Natural Climate Solutions for Wisconsin Agriculture:

A ROADMAP TO NET-ZERO AGRICULTURAL EMISSIONS BY 2050

ADVOCACY REPORT
CLEAN WISCONSIN
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cleanwisconsin.org

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Executive Summary

Natural Climate Solutions (NCS) are systems and practices for the management, restoration and protection of natural ecosystems and working landscapes, including agricultural land (agro-ecosystems). NCS *measurably* reduce emissions of greenhouse gases and sequester atmospheric carbon into soils and above- and below-ground biomass for the long term.

This report (the NCS Roadmap) offers Wisconsin its first data-driven guide to achieve net-zero emissions for Wisconsin agriculture. Our report outlines the agricultural systems, management practices, adoption incentives and investment strategies that, if supported by policy, can reinvigorate rural economies, strengthen value-added markets and ensure Wisconsin farmers remain competitive in a changing climate.

The NCS Roadmap evaluates the potential of practices prioritized in state climate action plans (cover crops, no-till farming and nutrient management) to reduce greenhouse gas (GHG) emissions within existing systems of annual crop cultivation and confined livestock management. It then expands the analysis to examine the GHG-reduction potential of other agricultural systems (agroforestry, perennial row crops and managed grazing) and management practices (biochar amendments, manure management changes) to illuminate the agricultural systems changes that would be needed to meet Wisconsin's net-zero emission goals by 2050.

The NCS Roadmap outlines a series of theoretical adoption scenarios for these management practices and production systems across the landscape and identifies three scenarios that could achieve net-zero emissions in Wisconsin agriculture by 2050. The report then identifies many of the current barriers to implementation of those scenarios, opportunities to enhance rural economic development and state policies needed to support adoption of these agricultural climate solutions.

The results of our analysis are limited by the practices and systems evaluated, and the scenarios conceptualized. Furthermore, they strictly adhere to ecological outcomes without comprehensive economic analyses to weigh in on the implications of these pathways to Wisconsin's agricultural communities and economy over the near, mid and long term. We strongly encourage further socio-economic evaluation to complement our analyses and inform strategic planning. Nevertheless, the Roadmap's policy recommendations provide a foundation for of bipartisan strategies that integrate ecological outcomes with rural economic resilience. With bold action and strategic investment, Wisconsin can chart a new path for agriculture—one that leaves a lasting legacy of environmental sustainability, economic prosperity, and climate resilience.

KEY FINDINGS:

- While practices like cover crops and no-till farming can provide substantial water quality and soil health benefits, their capacity to increase long-term soil-carbon storage is limited. Relying on these practices alone will not achieve net-zero emissions from Wisconsin's agricultural sector.
- Reducing application rates of nitrogen fertilizer immediately reduces GHG emissions from agricultural soils and is critical to achieving net-zero goals.
- Direct reductions in emissions from manure management and enteric fermentation is also necessary to achieve net-zero goals.
- Perennial agriculture systems—such as agroforestry, silvopasture, rotationally-managed pastures, and perennial crops—offer the greatest GHG reduction potential of the systems reviewed. They also produce high-value, nutrient-dense products and provide environmental benefits including improved water quality, flood reduction and enhanced biodiversity.
- The primary barriers to adoption of perennial agriculture include:
  - (i) Limited technical assistance capacity and lack of science-based decision-support tools for landowners
  - (ii) Lack of financial support for transition and establishment
  - (iii) Lack of risk management services and services tailored to long-term perennial agriculture systems
  - (iv) Limited market development and market access

(v) Absence of local supply chain infrastructure

(vi) Need for value chain development of perennial agriculture inputs, products and markets. perennial agriculture inputs, products and markets.

Addressing barriers to adoption

- Barriers to adoption of perennial agriculture systems could be addressed through:

  (i) **Expanding technical assistance**—Build state technical capacity through expansion of place-based, "train-the-trainer" technical assistance programs that provide peer-led training opportunities, create decision-support tools and enable peer-to-peer knowledge exchange.

  (ii) **Advancing rural economic development**—Leverage the goals of rural agricultural economic areas to develop stronger public-private partnerships with corporations sourcing agricultural products that align with net-zero goals and invest in geographically-clustered perennial-food hubs to direct capital toward critical supply chain infrastructure and value chain development.

  (iii) **Deploying blended finance mechanisms**—Expand public-private-civic partnerships, pooled public-private capital funds and strategic-impact investments to support diversified crop production and value chain development.

- Public policy changes to reduce barriers and encourage adoption of agricultural systems and management practices that move Wisconsin toward net-zero emissions include:

  (i) Aligning incentive programs and state technical assistance to promote agricultural systems and management practices with the greatest GHG-reduction potential.

  (ii) Reducing transition costs for farmers.

  (iii) Supporting rural economic development opportunities that strengthen public-private partnerships and invest in perennial supply chain infrastructure and value chain development.

  (v) Attracting private investment and coordinate blended public-private finance mechanisms to capitalize agricultural system transitions.

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Introduction

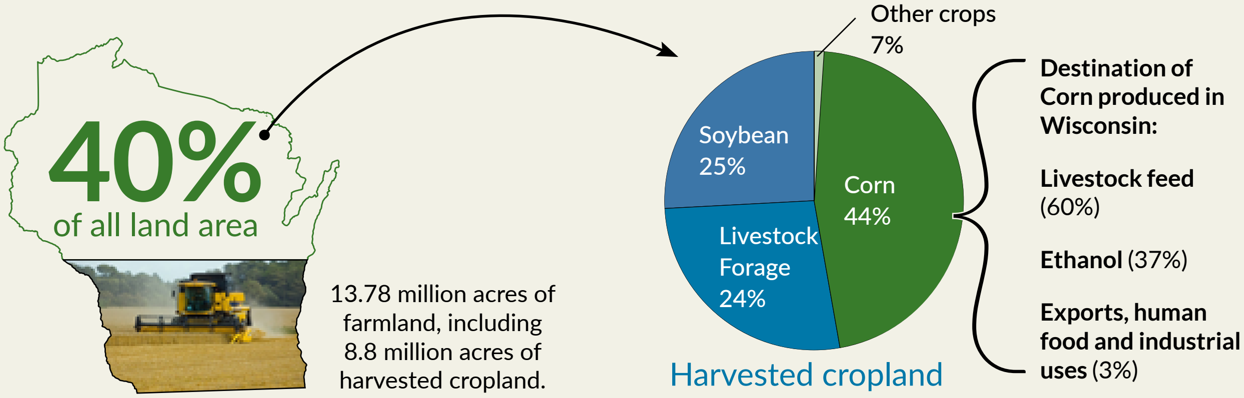
Wisconsin agriculture is a cornerstone of the state economy, generating $116.3 billion annually—14.3% of the total state economy—and supporting 353,900 jobs across on-farm and processing activities (DATCP 2025, Deller & Hadacheck 2024). The agricultural sector contributes $21.2 billion in labor income and $37.8 billion in state income, making it one of Wisconsin's most powerful economic drivers. Agriculture is also the state's third largest source of greenhouse gas (GHG) emissions (15%). While emissions from all other sectors decreased between 2005 and 2018, agricultural emissions increased by a staggering 21.3%, releasing an additional 3.5 MMT CO_2 equivalents (CO_2e) into the atmosphere (OSCE 2022, WDNR 2021).

High and rising GHG emissions intensify climate impacts causing extensive economic and environmental damage that harm agricultural productivity and rural communities. Increases in the frequency and intensity of rainfall events flood crop fields and erode topsoil, droughts decimate crop yields, and seasonal weather variations intensify pest pressure and stress livestock health (Kucharik et al. 2023, Kucharik & Walling 2021). Wisconsin agriculture alone experiences GHG-related damages estimated between $902 million and $3.3 billion annually (Deller & Hadacheck 2022).

At the same time, consumer demand for sustainably produced food products has never been higher. Nearly two-thirds of U.S. consumers now expect companies to source sustainably (ADM 2023), driving major corporations to commit to regenerative practices across their supply chains.

Positioning Wisconsin farms to be resilient to our changing climate will mean adapting and transitioning our crop rotations and management practices to those that can thrive productively under future projected climate conditions while simultaneously reducing agriculture's GHG emissions, protecting water quality, improving soil health, mitigating climate impacts like flooding and drought, and supporting the economic and social wellbeing of rural communities. Agriculture's economic significance, rising climate costs, and shifting consumer demand underscore the opportunity for program and policy action that can assist producers in the transition to climate-resilient, regenerative agroecosystems that grow rural livelihoods, prosperity, health, and wellbeing while securing the state's long-term economic competitiveness.

Agricultural Land in Wisconsin



Less than 3% of harvested cropland is used for the production of fruits and vegetables grown for human consumption.

Adapted from USDA-NASS 2024, Wisconsin Corn Growers Association 2024.

Relevant GHG Inventory Sector: Agriculture/Natural and Working Lands

Cumulative GHG emission reductions 2025–2030: 0.6 MMT CO_2e

Cumulative GHG emission reductions 2025–2050: 1.5 MMT CO_2e

From: OSCE, 2022. Measure 6: Agriculture and Soil Solutions, p35. *Wisconsin Emissions Reduction Roadmap.* Office of Sustainability and Clean Energy, Wisconsin Department of Administration. *Accessed 2025.*

Promote Soil Carbon Intensity Best Practices

Model: Energy Policy Simulator	**2025** (million metric tons CO_2e)	**2030** (million metric tons CO_2e)	**2050** (million metric tons CO_2e)
Business as Usual	113.5	111.0	106.1
GHG Emissions with Measure	-	110.4	104.6
Reduction from Base Year 2025	-	3.1	8.9
Reduction from Business as Usual	-	0.6	1.5

From: OSCE, 2022. Appendix A: Quantified Emissions Background, p. 43. *Wisconsin Emissions Reduction Roadmap.* Office of Sustainability and Clean Energy, Wisconsin Department of Administration. *Accessed 2025.*

In 2019, Governor Evers signed Executive Order #38 committing the State of Wisconsin to reducing GHG emissions by 50-52% by 2030 and achieving net-zero emissions by 2050, which would fulfill the U.S. Climate Alliance's GHG-reduction goals outlined by the 2015 Paris Climate Accord. That same year, he created the Governor's Task Force on Climate Change (GTFCC) to identify policies to reduce GHG emissions across all sectors (see GTFCC 2020), and authorized the Wisconsin Department of Administration to create an Office of Sustainability and Clean Energy (OSCE) to partner with other state agencies and utilities to develop the Wisconsin Emissions Reduction Roadmap (OSCE 2022). The documents recommended using existing state programs and funding to pay farmers to increase soil carbon storage in agricultural and working lands using practices like no-till farming, short-season cover crops and nitrogen-fertilizer management (OSCE 2022; GTFCC 2020, p52). These programs included:

- Producer-Led Watershed Protection Grant Program
- Commercial Nitrogen Optimization Pilot Program
- Crop Insurance Premium Rebates for Planting Cover Crops
- Nutrient Management Farmer Education

State and federal agricultural programs have already invested millions to incentivize adoption of practices like no-till farming, short-season cover crops and nitrogen fertilizer optimization—practices collectively referred to as "conservation agriculture" that provide significant positive benefits for farmers and the environment by reducing soil erosion, runoff and leaching of nutrients to surface and groundwater.

