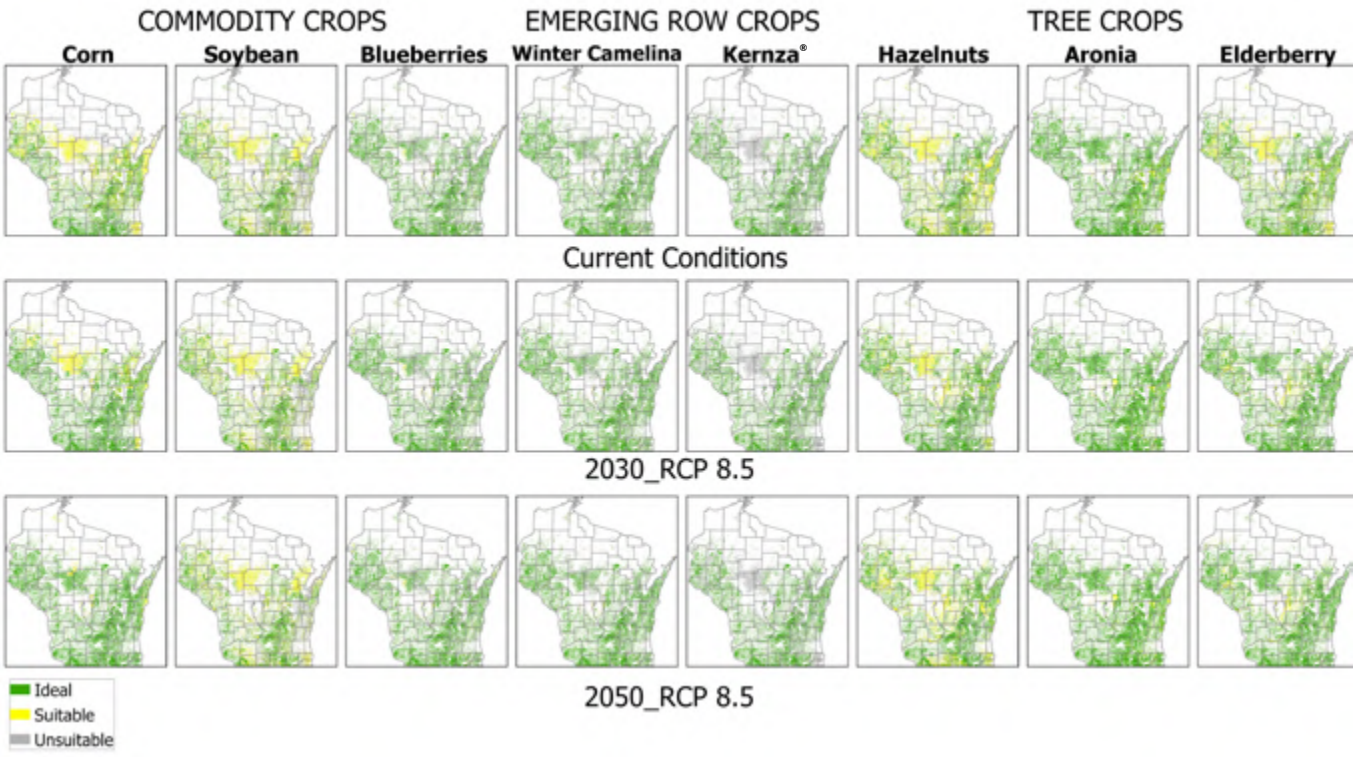

Figure 1. Current and average future crop suitability under high global emissions scenario (RCP8.5).

While these maps don't account for the extreme temperature and precipitation events we know are projected to significantly impact corn and soybean production in Wisconsin (Rezaei et al. 2023, Environmental Defense Fund 2022, Hsiang et al. 2017, Schlenker and Roberts 2009), even for average climate conditions they demonstrate that **a transition towards perennial crops is possible, and maybe even ideal for certain crops/counties.**

The following tables provide more insight of expected changes to suitability:

Percent of agricultural land shifting suitability.

Table 2a. Percent of agricultural land shifting suitability between current and 2030 (RCP8.5) climate conditions for eight selected crops

	No Change	Suitable to Ideal	Unsuitable to Ideal	Unsuitable to Suitable	Ideal to Suitable	Ideal to Unsuitable	Suitable to Unsuitable
Corn	81.0%	15.9%	1.3%	1.8%	0.0%	0.0%	0.0%
Soybeans	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Blueberries	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Winter Camelina	99.8%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%
Kernza®	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hazelnuts	70.5%	23.3%	0.1%	1.1%	5.1%	0.0%	0.0%
Aronia	93.3%	3.0%	0.7%	3.0%	0.0%	0.0%	0.0%
Elderberries	71.7%	23.0%	0.0%	0.1%	5.2%	0.0%	0.0%

Table 2b. Percent of agricultural land shifting suitability between current and 2050 (RCP8.5) climate conditions for eight selected crops