But can these practices alone fulfill Wisconsin's goal of net-zero emissions by 2050 in the agricultural sector?

Using scientific studies and data most applicable to Wisconsin, the NCS Roadmap evaluates the potential for the practices prioritized in state climate action plans (cover crops, no-till farming and nutrient management) as well as alternative systems (agroforestry, perennial row crops and managed grazing) to contribute to net-zero goals. Using per-acre GHG reduction potential data, we assessed a suite of agricultural systems and practices to determine their relative effectiveness on a per-acre basis. Working in consultation with state and regional agricultural experts, we then calculated how many acres of each practice, production system or combinations of each would achieve net-zero emissions in Wisconsin's agricultural sector. Evaluating multiple scenarios for adoption of these production systems and management practices sheds light on which combinations could make the most progress toward the state's climate commitment.

This work is, to our knowledge, the first effort to explicitly illustrate what it would take to achieve net-zero agriculture in Wisconsin using NCS. As a first-of-its-kind analysis, we recognize that there are additional agricultural practices, systems, and combinations thereof that are possible (see Appendix A for more detailed discussion of analysis limitations). **Additionally, our**

analysis does not attempt to incorporate the extremely important socio-economic implications of widespread transitions described in this report. Instead, we hope that the NCS Roadmap can serve as a foundation from which future analyses can build and improve upon.

While the first section of the NCS Roadmap identifies conceptual **pathways for agricultural transition** toward emissions neutrality, the second section focuses on **actions needed** to support their implementation. To illuminate some of the existing barriers to expansion of specific perennial agriculture systems, *Clean Wisconsin* partnered with the *Michael Fields Agricultural Institute*, the *Savanna Institute* and UW-Madison-based *Grassland 2.0* to conduct two-year pilot projects focused on supporting adoption of a particular perennial crop (Kernza® grain) or system (managed grazing) and the development of a science-based tool to inform perennial agricultural transition decisions (agroforestry crops, emerging herbaceous crops and commodity crops).

Natural Climate Solution Case Studies:

- **Perennial grain**—Establish a Kernza® Supply Chain Hub in Wisconsin that provides technical assistance and expands markets for small-scale early adopters of Kernza®, a dual-use intermediate wheatgrass grown for food-grade grain and livestock forage. The hub expands local processing capacity and coordinates the supply chain among growers, processors, and end-users (e.g. breweries, distilleries, bakeries) to increase both supply and demand for Wisconsin-grown Kernza®.
- **Managed grazing**—Demonstrate how managed grazing of beef and dairy can improve profitability, water quality, and emissions reductions, while gauging stakeholder interest in expanding development of these practices through a regional Learning Hub in Wisconsin's Lake Michigan Basin.
- **Perennial and annual crop decision-support tool**—Develop a science-based decision-support tool to map, evaluate and compare changing crop suitability for over 30 crops—including tree crops, emerging and existing perennial and annual crops —under future projected climate conditions.

These pilot projects help illuminate many of the on-the-ground opportunities and challenges facing adopters of perennial agriculture. Case studies drawn from these pilot projects are used throughout this report to describe existing barriers for farmers and supply chain actors and opportunities to use public policy to support perennial crop production. The accompanying NCS Toolkit contains extensive supporting materials including technical support documents, analysis methodology and other resources developed by each pilot project to inform strategies and on-the-ground actions to increase adoption of these agricultural systems.

Our project provides a scientific and policy roadmap to work toward net-zero greenhouse gas emissions in Wisconsin's agricultural sector.

What are Natural Climate Solutions?

Natural Climate Solutions (NCS) are systems and practices for the management, restoration and protection of natural ecosystems and working landscapes, including agricultural land (agroecosystems). NCS *measurably* reduce emissions of greenhouse gases and sequester atmospheric carbon into soils and above- and below-ground biomass ***for the long term***. Climate mitigation is a main benefit of NCS, but these practices also improve soil health, water quality, biodiversity and resilience to climate shocks and extreme weather events. They also strengthen the resiliency of agricultural communities and rural economies.

IMAGE: Natural Resources Conservation Service (NRCS). N.d. *Soil Health*. Department of Agriculture, Trade and Consumer Protection. https://datcp.wi.gov/Pages/Programs_Services/SoilHealth.aspx

Greenhouse Gas Reduction Potential of Wisconsin Agriculture:
Assessing Pathways to Net-Zero

According to the Wisconsin Department of Natural Resources's (WDNR's) 2021 GHG Emissions Inventory, Wisconsin's agricultural sector is responsible for 19.1 MMT CO_2e of GHG emissions annually, largely in the form of emissions from livestock (enteric fermentation and manure) and agricultural soils (Figure 1).[1,2] The NCS Roadmap project set off to evaluate the role natural climate solutions could play in reaching net-zero GHG emissions in the agricultural sector by 2050 by quantifying the climate-change mitigation potential of the following agricultural practices and crop system changes:

- Adopting cover crops and no-till practices on existing annual cropland.
- Reducing nitrogen fertilizer use.
- Establishing perennial row crops or agroforestry systems.
- Incorporating trees (silvopasture) and improving grazing management on existing pasture.
- Shifting dairy manure management practices towards less liquid management or capturing manure methane emissions.
- Shifting milk production from confined feeding to rotationally-managed pasture-based milk production.
- Applying woody biomass biochar amendments to agricultural fields.

Existing quantifications of the potential agricultural management practices to offset or reduce greenhouse gas emission have mainly been conducted at the global or national scale (e.g., Griscom et al. 2017, Fargione et al. 2018, Walton Family Foundation 2022). Analyses that use practice-specific carbon sequestration rates or emissions factors derived from national or global datasets may not reflect the conditions in Wisconsin. Generalizing about an agricultural practice's ability to mitigate climate change is highly uncertain and sequestration rates are very site- and context-specific. Furthermore, soil carbon change and GHG emissions are highly variable in time and space, meaning the same unit of soil, managed in the same way, can be a net source or a net sink on a daily, monthly, yearly, and decadal basis. Thus, not all estimates of sequestration or emission reduction potential accurately represent Wisconsin's conditions. For example, while Nature4Climate's *United States NCS Mapper* applies the sequestration and emissions factors from a national analysis (Fargione et al. 2018) to individual states to provide a state-level estimate, a single global or national value used to inform this tool may not accurately reflect the climatic and geographic conditions in Wisconsin.

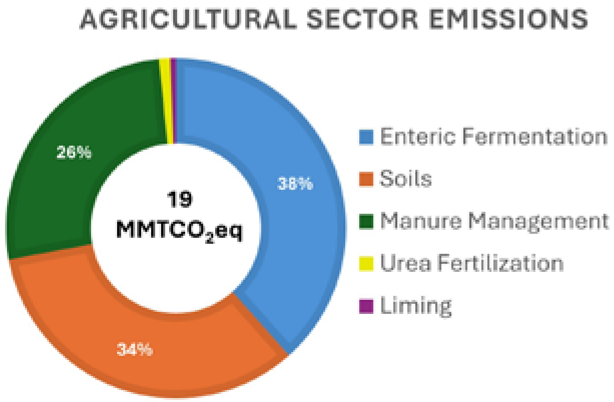


Figure 1. Wisconsin's Agricultural Sector Emissions. *Adapted from* WDNR (2021). Table 11. Agriculture Emissions ($MMTCO_2e$)[2] *In*: 2021 Wisconsin greenhouse gas emissions inventory report. Wisconsin Department of Natural Resources. Madison, Wisconsin. P15.

[1] *Note:* Because the WDNR GHG inventory does not attribute emissions from on-farm fuel or electricity use to the agricultural sector, they are not included in our analysis.

[2] We updated total emissions to address a recognized error in the underlying WDNR inventory model that double-counted manure emissions from pastures, reducing total sector emission from 19.9 MMT to 19.1 MMT CO_2eq of GHG emissions.

Similarly, the *Carbon Reduction Potential Evaluation* (CaRPE) tool provides interactive quantification of some agricultural practices at the state and county level. This tool, however, also relies on a single estimate of the mitigation potential of modeled practices (the *COMET model*). While this model provides useful insight, it lacks significant field validation and only models the surface 30 cm of soil, likely resulting in overestimation of the soil carbon sequestration potential of several conservation practices.

In contrast, the NCS Roadmap relies on published estimates most appropriate to Wisconsin (i.e., studies specific to Wisconsin or areas climatically similar to Wisconsin) for its analyses and we include a range of values to account for the potential variability in carbon storage and emission reduction of practices assessed. This work is, to our knowledge, the first effort to quantify and evaluate what it would take to achieve net-zero emissions in Wisconsin agriculture using currently available technologies and management practices. Our analysis is fully transparent, replicable, and modifiable. Complete details on our methodology, limitations in our analyses and further discussion can be found in the Appendix A: GHG and Scenarios Analyses. As a first-of-its-kind analysis, we recognize that there are additional agricultural practices, systems and combinations that are possible and hope that this assessment can serve as a foundation from which future analyses can build and improve. **No one scenario is intended to be prescriptive, but rather the analysis is intended to illustrate the relative efficacy of different practices and crop production systems and establish an evidence-based foundation for discussions around the climate impact of agricultural policy in the state.**

Evaluating mitigation potential of agricultural practices and systems in Wisconsin

Our evaluation sought to estimate the GHG-reduction potential of the conservation agriculture practices (cover crops, no-till farming and improved nitrogen management) prioritized in Wisconsin's state climate action plan as well as other agricultural systems (agroforestry, perennial row crops and managed grazing) and management practices (biochar amendments, improved manure management) less commonly considered at the state-level. This work represents our best interpretation of the available science and its application to Wisconsin.

Understanding the efficacy of individual practices on a per-acre basis is a key first step to determine the total potential for reducing agricultural emissions in Wisconsin. Because the carbon sequestration potential of agricultural practices is highly dependent on local climate and soil conditions, we compiled a database of carbon sequestration rates using published studies relevant to Wisconsin climatic and geologic conditions to evaluate the sequestration potential of no-till farming, cover crops and conversion of annual row crops to perennial or agroforestry systems. From these reported values,

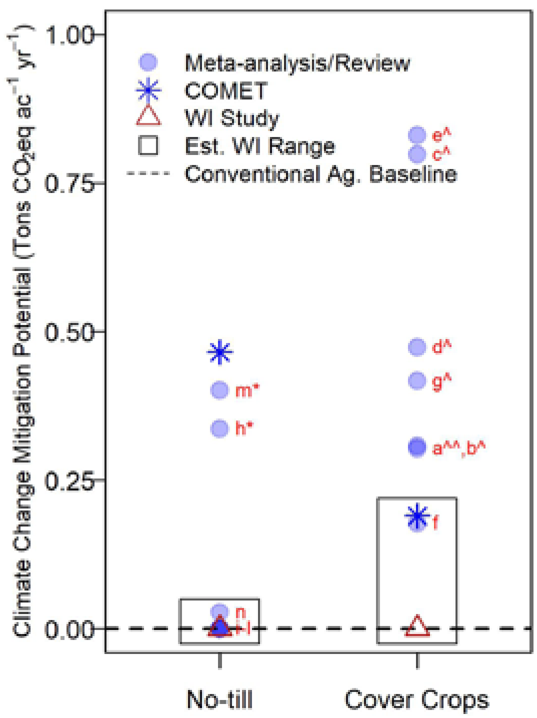


Figure 2. Detailed per-acre GHG mitigation potential of cover crops and no-till, as reported in the literature and existing models.

* indicates studies that report sequestration within the surface 30 cm of soil, only.

Δ identifies Wisconsin-specific findings from Arlington Field Station (Dietz et al. 2024).

^ indicates values reported in global studies

^^ indicates values reported in temperate subsets of global studies.

Study code: [a]McClelland et al., [b]King & Blesh, [c]Abdalla et al, [d]Poeplau & Don, [e]Jian et al., [f]Blanco-Canqui, [g]Joshi et al., [h]Virto et al., [i]-lLiang et al., Meurer et al., Haddaway et al, Luo et al., [m]Ogle et al., [n]Drever et al. The COMET results are averaged county-level estimates from COMET Planner.

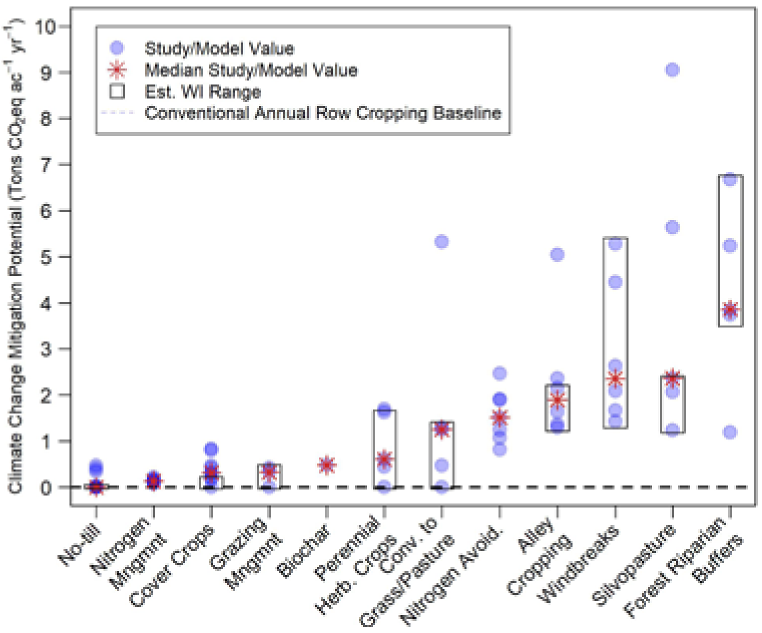


Figure 3. Per-acre GHG mitigation potential of field-based practices, as reported in published literature for no-till and cover crops (left) and the full suite of field-based agriculture practices (right). *Nitrogen Management* values represent the N_2O reduction associated with a 20% reduction in nitrogen fertilizer use across all cropland statewide. *Nitrogen Avoidance* reflects conversion from corn (assuming 180 pounds N fertilizer per year; Laboski & Peters 2012) to a land use that does not use nitrogen fertilizer. The range of values within the table indicate the best estimates for Wisconsin that were used in our analysis. *See Appendix A for rationale behind the selected range of values.*

Table 1. Per-acre GHG mitigation potential of field-based practices from published literature or existing models as shown in Figure 3, including those determined to be most appropriate to Wisconsin's climate and soil conditions. All units are metric tons CO_2e per acre per year.

Practice	Total Range	Median Value	Est. Wisconsin Range
No-till	0-0.47	0.00	0-0.03
Nitrogen Management[A]	0.07-0.22	0.14	0.07*
Cover Crops	0-0.83	0.31	0-0.18
Grazing Management	0-0.42	0.32	0-0.42
Woody Biomass Biochar[B]	0.48	0.48	0.48
Perennial Herbaceous Crops	0-1.69	0.61	0-1.26
Conversion to Pasture	0-5.33	1.25	0-1.30
Avoided Nitrogen Fertilizer[C]	0.81-2.46	1.51	0.81*
Alley Cropping	1.29-5.05	1.89	1.29-2.19
Windbreaks	1.42-5.28	2.35	1.42-5.28
Silvopasture	1.23-9.05	2.36	1.23-2.36
Forested Riparian Buffers	1.19-6.68	3.86	3.74-6.68

[A] GHG emission reductions associated with a 20% reduction in nitrogen (N) use across all cropland statewide

[B] Assuming 0.2 tons can be incorporated into the plow layer per acre per year (Woolf et al. 2010).

[C] Represents GHG emissions reductions associated with converting one acre of corn to land that does not use any N fertilizer input (assuming 180 pounds of N fertilizer per year; Laboski & Peters 2012)

*Used same value as the WDNR GHG inventory to maintain consistency with the baseline inventory.

we identified a potential range of carbon sequestration rates appropriate for Wisconsin. Similarly, we compiled reported GHG reductions from avoided nitrogen fertilizer use; in our analysis, however, we use emission factors from the WDNR GHG inventory to ensure consistency with the baseline inventory. For the potential carbon storage of biochar application to cropland, we use the approach recommended by IPCC 2019.

Using the per-acre GHG-reduction potential of an individual agricultural production system or management practice, and change in GHG-reduction potential through converting from annual to perennial crops, we can estimate the mitigation potential of these practices when applied across Wisconsin's agricultural landbase under different adoption rate scenarios. To do this, we developed adoption scenarios that varied in the type and acreage of practice adoption and multiplied the per-acre GHG-reduction potential rate by the acreage of adoption in a given scenario to arrive at a total reduction potential for that combination of practices. For example, if we use a soil carbon sequestration rate of 0.18 tons CO_2e per acre for establishment of cover crops and assume a scenario in which cover crops are used on 1 million acres of cropland, this scenario could generate a total mitigation potential of 180,000 tons of CO_2e.

Some scenarios incorporate practices to reduce livestock emissions such as capturing manure-methane emissions or pasture-based livestock rearing in addition to the field-based practices that we previously described. We use livestock-emission factors from the WDNR GHG inventory to ensure consistency with the baseline inventory.

For each practice, we defined two adoption scenarios: an optimal upper estimate that assumes high rates of adoption of the practice across Wisconsin and a more conservative lower estimate that assumes modest increases in practice adoption by Wisconsin farms. Table 2 further describes how scenarios were progressively and additively built. **No one scenario is intended to be prescriptive, but rather the analysis is intended to be illustrative of how stacking conservation agriculture and/or crop systems changes could influence agricultural GHG emissions over time.** Adoption scenarios were informed by historical land-use and management change and discussions with pilot-project partners and state and regional agricultural experts familiar with the on-the-ground realities of these practices and management implications. However, others may want to use alternative assumptions or scenarios, which can be done using the spreadsheet tool included in our NCS Toolkit. Complete details on our methodology, limitations in our analyses and further discussion can be found in the Appendix A: GHG and Scenarios Analyses.

Scenarios 1-4: "Working within the current system"

We first created and modeled a set of adoption scenarios that include practices currently being incorporated into Wisconsin's annual row cropping and confinement dairy production systems at various rates. In Scenario 1, we evaluated the GHG-mitigation potential of cover crops and no-till farming if adoption continues at the rates seen between 2012[3]–2022 and then projected those rates out to 2050. For Scenarios 2–4, we added a 20% reduction in use of nitrogen fertilizer (Scenario 2) and manure management changes, including increased use

A note on enteric emissions

Enteric emissions are a major source of GHG emissions in the state, representing a third of all emissions from the agricultural sector (WDNR 2021). Considerable interest in use of feed additives and supplements to reduce these emissions has resulted in some promising innovations, such as 3-NOP with data indicating enteric emissions reductions over 30% can be achieved (Dijkstra et al. 2018, Kebreab et al. 2023). Studies to date, however, are short-term (up to several months) and the long-term efficacy of supplements in reducing enteric emissions is highly uncertain. Indeed, some of the longer-term studies indicate that emissions begin to return to baseline levels over time as the rumen microbial community adjusts to the supplement (Melgar et al. 2020, 2021, Schilde et al. 2021). As such, we do not consider supplements to represent a feasible option for long-term emissions reductions at this point in time. Further study is needed to establish feed additives as an important and effective tool for potential GHG reductions. Lowering enteric fermentation emissions through innovative efforts like animal breeding for lower methane production provide evidence that enteric reductions up to 24% from selective breeding are possible by 2050 (Bell et al. 2010, de Haas et al. 2021).

[3] The USDA's Census of Agriculture began reporting no-till and cover crop acreage in the 2012 census. Thus we use data from the 2012, 2017, and 2022 census years to establish our historical adoption rates.

of liquid-solid-separation technology (Scenario 3, lower) or installing anaerobic digesters on large farms and covering and flaring manure storage lagoons (Scenario 3, upper). Finally, we stacked on applications of biochar soil amendments at recommended rates and improved grazing practices on existing pastures (Scenario 4).

Scenarios 5-6+: "Transition to perennial agriculture"

In our second set of scenarios, we examined the potential GHG mitigation if acreage currently used to grow annual row crops (e.g. corn and soybeans) *for non-food or livestock feed* (e.g. ethanol or other industrial uses) were transitioned into perennial systems (e.g. perennial row crops and agroforestry systems like alley crops, windbreaks and riparian buffers) or introduced trees in existing pasture (silvopasture).

In Scenario 5, we looked at the conversion of a portion of current corn and soybean acreage to perennial crops and agroforestry systems, while assuming 100% adoption of cover crops + no-till + 20% reduction in use of nitrogen fertilizer + recommended application rates of biochar amendments + improved grazing scenarios on the remaining annual cropland and pastures.

Scenario 6 includes everything from Scenario 5 and adds manure management changes. While a 24% reduction in enteric emissions from milk cows added to Scenario 6

Table 2. Summary of scenarios and lower/upper estimates of Total GHG reduction potential (million metric tons of CO_2e).

CC = Cover crop adoption; NT = no-till adoption; N = nitrogen fertilizer management.
See Appendix A, Table A.19 for more specific inputs into each scenario.

Working within current system				Transition to perennial agriculture* *Excluding transition to grassfed milk production			Transition to perennial agriculture + Transition to grassfed milk production		
Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 6 +	Scenario 7	Scenario 8	Scenario 9
CC + NT	(Scenario 1) + N	(Scenario 2) + Manure Management	(Scenario 3) + Biochar + Improved Grazing	Conversion to perennial systems + CC + NT + N + Biochar on all remaining cropland + Improved Grazing	(Scenario 5) + Manure Management	(Scenario 6) + Avoided enteric/ manure emissions (via reducing dairy food waste by 50%) to reach net-zero	(Scenario 5) + Maintain current milk production but shift 25-47% milk production to grassfed.	(Scenario 5) + Shift to 100% grassfed milk production while maintaining the current milk cow herd size	(Scenario 5) + Shift to 100% grassfed milk production only using current dairy milk production land base
Lower: 0 - 1.15 MMT Upper: 0 - 1.17 MMT	*Lower: 0 - 1.5 MMT Upper: 0.64 - 1.81 MMT*	*Lower: 0.75 - 0.90 MMT Upper: 3.30 - 4.47 MMT*	*Lower: 1.75 - 2.04 MMT Upper: 5.30 - 6.47 MMT*	*Lower: 4.10 - 6.20 MMT Upper: 8.81 - 15.28 MMT*	*Lower: 4.85 - 6.95 MMT Upper: 11.47 - 17.94 MMT*	*Lower: 4.85 - 6.95 MMT Upper: 11.47 - 19.14 MMT*	*Lower: 4.09 - 7.30 MMT Upper: 6.74 - 13.78 MMT*	*Lower: 9.71 - 13.80 MMT Upper: 12.87 - 20.08 MMT*	*Lower: 11.78 - 14.99 MMT Upper: 16.48 - 23.87 MMT*

Table 3. Summary of total acres and rationale for NCS practice adoption used in our analyses under the low and high adoption scenarios. Conversion for most practices here refers to conversion of current corn and soybean acreage *not currently used for livestock or human feed* (3.2 million total acres) to each NCS practice listed. The exceptions are *silvopasture*, which represent the acres of existing pasture that trees are added to, and *grazing optimization*, which refers to the number of current pasture acreage (1.1 million total acreage) that could have improved grazing management.