	No Change	Suitable to Ideal	Unsuitable to Ideal	Unsuitable to Suitable	Ideal to Suitable	Ideal to Unsuitable	Suitable to Unsuitable
Corn	68.5%	27.9%	2.8%	0.7%	0.0%	0.0%	0.0%
Soybeans	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Blueberries	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Winter Camelina	99.8%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Kernza®	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hazelnuts	72.9%	18.0%	0.0%	1.1%	8.0%	0.0%	0.0%
Aronia	93.3%	3.0%	0.7%	3.0%	0.0%	0.0%	0.0%
Elderberries	71.7%	23.0%	0.0%	0.1%	5.2%	0.0%	0.0%

For the two annual commodity crops, this analysis showed no decline in suitability by 2050. There are modest expected increases in suitability for corn by 2050, while soybeans have significant increases in suitability by 2050. Of the emerging crops, elderberries and hazelnuts are expected to have 20% more suitable acres by 2050, although some of this will be offset by small areas of declining suitability. Aronia is also expected to see increased suitability at a lesser scale (6% increase in suitable areas) while blueberries, winter camelina, and Kernza® are not expected to see any change.

Harvested elderberries, Wisconsin.
Photo credit: Savanna Institute.

Counties where corn/soy suitability remains constant, but emerging crops suitability increases.

Table 3. Counties where corn/soy suitability remains relatively unchanged, but emerging crop suitability increases

Crop	No Change	% Acres increasing suitability in 2030	% Corn acres no change in 2030	% Soybean acres no change in 2030	% Acres increasing suitability in 2050	% Corn acres no change in 2050	% Soybean acres no change in 2050
Hazelnuts	Sheboygan	60	97	100	53	89	100
Hazelnuts	Iowa	56	97	100	54	97	100
Hazelnuts	Ozaukee	49	100	100	49	78	100
Hazelnuts	Richland	46	94	100	18	94	100
Hazelnuts	Jefferson	31	91	100	31	91	100

Using this analysis we can identify areas of the state where emerging crops will increase in suitability while suitability for existing commodity crops are expected to remain unchanged (Table 3). Of particular note are several counties where suitability for hazelnuts is expected to increase by more than 30%, while the vast majority of commodity crop acreage is expected to remain the same in suitability.

Wisconsin Hazelnuts.
Photo credit: Clean Wisconsin.

We emphasize that our modeling is a first step taking a look at the potential impact of average monthly temperature and precipitation changes on crop suitability. It does not analyze the effect of these changes directly on crop yield nor does it incorporate the effect of weather extremes like extreme heat, drought, or heavy rainfall events. Such extreme events (and synergistic interactions between factors like the combination of drought and extreme heat) are well-documented to negatively impact commodity crop yield but are not captured in the average conditions used in our analysis.

Indeed, more detailed modeling that accounts for such extreme events generally report a reduction in corn and, and to a lesser extent, soybean yields. For example, an analysis from the Environmental Defense Fund (2022) found that while growing degree days are expected to increase with climate change for corn in Iowa and soybeans in Minnesota, the number of killing degree days (days when maximum temperatures are too hot for the plant to grow and even damage the plant) will also increase, but at a higher rate. This results in a net reduction in yield for both crops in these states.

A recent global review of prior analyses of climate change-related crop yield changes found 8% (low emissions scenario) and 35% (high emissions scenario, more likely based on current trajectory) reductions in corn yields in the United States by the end of the century (Rezaei et al. 2023). Similarly, Schlenker and Roberts (2009) predict 20-35% reduction in corn and ~20% reduction in soybean yields by 2030, depending on the climate scenario being considered. These reductions increase to 40-80% for corn and 35-70% for soybeans by the end of the century. Finally, Hsiang et al. (2017) estimate 10-20% reductions in corn and soy yields in southern Wisconsin by the end of the century.

Conclusion

To achieve any one of the three viable pathways described in the NCS Roadmap to Net-Zero report, by 2050 will require significant transformation of Wisconsin's agricultural landscapes towards practices that:

(i) Require fewer inputs than intensive annual production requires,

(ii) Have a higher—or at least equal—tolerance to the changing climate than current crops,

(iii) Receive higher—or at least equal—returns on investment than current corn/soybean production.

These maps demonstrate that a transition towards perennial crops is possible.

They also highlight the urgent need for Wisconsin's Department of Agriculture, Trade and Consumer Protection (WDATCP) to integrate the best available data on the soil and climate productivity thresholds of a wide variety of commercial and emerging crops, coupled with climate variability projections, to prepare Wisconsin's farmers, insurance agents and technical field assistants with the critical information needed to guide their decisions today and into the future. This should include the provision of science-based, forward-looking decision-support tools to inform long-term planning and budgeting at the farm-, county or regional-, and state- and federal-levels:

- Farm-level decisions:
  - Long-term risk assessments and planning
  - Climate-resilient crop selection
- County/regional-level decisions:
  - Strategic areas for technical agricultural support
  - Targeted investments into rural economic development of supply chain infrastructure and value chain development
- State/federal-level decision:
  - Climate-smart agricultural policies
  - Strategic areas to prioritize technical assistance outreach
  - Informed crop insurance frameworks
  - Long-term food system resilience

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