NCS Practice	Lower Adoption Rate (acres)	Brief Rationale	Upper Adoption Rate (acres)	Brief Rationale
Conversion of annual cropland to perennial row crops	240,000	Equivalent to an established commodity crop (wheat)	840,000* *240,000 when including 47% transition to grassfed dairy	Replacing remaining available corn and soybean acres not used for livestock feed in the state
Conversion of annual row crops to solar arrays maintained with native grasses	100,000	Acreage needed for 50% implementation of utility scale solar required for 100% carbon free electricity generation in state	200,000	Acreage needed for full implementation of utility scale solar required for 100% carbon free electricity generation in state
Forested riparian buffer establishment	71,323	Non-forage agricultural land within 50 feet of waterbodies	261,350	Non-forage agricultural land within 200 feet of waterbodies
Windbreak establishment	77,000	5% of erosion-prone cropland in the state	438,000	5% of all cropland using economically-beneficial threshold
Alley cropping	876,000	10% of current cropland	1,476,000* *876,000 when including 47% transition to grassfed dairy	Replacing remaining available corn and soybean acres not used for livestock feed in the state
Silvopasture	112,000	10% of existing pasture	564,000	60% of existing pasture on historically forested or savanna land
Grazing management	335,764	30% of existing pasture	671,527	60% of existing pasture
Expanded pasture from transitioning dairy production to grassfed	644,444	Transitioning 25% of current milk production	1,200,000	Transitioning 47% of current milk production
"Conservation" agriculture practices	Cover Crops: 573,472 No-till: 1,907,040	Projection from 2012-2022 trends	Cover crops: 1.8m - 2.667 million No-till: 160k - 1.014 million*	100% adoption of cover crop and no-till practices on all harvested annual cropland remaining, following conversion to NCS crops in a given scenario
Nitrogen management	Nitrogen fertilizer application reduction from converting annual row crop acreages as outlined in each scenario to NCS crops + a 20% reduction in nitrogen use on remaining cropland			
Biochar	Annual application of 420,000-840,000 tons of biochar to remaining cropland (applied at a rate of 0.2 tons per acre per year)**			

* The greater conversion to perennial crops reduces the amount of potential new acres of no-till compared to the lower adoption rate. We don't see the same thing with cover crops because the current cover crop adoption rate is much lower than that for no-till adoption; even with the more aggressive transition to perennials, there are still more available cropland acres that don't currently have cover crops.

** The acreage on which biochar is applied varies by scenario, but in all scenarios there is more than enough cropland to apply biochar at the recommended rate. The GHG-reduction potential is calculated on a per-unit feedstock basis rather than a per-acre basis.

would close the gap to 100% net-zero in the agricultural sector, we maintain that continued research on innovative tools for reducing enteric emissions is needed. Instead, we chose to address the remaining 6% emissions from Scenario 6 by evaluating the reduction of current dairy product food waste (Scenario 6+).

Scenarios 7-9: "Transition to perennial agriculture + Transition to grassfed milk production"

Finally, to consider pathways towards supporting dairy agroecosystems for multiple outcomes, we explored scenarios that stacked transitions of confinement dairy production to pasture-based, grassfed milk production on top of the other conversions and practice changes in prior scenarios. These scenarios include maintaining current milk production levels but shifting 25-47% of milk production from confinement to grassfed systems (Scenario 7); shifting 100% of the current milk cow herd in Wisconsin to grassfed systems (Scenario 8); and lowering total milk production to the amount that can be produced by the number of grassfed cows that can be supported on the acreage currently growing feed for confinement livestock operations (Scenario 9).

Note: In scenarios that do not include a shift towards grassfed dairy production (Scenarios 1–6), we only considered conversion of corn and soybean acreage not used for feeding livestock in the state (e.g. corn grown for ethanol production, surplus or exported corn or soybeans). This provided 3.2 million acres available for conversion to perennial systems without affecting land needed for livestock-feed production. When modeling acreage needed to support a transition from confinement to grassfed dairy production (Scenarios 7–9), we do take into account the cropland currently used to feed confined cows. We also apply an ecological bounding condition where agroforestry is not implemented on land that was prairie in original land-survey records from the mid-1800s. This placed no practical limitation on conversion from cropland to agroforestry but did limit total pasture-to-silvopasture conversion to 963,000 acres. A summary of the range of practice adoptions is provided in Table 3.

Evaluating Pathways to Achieve Net-Zero Emissions in Wisconsin Agriculture

The results of our analysis illuminate key themes around the efficacy of current "climate-smart" approaches and reveal the sobering reality of the magnitude of change required to achieve ambitious net-zero goals by 2050. We summarize the per-acre mitigation potential of each practice and system in Figures 2 and 3, and the results of the adoption scenarios evaluated (total mitigation potential) in Table 4 and Figure 5. It is important to recognize that the results of our analysis are limited by the practices and systems evaluated, and the scenarios conceptualized. Furthermore, they strictly adhere to ecological outcomes without comprehensive economic analyses to weigh in on the implications of these pathways to Wisconsin's agricultural communities and economy over the near-, mid- and long-term. We strongly encourage further socio-economic evaluation to complement our analyses and better inform strategic planning. Nevertheless, our analysis and the following results demonstrate the need to at least consider a broader suite of agricultural practices and cropping systems to inform and meaningfully direct the state towards net-zero goals.

"Working within the current system"

Conventional row crop production systems alone are ineffective at storing soil carbon long-term. Incorporating conservation agriculture practices like no-till and cover crops into conventional agricultural systems can provide a modest reduction in GHG-emissions on a per-acre basis (Figure 2). However, relying only on increasing historic adoption rates of conservation agriculture practices cannot sequester enough soil carbon to offset agricultural emissions by 2050 (Table 4, Figure 5). At best, no-till and cover crops can only offset up to 6% of total agricultural emissions. Even if the state climate plan for agriculture was fully implemented on all land currently in annual crop production (100% adoption of cover crops and no-till practices, and a 20% reduction in nitrogen fertilizer use), total agricultural emissions would only be offset by 9%. If we then consider all the practices that could theoretically be incorporated into conventional row crop production systems and confined dairy production and apply carbon sequestration rates of cover crops and no-till practices, optimized nitrogen-fertilizer applications and improved manure management to all acreage currently used for these systems in Wisconsin, *and* we added annual applications of biochar soil amendments and improved grazing practices on existing pastures, current agricultural emissions could only be offset by 35% (see Scenario 4 in Table 4, Figure 5). This finding highlights the reality that if Wisconsin intends to meet its agricultural climate goals and directly address the costly and intensifying GHG-related impacts and damages, it cannot be done through incremental improvements to the existing agricultural production. Other practices and agricultural systems need to be considered relative to our priorities for safeguarding environmental, economic and social wellbeing in Wisconsin for the long-term.

"Transition to perennial agriculture"

When we consider a broader suite of agricultural practices and cropping system changes suitable for Wisconsin, it becomes clear that transitioning annual cropland into **perennial agricultural systems offer substantially higher GHG-reduction potential on a per-acre basis than no-till farming or cover crops** (Figure 3). Moreover, our scenario for a conservative transition to perennial systems, coupled with aggressive reductions in manure emissions by adding anaerobic digesters to all large farms (more than 1,000 milk cows) could offset up to 51% of total agricultural emissions. Our scenario for a more ambitious, widespread transition to perennial systems, coupled with digesters on large farms, illustrates a potential to offset up to 94% of agricultural emissions (see Scenario 6 in Table 4, Figure 5). Reducing current dairy food waste (by 50%) in addition to optimal adoption rates of Scenario 6 would theoretically address total agricultural emissions and achieve net-zero goals (Scenario 6+). However, this increase in efficiency would also reduce total milk production by 10%.

"Transition to perennial agriculture + Transition to grassfed milk production"

In consideration of supporting dairy agroecosystems for multiple outcomes, we do find a potential for exceeding net-zero goals and pathways for Wisconsin agriculture to become a net-sink of GHG emissions (sequestering more emissions than it emits). Maintaining current milk-cow herd sizes but shifting them to 100% grassfed, coupled with an exceedingly more aggressive transition to perennial systems, has the potential to offset up to 105% of total agricultural emissions (*See* Scenario 8 in Table 4, Figure 5). This shift, however, would result in a

Table 4. Percent of agricultural sector emissions offset in adoption scenarios by 2050

Scenario		Percent of WI Ag Emissions Offset
	"Business as Usual"	
1a	Current adoption rates of no-till (65%) + cover crop (20%) practices on annual cropland[4]	0-1%
	Incrementally Improved "Business as Usual"	
1b	**100% adoption of no-till + cover crops on** all available annual cropland[4]	0-6%
2	(Scenario 1b) + **20% reduction in nitrogen fertilizer** applications, statewide	3-9%
3	(Scenario 2) + **Manure management (anaerobic digesters)**	17-23%
4	(Scenario 3) + **Biochar + improved grazing on existing pastures**	28-34%
	Transitions to Perennial Agriculture Excluding Transition To Grassfed Milk Production	
5	**Conversion to perennial systems + CC + NT + N + Biochar + Improved Grazing**	22-80%
	Scenario 5a: Low NCS adoption	21-32%
	Scenario 5b: High NCS adoption	46-80%
6	**(Scenario 5) + Manure management**	25-94%
	(Scenario 5a) + Manure management (solid - liquid separation)	25-36%
	(Scenario 5b) + Manure management (anaerobic digesters)	60-94%
6+	(Scenario 6) + **10% milk reduction via dairy food waste reduction (by 50%)**	66-100%
	Transitions to Perennial Agriculture Including Transitions To Grassfed Milk Production	
7	(Scenario 5a) + **Shift 25% current milk production to grassfed.**	21-38%
	(Scenario 5b) + **Shift 47% current milk production to grassfed.**	35-72%
8	(Scenario 5b) + **Shift to 100% grassfed milk production while maintaining the current milk cow herd size**	67-105%
9	(Scenario 5b) + **Shift to 100% grassfed milk production only using current dairy milk production land base,** reducing total dairy herd size proportionally.	86-125%

[4] Scenario 1a extrapolates from current (2012-2022) adoption rates of 1% increase per year for no-till and 0.3% increase per year for cover crop practices, to project that by 2050, 65% of cropland is farmed using no-till practices and 20% has cover crops.

Comparing GHG emissions from dairy agroecosystems for multiple outcomes

Greenhouse gas emissions from the dairy industry represent a large portion of total emissions from the agricultural sector in Wisconsin. The specific management practices on a farm determine its carbon footprint, primarily from feeding and manure management practices. Most published comparisons of the carbon balance of dairy agroecosystems (e.g., comparing confinement production to grassfed production) do so on the basis of carbon intensity, which is the amount of greenhouse gases emitted per unit of milk produced (Aguirre-Villegas et al. 2022). This approach biases comparisons by privileging higher-yielding production systems and can lead to higher absolute GHG emissions (Bartlett et al. 2023, van der Werf et al. 2020). This GHG accounting assumes milk scarcity, that we must produce more milk, and that producing more always results in positive outcomes for farmers and society. These assumptions do not hold for Wisconsin dairy (Jackson 2024). Here, we provide an alternative accounting, which starts with the assumption that the land provides a fundamental limit to the amount of livestock that can be supported sustainably, and that this limit (sometimes referred to as 'carrying capacity') is best represented by land in perennial grass being rotationally grazed by large herbivores approximating the original prairie/savanna biome. We make this assumption based on decades of research showing that this type of agroecosystem builds soil (Becker et al. 2022, Rui et al. 2022), retains nutrients (Wepking et al. 2022, Jackson 2020), reduces flooding (Basche and DeLonge 2017, Basche and Edelson 2017), almost eliminates the need for antibiotic use on livestock and pesticide use on the land, and when managed intentionally, can enhance trout, pollinator, and bird abundance (Lyons et al. 2000a, Lyons et al. 2000b, Temple et al. 1999). A coarse accounting of net GHG emissions from these competing systems shows the managed livestock grazing approach produces nearly one-quarter lower emissions per acre than the confined and fed livestock approach (Figure 4). Enteric fermentation drives most of the emissions in the grazing system, while manure lagoons drive most of the confinement emissions, followed by enteric emissions of the larger confined herd.

The well-managed livestock grazing approach to dairy has repeatedly been shown to be more profitable than the confined and fed approach (Winsten 2024, Wiedenfeld et al. 2022, Dartt et al. 1999), which certainly produces more milk overall, but with higher costs to the farmer (i.e., lower profit) and higher costs to society (i.e., global warming, water pollution, flood exacerbation, biodiversity reduction, and reduced human health and well-being) (Spratt et al. 2021, Franzluebbers et al. 2012).

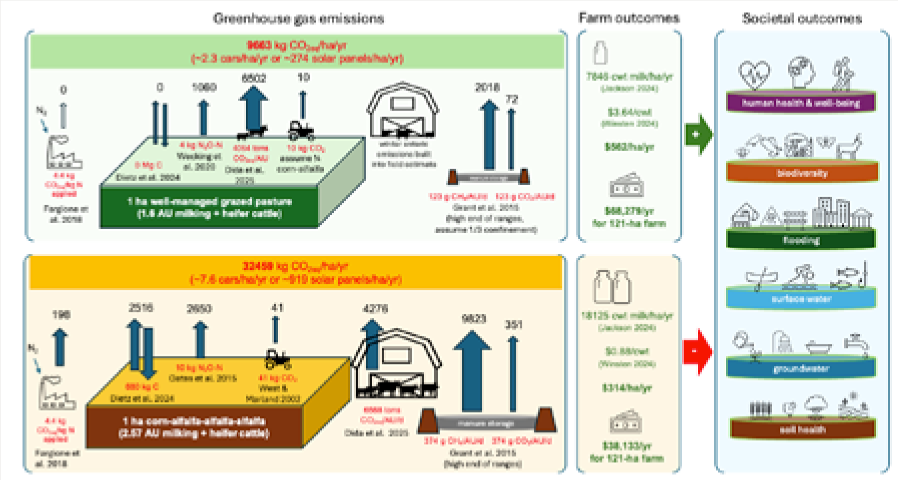


Figure 4. Comparison of GHG emissions, farm production and profit outcomes, and societal outcomes from one hectare (2.47 acres) of land supporting dairy (milk cows + replacement heifers) with either well-managed livestock grazing on perennial pasture or a corn-alfalfa-alfalfa-alfalfa rotation producing feed for confined livestock[5]. GHG emissions are summed for each system then related to CO_2e for typical car use and for typical solar panel installation per the US EPA GHG equivalencies calculator. Per hectare farm production and profit outcomes are scaled to a 121-ha farm and societal outcomes are depicted qualitatively, but quantitative documentation of evidence-base for these outcomes is available.

[5] Dietz et al. 2024, Jackson 2024, Winsten 2024, Jackson 2022, Fargione et al. 2018, Grant et al. 2015.

42% reduction in milk production since grassfed cows are less productive than confined cows. Similarly, limiting milk production to that which can be produced by 100% grassfed cows on the land area currently used for dairy production, coupled with the more aggressive transition to perennial systems could offset up to 125% of agricultural emissions (Scenario 9). However, this approach would result in a 56% reduction in milk production. Economic implications of reduced milk production are complex and would have impacts on global supply and export markets, and would need considerable additional assessment to understand the repercussions of such a significant supply reduction. Such an assessment was outside this report's GHG emission scope.

We emphasize that no one scenario is intended to be prescriptive, but rather the analysis is intended to illustrate the relative efficacy of different practices and establish an evidence-based foundation for discussions around the climate impact of agricultural policy in the state. With that context in mind, we can look at what this analysis reveals with respect to specific pathways for reaching net-zero.

A note on anaerobic digesters

Manure management is an important source of methane and nitrous oxide emissions in Wisconsin, accounting for 25% of GHG emissions from the agricultural sector (5 MMT CO_2e). The majority of emissions from manure management (i.e., not including emissions once manure is landspread) are generated during manure storage which releases methane. Methane is a potent greenhouse gas, with a global warming potential 80x that of CO_2 in the short-term (25 years) and 25x that of CO_2 in the long term (100 years). Methane is produced by the bacterial breakdown of volatile solids in manure when stored under anaerobic conditions. Warm, anaerobic, water-based conditions are most conducive to methane production.

GHG emissions from manure management in Wisconsin have tripled since 1990 and are responsible for half of the agricultural sector's increase in emissions since 2005. While milk production per cow has also increased, manure management emissions per unit of milk increased by 50% between 1990 (0.2 Mg CO_2e per Mg milk produced) and 2018 (0.31 Mg CO_2e per Mg milk). The increase was largely driven by the shift away from daily spreading and solid storage of manure on smaller farms (methane conversion factor of <5%) to manure storage lagoons and deep pits at larger farms, which create anaerobic conditions that promote methane conversion (methane conversion factors of 24-68%).

One approach to addressing this major source of GHG emissions is to capture and utilize methane released by anaerobic lagoons by incorporating anaerobic digesters on the state's largest livestock farms. Digesters intentionally create optimal conditions for methane production, but instead of releasing the methane to the atmosphere, the methane is captured and used for energy generation on- or off-farm. Best estimates for the methane conversion factors (MCF) for digesters range from 0-10%, depending on the type and quality of digester which is a significant improvement on the 67% MCF for anaerobic lagoons, and provides an opportunity to substantially reduce GHG emissions in the state.

Expanding the use of anaerobic digesters on livestock farms is not without challenges and implications for the dairy industry. Digesters are currently only practical on large farms that can produce a sufficient quantity of manure to keep digesters running and justify the high cost of construction and complexity of operation. Thus, addressing manure emissions via this route reinforces the current and historical trends of farm consolidation in the dairy industry, creating numerous serious social, economic and environmental issues that go beyond this report's narrow focus on GHG emissions and should be explored further.

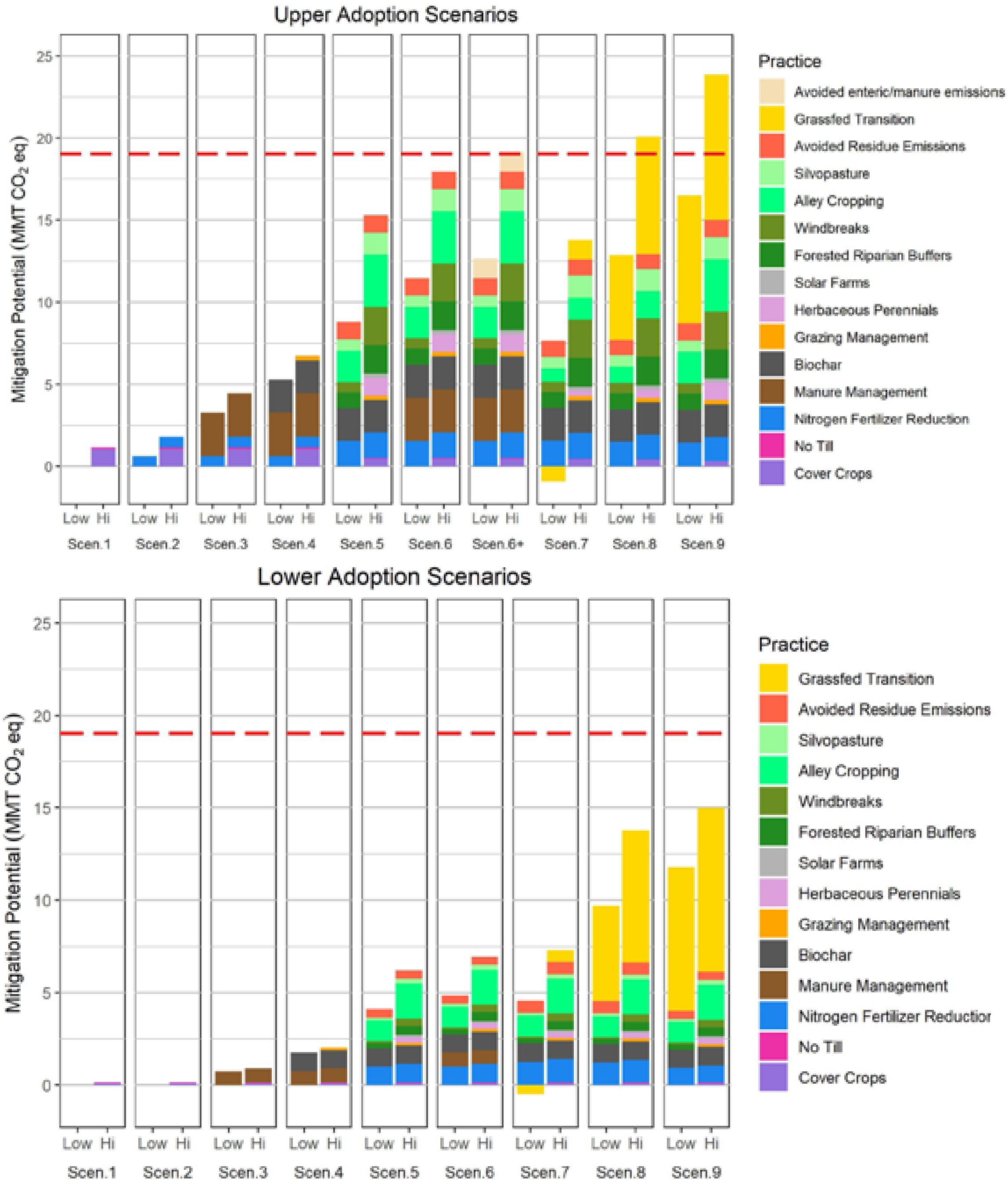


Figure 5. Greenhouse gas mitigation potential under Upper Adoption Rate Scenarios (top) and Lower Adoption Rate Scenarios (bottom). In the *Lower Adoption Rate Scenarios*, estimates assume more conservative increases in practice adoption on Wisconsin farms. The *Upper Adoption Rate Scenarios* uses an optimal upper estimate that assumes complete or nearly-complete adoption across all applicable acreage in Wisconsin. The horizontal dashed red line indicates the total agricultural sector emissions in the 2021 WDNR GHG Inventory. Scenarios are described in Table 2. Each scenario includes an upper (*hi*) and lower (*low)* range of mitigation potential estimates for each practice in Wisconsin (see Table 1 for range of practice-specific mitigation potential rates)*.

* *Note*: In Scenario 7, the low estimate for shifting 25-47% of milk production from confined to grassfed systems results in a net increase in GHG emissions due to the assumption that there is no soil carbon sequestration when converting row crops to pasture. However, when assuming that there is soil carbon sequestration, this shift can result in a net decrease in GHG emissions, as shown in the high estimate for Scenario 7.

Scenarios 6+, 8 and 9 are the only scenarios evaluated that, under high adoption rates, reveal the potential to meet or exceed net-zero goals using existing agricultural practices and technologies. All three scenarios are similar in that they would require:

- 100% adoption of no-till and cover crop practices
- 20% reduction in nitrogen fertilizer use on all remaining cropland
- Widespread use of biochar soil amendments
- Improved grazing practices on existing pasture
- Widespread adoption of perennial agriculture practices (30-43% of current annual cropland)

The three scenarios diverge in how each approaches managing emissions from livestock.

Scenario 6+ indicates the potential to offset 100% of total agricultural emissions *only if* agroforestry systems and perennial row crops are widely adopted (1.86 million to 3.02 million acres, or 13–22% of current agricultural land-use) and all confined livestock facilities with greater than 1,000 milk cows install anaerobic digesters and dairy food waste is reduced by 50% which would stimulate a 10% reduction in statewide milk production due to reduced overall demand.

Scenarios 8 and 9 indicate the potential to exceed net-zero emission goals in the agricultural sector and mitigate more emissions than it releases only if dairy production shifts to 100% grassfed milk production (850,000–1.5 million acres converted from annual crop production, or 6–11% of current agricultural land-use). Shifting to grassfed milk production has the potential to offset up to 105–125% of Wisconsin's agricultural GHG emissions by either maintaining the current milk cow herd size (Scenario 8) or reducing the herd size to what can be supported by pasture (known as "carrying capacity") on all land currently being used for dairy production[6], including the acreage currently grown for livestock feed, (Scenario 9). Notably, because grassfed cows produce less milk, Scenario 9 results in a 42-57% reduction in milk production if the same amount of land used to produce feed for dairy cattle now is put into well-managed grazed pasture (Jackson 2024). But as Jackson (2024) argues, this approach has been shown to be ~2 to 4 times more profitable (albeit less productive) than the confined livestock production method (Winsten 2024, Wiedenfeld 2022) and putting more land into perennial grassland has massive benefits to soil, water, air, and biodiversity (Franzluebbers et al. 2012, Spratt et al. 2021, Rotz et al. 2009), so while ambitious, this approach should not be dismissed.

Table 5. Total agricultural land-use change needed to meet net-zero goals in Wisconsin[7]

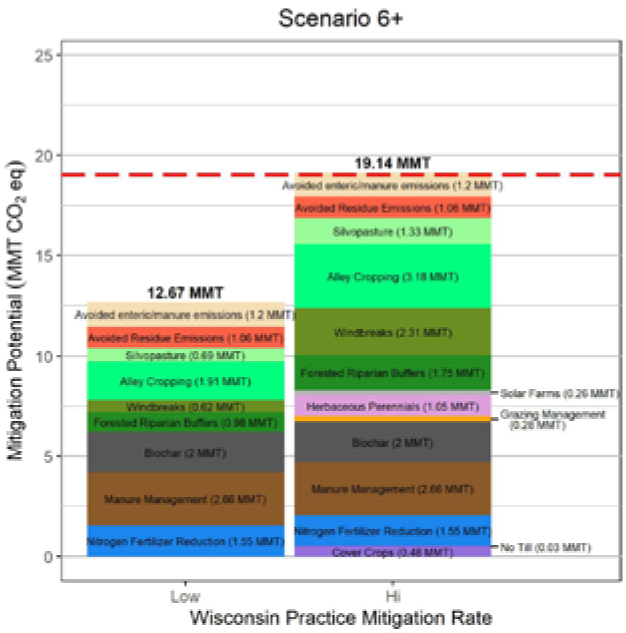
Land-use change[8]	% total ag land	Acres converted to NCS
Annual cropland converted to **solar arrays**	1%	200,000 acres
Annual cropland converted to **perennial row crops**	3-6%	390,000 - 840,000 acres
Existing pasture converted to well-managed **rotational grazing and silvopasture**	9%	1,240,000 acres
Annual cropland converted to **grassfed milk production**	6-11%	850,000 - 1,500,000 acres
Annual cropland converted to **agroforestry**	11-16%	1,470,000 - 2,180,000 acres
Total land-use change	***30-43%***	***4,150,000 - 5,960,000 acres***

We recognize that realistically, the land-use change and management transitions identified within the limitations of our analysis are unlikely to be achieved by 2050. However, they are still valuable in terms of clarifying the scope of agricultural transition needed if we are serious about making meaningful reductions to agricultural emissions.

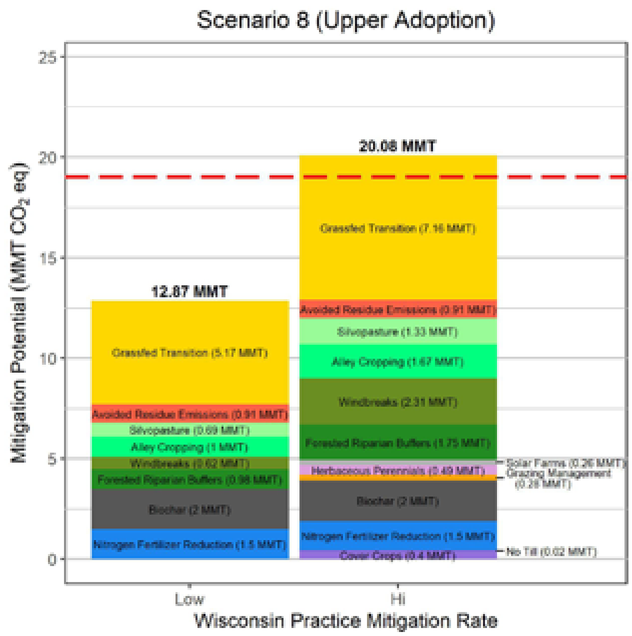
[6] "All land currently being used for dairy production" means all crop acreage used to grow feed for dairy cows. This is defined in more detail in Appendix A: GHG and Scenarios Analyses.

[7] As of the 2022 USDA Census of Agriculture, Wisconsin has 13.8 million acres in agricultural land-use.

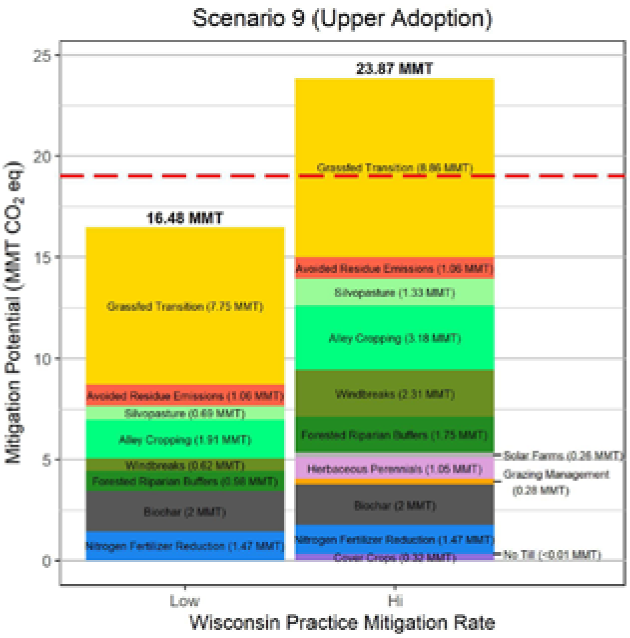
[8] 'Annual cropland' denotes current acreage of corn and soybean not produced for food or livestock feed (3.2 million total acreage as of 2022 USDA Census of Agriculture).



Total greenhouse gas reduction potential				
Scenario 6 GHG reduction	+	10% milk production reduction (i.e. halving dairy food waste) to reduce both enteric and manure emissions	=	**19.14 MMT CO_2e**
17.94 MMT CO_2e		1.2 MMT CO_2e		



Total greenhouse gas reduction potential		
Scenario 8 GHG reduction	=	**20.08 MMT CO_2e**



Total greenhouse gas reduction potential		
Scenario 9 GHG reduction	=	**23.87 MMT CO_2e**

Figure 6. Total GHG reduction potential for a transition to perennial agriculture + grassfed milk production (optimal, upper adoption rates)

Summary of Key Findings:

In sum, there are no easy or quick solutions and ultimately significant changes to Wisconsin's current agricultural production systems are needed to achieve Wisconsin's climate goals for the sector.

- The soil carbon sequestration potential of no-till and cover crop practices on annual cropland in Wisconsin is limited.

  (i) Studies that only look at the surface 30 cm of soil, and nationally-used tools like COMET that aggregate and model those studies likely *overestimate the soil carbon sequestration potential of no-till and cover crop practices on annual cropland in Wisconsin*.

  (ii) Existing models aggregate national averages across all states, including those with very different climate, geologic and ecological contexts from Wisconsin. To make informed decisions, *we must use the best available data that is representative of cool, humid temperate climates like Wisconsin*.

  (iii) The potential for no-till practices and cover crops to sequester CO_2e is highly variable depending on soil type and duration of growing season[9]. Because of Wisconsin's relatively short growing season, warm-season cover crop rotations are not in place long enough to achieve the substantial climate benefits ascribed to them in states with longer growing seasons (Chenyang et al. 2021, Ogle et al. 2019).

  (iv) Using our best estimates for GHG reduction potential of these practices in Wisconsin, **cover crop and no-till practices alone only offset up to 6% of agricultural emissions**, even if 100% adoption across all annual cropland is achieved. Relying only on increasing adoption of "conservation agriculture" practices like no-till and cover crops at historic adoption rates cannot sequester enough soil carbon to offset agricultural emissions by 2050 (Table 4, Figure 5).

  (v) We emphasize that there are important s*oil health* and *water quality* benefits to using cover crops and no-till practices, which may have additional economic benefits for producers. However, any soil carbon sequestration benefit of these practices should most appropriately be considered a modest co-benefit rather than a primary purpose.

Relying only on increasing adoption of "conservation agriculture" practices like no-till and cover crops cannot sequester enough soil carbon to offset agricultural emissions by 2050.

- **Reductions in use of nitrogen fertilizer are critical to achieve net-zero in agriculture.**

  (i) In contrast to the uncertainties of soil carbon sequestration and the delayed timeline for agroforestry sequestration benefits, reducing use of nitrogen fertilizer will have a known, positive and immediate impact on agricultural emissions.

- **Working exclusively within the current dominant paradigm of annual row crops and confined dairy production *only offsets up to 35% of total sector emissions*** at best, illustrating the need to move beyond mere adjustments to the current system in order to make meaningful progress towards net-zero agriculture in the state.

  (i) Practices that can be incorporated into the current system include no-till, cover cropping, nitrogen fertilizer reductions, biochar soil amendments, grazing optimization, and improved manure management. Even maximizing the potential of these practices falls far short of net-zero.

- **Large-scale transition to perennial systems is essential to meeting net-zero goals in the sector.**

[9] The surface 30cm of soil is where carbon accumulates in the form of decomposing organic matter. This surface-level carbon isn't necessarily stored for the long-term (sequestration) with small-statured, short-living, shallow-rooted herbaceous plants (i.e. annual cover crops) like it is with large statured, long-living, deep-rooted woody plants (tree crops). Therefore, carbon sequestration from agroforestry systems is more certain, with most of the carbon sequestration potential coming from above- and below-ground biomass of these long living, deep rooted woody species (Chenyang et al. 2021).

(i) Perennial systems have greater potential for soil carbon sequestration than adopting no-till and/or cover crops on annual cropland.

(ii) Agroforestry, in addition to potential soil carbon increases, has significant biomass sequestration potential, representing an important opportunity in a state largely forested historically.

(iii) In addition to increased carbon sequestration potential, perennial systems are less nitrogen fertilizer intensive than corn, representing an opportunity for further nitrogen fertilizer reductions beyond those that could be realized through improved nitrogen management or use efficiency on annual crops alone.

(iv) We have identified acreage in annual row crops not used to feed livestock or humans in Wisconsin that could be made available for such a transformative transition, underscoring its feasibility should the necessary supply chains and markets be developed..

- **Wisconsin cannot achieve net-zero emissions in the agricultural sector without significant reductions in livestock emissions** (manure and enteric emissions):

(i) Emissions from **enteric fermentation and manure represent nearly two-thirds of agricultural emissions**. Carbon sequestration in cropland soils and perennial biomass production alone are insufficient to offset these emissions.

(ii) Continuing to support and maintain a dairy production system that maximizes efficiency and production **will require technological solutions** to reducing livestock emissions such as manure digesters and feed supplements to reduce enteric emissions, in tandem with resetting production needs after addressing food waste on the consumer side.

(iii) Alternatively, shifting towards a grassfed dairy production that aligns milk production with the carrying capacity of the land provides significant GHG emission reductions, along with numerous other social, environmental and economic benefits. However, it also comes with significant milk production reductions compared to current levels, the consequences of which need further examination beyond the scope of this project.

Wisconsin cannot achieve net-zero emissions goals in the agricultural sector without widespread transition to perennial agriculture systems and significant changes to livestock management.

Roadblocks to the Roadmap:
Key Barriers to Adoption of Natural Climate Solutions in Wisconsin

Now that we have identified agricultural systems and practices with the greatest potential to reduce agricultural emissions (natural climate solutions) and outlined conceptual adoption scenarios across the landscape, we can take a closer look at what it will theoretically take to expand adoption of natural climate solutions to meet or exceed net-zero emissions goals in Wisconsin's agricultural sector.

Each of the adoption scenarios that could achieve net-zero by 2050 contemplate widespread adoption of perennial agriculture and livestock management changes by transitioning:

- Existing pasture to well-managed **rotational grazing and silvopasture** (1.24 million acres)
- **3-6%** of total annual cropland currently used for corn/soybean not grown for food or livestock feed to **perennial row crops** (390,000–840,000 acres)
- **6-11%** of of total annual cropland currently used for corn/soybean not grown for food or livestock feed to **grassfed dairy and beef** (850,000–1.5 million acres)
- **11-16%** of total annual cropland currently used for corn/soybean not grown for food or livestock feed to **agroforestry systems and tree crops** (1.47–2.18 million acres)

The scenarios in which net-zero is achieved require transitions that we recognize are unrealistically achievable by 2050 given current political and socio-economic realities; however they are still valuable in terms of illustrating the scope of transition needed and the current barriers to adoption of perennial agriculture and livestock management changes if we are serious about reaching net-zero and avoiding adverse and costly climate impacts. Understanding the conditions creating these barriers can help us identify strategies to better leverage current political and socio-economic realities and more effectively expand adoption of natural climate solutions in a transition towards a more climate-resilient agricultural sector.

Agricultural food systems are highly complex, inter-connected and influenced by global trade economies, political dynamics and broader generational (cultural) norms. This complex landscape presents Wisconsin farmers with a confusing web of economic, social and environmental challenges to navigate that informs their decision-making and ability to adopt alternative agricultural practices, particularly for perennial cropping and grazing systems. **Our analysis was informed by the experiences shared by Wisconsin farmers, processors and end-users during our two-year pilot projects, by discussions with state and regional perennial agriculture leaders, and by published literature and the systems-level strategies currently at play within the wider regenerative food system movement—regionally, nationally and globally.**

The summary tables below reflect common challenges and barriers to adoption of perennial systems and practices in Wisconsin, at different scales of interaction: on-farm, off-farm (middle of the supply chain and markets) and enabling conditions (statewide). Because of the complexity of agricultural food systems and systemic barriers exist at various scales simultaneously, several barriers intentionally appear within multiple tables. Other broader systemic barriers (e.g. global economic markets, federal agricultural policy, cultural norms, etc.) are intentionally withheld to simplify interpretation and to instead focus on highlighting the most actionable levers within the state within this broader context.

Further detailed analysis can be found in Appendix B: Barriers to Adoption of NCS in Wisconsin.

Farm-operation level

Table 6. Barriers to NCS: *Farm-operation level*

Barrier	Summary of Key Issues	Additional References
Land Access & Tenure	Industry consolidation, aging farmers and exurban pressures for farmland conversion increase long-term tenure challenges, especially for renting farmers and those historically marginalized. Rising land costs and fragile, short-term leases limit wider adoption of perennial agriculture.	Hadacheck & Deller 2025, USDA-ERS 2025a, World Economic Forum 2024, USDA-NASS 2024b, USDA-NASS 2023, American Farmland Trust 2022, Lowe et al. 2023
Availability of Plant Stock	Underfunded public R&D delays regionally adapted, market-ready perennial cultivars. Absence of cultivar propagation centers and tree crop nurseries limits distribution and increases material costs for perennial system establishment.	Midwest Hazelnuts 2025, Savanna Institute 2025, Bennell et al. 2021
Technical Assistance Capacity	Farmers need peer-led, place-based in-field training and technical assistance, support from communities of practice, and science-based decision-support tools for long-term planning. Demand for technical assistance for agroforestry, rotational grazing and perennial grains currently exceeds available funding and capacity.	Savanna Institute 2025, WI Land & Water 2025, Fudge et al. 2025, Bogado et al. 2024, World Economic Forum 2024, Lowe et al. 2023, NRCS 2023, Savanna Institute 2023, Bennell et al. 2021
Transition Costs & Risk Management	Perennials face high upfront costs and delayed returns, often requiring specialized equipment; conventional production equipment cannot be easily adapted to fit the need. Traditional lenders and insurance programs are structured to favor annual commodities with familiar risk-profiles, historical yield data and fast returns, and are misaligned to the multi-phase transition needs and costs, long-term risk-profiles and co-benefits of perennial systems. Long-term yield data may be lacking, resulting in high insurance rates and minimal or partial coverage.	Environmental Working Group 2025, TIFS 2025a, World Economic Forum 2024, Bennell et al. 2021,NSAC 2023, USDA-ERS 2025b, Agroforestry Partners 2024, Asprooth et al. 2024, USDA-RMA 2024, Environmental and Energy Study Institute 2022, O'Neill & Kerska 2021, USDA-FSA 2019
Market Access	Commodity markets offer few opportunities for perennial crops. Corporate market entry is uncertain and can be cost-prohibitive for small- or medium-sized farms (e.g. certifications, verification processes). Perennial farmers navigate new and underdeveloped markets, uncertain demand, with limited entrepreneurial support or resources to develop new products. Consumer awareness of benefits of perennial crops (e.g. health benefits, nutrient density, flavor profiles, etc.) is generally low. Grass-fed supply-demand mismatches persist.	Grassland 2.0 2025, Savanna Institute 2025, USDA-ERS 2025c, Ecotone Analytics 2023
Processing & Distribution	Lack of local or regional processing forces long-distance transport, raising costs and emissions, and leaves many producers underserved.	MFAI 2025, Savanna 2025, Grassland 2.0 2025, DATCP 2024b, Bennell et al. 2021

Supply chain-level

Table 7. Barriers to NCS Adoption: *Off-farm processing, aggregation, distribution and markets*

Barrier	Summary of Key Issues	Additional References
Existing Supply Chain Infrastructure	Existing state assets for commodity and specialty supply chains provide a foundation for small grains, emerging nuts and berries and grassfed milk/meat products, but are insufficient statewide. Significant infrastructure gaps constrain access, limit market entry for producers and stall value-chain development of emerging climate-resilient crops and systems.	MFAI 2025, RFSI 2025, Savanna Institute 2025, Grassland 2.0 2025, DATCP 2024b, Ecotone Analytics et al. 2023, Bennell et al. 2021
High Establishment & Operating Costs	Specialized equipment and infrastructure is expensive (e.g. dehusking, steam-flaking, de-stemmers, juice presses, refrigeration/freezers, food-grade dry storage, refrigerated transport); most rural and small businesses cannot front costs or take out high-interest business loans. Small/mid-tier processors face higher per-unit operation costs than large-scale facilities, raising costs for producers and consumers and reducing competitiveness.	MFAI 2025, Savanna Institute 2025, Bennell et al. 2021
Industry Standards & Market Access	Emerging perennial crops face underdeveloped markets. High entry costs for organic or regenerative certification (ROC) and inconsistent grading standards disrupt supply chain efficiency and reduce buyer certainty. Market development is needed to create consistent grading standards and product specifications, develop new products, diversify market opportunities and to strengthen supply chains of perennial crops and systems.	Savanna Institute 2025, MFAI 2025, Grassland 2.0 2025, Bennell et al. 2021
Marketing & Distribution Support	Post-harvest handlers and food businesses must navigate emerging markets, develop new products, and manage operations. Farmers and entrepreneurs need access to business development, marketing, and traceability tools. Low consumer awareness of Wisconsin perennial crops (hazelnuts, aronia, elderberry, Kernza®) reduces market pull.	Savanna Institute 2025, MFAI 2025, Ecotone Analytics et al. 2023, Bennell et al. 2021,
Capital & Financing	Many rural and small businesses cannot meet match requirements for infrastructure grants. Federal programs (e.g. USDA's Resilient Food Systems Infrastructure Grant (RFSI) and Specialty Crop Block Grant (SCBG)) are highly competitive and oversubscribed, leaving many viable rural businesses under-capitalized. Lack of early-stage subsidies and dedicated capital pools delays processing infrastructure, adoption, and rural job creation. Restrictions on soft-cost spending (project management, technical assistance, networking) further limit impact.	MFAI 2025, RFSI 2025, Savanna Institute 2025, World Economic Forum 2024, Bennell et al. 2021, Food Systems Leadership Network n.d.
Value Chain Coordination	Producers, processors, and buyers often operate independently, lacking a centralized system to coordinate efforts or share information. Restrictions on soft-cost spending constrain value chain development.	RFSI 2025 Savanna Institute 2025, Bennell et al. 2021, Food Systems Leadership Network, n.d.

State systems-level

Table 8. Barriers to NCS Adoption: *State-level enabling conditions*

Barrier	Summary of Key Issues	Additional References
Applied Research, Development & Extension	Applied R&D for regionally-adapted perennial crop breeding, rapid propagation, well-managed rotational grazing systems and grassfed livestock is publicly underfunded. Lack of nutritional analyses and agro-economic data slows market adoption. Technical Assistance Providers (TAPs)—through LWCDs, NRCS, UW-Extension, UW-Madison's Grassland2.0 and NGOs like Michael Fields Agricultural Institute, the Savanna Institute and others—provide critical training and technical support but demand exceeds capacity and public funding allocation. Stable state investment is essential to maintain and expand long-term food security and the state's technical capacity.	WI Land & Water 2025, Fischbach & Mirsky 2024, USDA-NRCS 2023b, Savanna Institute 2023
Existing Policies & Programs	Existing state agricultural policies and programs fail to target high-impact climate-smart practices, are oversubscribed and underfunded. Strategic program and capital coordination is needed to direct state financial and human resources into transitioning existing systems for climate resiliency, with expanded priority, eligibility and capital pools for natural climate solutions practices and systems.	*See* Appendix D: NCS Roadmap Policy Recommendations
Risk Management & Insurance	Federal crop insurance favors annual commodity crops; perennial crops and NCS practices face minimal, expensive, or partial coverage. Pre-disaster mitigation programs lack explicit incentives for agricultural climate solutions. Farmers face uncertainty about which outcomes should be prioritized and how progress should be measured or monitored effectively.	NSAC 2025, USDA-ERS 2025b, Agroforestry Partners 2024, Asprooth et al. 2024, O'Neill & Kerska 2021, USDA-FSA 2019
Rural Economic Development	Absence of early-stage processing subsidies and limited funding for post-harvest equipment, processing, storage, and distribution beyond USDA programs (e.g. RFSI and SCBG, both highly competitive and oversubscribed). Grant restrictions on "soft-costs" (e.g. value chain strategic planning, project management and post-harvest technical assistance) further reduce value chain coordination. Lack of dedicated capital delays adoption, infrastructure and rural job creation.	Boyce & Deller 2025, DWD 2024
Labor & Workforce	Persistent workforce shortages in the state (~93,000 openings monthly), in part due to mismatched skills, aging rural workforce, rural transportation/housing/childcare barriers, and immigration restrictions. Existing agricultural workforce development focuses exclusively on commodity crops and livestock systems. Workforce shortages and skills gaps constrain rural economic development for perennial agriculture.	CDR.FYI 2025, RFSI 2025, PDP 2025, Sarsfield 2025, UW Ext 2025, World Economic Forum 2024, Madsen 2024, WEDC 2024, Gathering Waters 2022
Capital & Finance	Public funding places burden on public tax dollars, is oversubscribed, misaligned timing with farmer needs and/or time-consuming (grants/cost-share programs), risky (loan interest) or broadly inaccessible (bonds). Market mechanisms are not guaranteed (premiums) and/or underdeveloped (payments for ecosystem services); timing of the financial benefit may not align with immediate farm needs or transition stage (e.g. agroforestry tree crops). Corporate programs favor large-scale, simplified production systems. Private funding operates on short-duration cycles and/or traditional lender risk profiles. Public-private investment is nascent. Coordination is needed.	MFAI 2025, Savanna 2025, Grassland 2.0 2025, DATCP 2024b, Bennell et al. 2021

Levers of Opportunity

Overcoming barriers to greater adoption of perennial agriculture in Wisconsin require high-impact programs and policy drivers. Key opportunities include: (1) expanding technical assistance capacity; (2) strengthening rural economic development tied to natural climate solutions; and (3) advancing blended capital and finance mechanisms to support the agricultural transition. Below, we summarize our findings and recommendations for each of these key levers of systems-level change. Further analysis and supporting evidence for these levers of opportunity can be found in Appendix C. Levers of Opportunity to advance NCS in Wisconsin.

Lever 1:
Expansion of Technical Assistance Capacity

Perennial crops and systems have longer establishment periods than annual crops before they yield marketable returns, requiring careful decision-making and transition planning for farmers. Farmers' ability to transition agricultural practices and systems depends on access to extension services, strong farmer-to-farmer networks, perceived environmental benefits, individualized risk assessments of needs, risks and cost of farm operations, and financial and technical capacity and support (Fudge et al. 2025, Bogado et al. 2024, Lowe et al. 2023).

Technical Assistance Providers (TAPs) play a crucial role in reducing risk for individual producers by assisting them with decision-support tools and long-term planning, field transition design and establishment, and best management practices aimed at improving soil health and water quality while optimizing harvest yields and quality. Technical assistance for producer-led groups provided through in-field training, research and demonstration farms, and decision-support tools is essential for building strong farmer support networks, learning new or different management practices and for ensuring successful agricultural transitions towards optimal ecological and economic outcomes. An important part of this work is facilitation and relationship building within and across community networks and public-private sectors.

There is high demand for field-based training, technical assistance and decision-support tools tailored to agroforestry, managed grazing and perennial grains in Wisconsin, but capacity is constrained by a lack of funding for these critical tools and services. State budget allocations for critical technical assistance provided by Land and Water Conservation Districts (LWCDs), UW Extension programs and land-grant university programs like UW-Madison's *Grassland 2.0* and the *Grassland Academy* is insufficient to fulfill these needs, and recent federal budget cuts to state-administered programs like USDA-NRCS's Environmental Quality Incentives Program have significantly limited Wisconsin's agricultural technical capacity. Current state TAPs and extension services are oversubscribed and unable to meet the growing demand. Their capacity is further hindered by limited or underdeveloped science-based tools to assist in long-term decision and resilience planning—including comparisons of crop suitability under future projected climate conditions specific to farmer locations and tools to assess on-farm profitability comparisons between crops—to ensure transition planning for perennial enterprises thrive both economically and ecologically (Bennell et al. 2021).

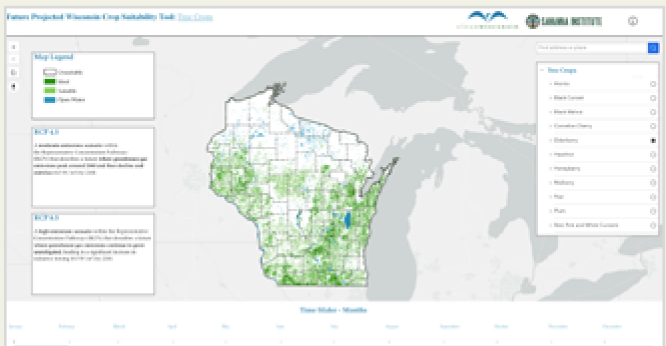
Stable, long-term public funding is necessary to support expansion of technical assistance capacity, development of science-based decision-support tools and to support the facilitation of networks of collaboration across private and public sectors to help guide the agricultural transition towards net-zero goals in Wisconsin.

The need for science-based tools to guide farm-, county- and state-level planning for the transition towards a resilient agricultural economy

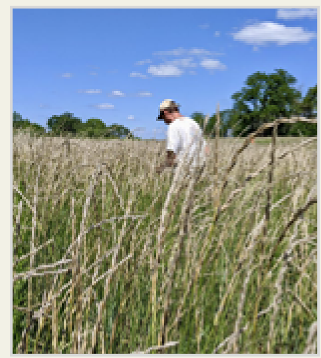
In a rapidly changing climate, farmers, crop insurance providers, technical assistance providers and state agencies need access to science-based tools to (i) better understand the climate risks to our crop commodities into the future, (ii) identify high-value alternative crops that can thrive under future projected conditions, (iii) identify strategic areas for targeted technical agricultural support, and (iv) guide long-term state planning to support transitions needed to maintain a resilient agricultural economy. Current tools, like the USDA's Plant Hardiness Zone Maps, rely on historical averages of annual minimum temperatures and **fail to fully capture current or changing 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 on a two-year pilot project to combine the best available current and future data in the development of the Future Projected Wisconsin Crop Suitability Tool (v1.0). In collaboration with the University of Wisconsin-Madison's Atmospheric and Oceanic Sciences Department and the Wisconsin Initiative on Climate Change Impacts (WICCI), 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) through 2050, under two global climate emission scenarios—RCP4.5 (where emissions begin to decline by 2040) and RCP8.5 (where emissions continue to rise at the current rate).

Young walnut trees near cornfield.
Photo credit: Savanna Institute.



Future Projected Crop Suitability Tool (v1.0).



Wisconsin Kernza® field.
Photo credit: Michael Fields Agricultural Institute.

While constraints in data availability and pilot project scope limited our ability to account for ***extreme temperature and precipitation events*** **projected to reduce corn and soybean production by 20-80%** (Rezaei et al. 2023, Environmental Defense Fund 2022, Hsiang et al. 2017, Schlenker and Roberts 2009), our tool demonstrates that **a transition towards perennial crops is possible, and may be even ideal for certain crops/counties** even under the most conservative (average) climate projections. More refined data modeling is needed.

Our pilot project provides a baseline for further development of science-based decision-support tools that account for future variations in extreme climate conditions, and—if paired with robust agroeconomic crop data—can guide both on-farm and long-term state planning and investments to support the transition towards a more resilient agricultural economy. See Case Study: Future Projected Wisconsin Crop Suitability Tool (v1.0) for more information and access to the online interactive tool.

Expanding place-based technical assistance and producer-led Learning Hubs

group of farmers, researchers, and public and private agricultural sector leaders working to develop pathways for livestock and agricultural production that gain nutrient efficiency and increase farm profitability while improving water quality, soil health, biodiversity, and climate resilience through grassland-based agriculture. *Grassland 2.0* engages with rural communities interested in managed grazing through regional learning-and-action networks called **Learning Hubs** (Figure 6). Participants in these hubs build scenarios and plans for change and share technical knowledge to overcome identified barriers to adoption of managed grazing. These efforts are assisted by decision-support tools such as the Heifer Compass, Smartscape™ and Grazescape™ to better understand the ecological and economic outcomes of their decisions, identify supply chain needs to build markets for grassfed products, and co-develop strategies that support both farm profitability and ecological health within their priority watersheds. To date, there have been three active learning hubs and five emerging Hubs in Wisconsin (Figure 6).

Figure 7. Location of *Grassland 2.0* Learning Hubs in Wisconsin and Minnesota. Dark polygons indicate more mature Learning Hubs, while grey polygons indicate emerging Learning Hubs where local communities are organizing to begin Collaborative Landscape Design process. For this project, we focused in NE Wisconsin, particularly the region west/northwest of Lake Winnebago.

In June 2024, *Grassland 2.0* began exploring the prospect of a new learning hub in northeastern Wisconsin by engaging with farmers, agency staff, NGOs, and other community partners in the northern Lake Michigan Basin. This region (focused on Oconto, Shawano, Outagamie and Winnebago Counties in the Fox-Wolf Watershed Basin) has significantly degraded water quality due to both urban industry and high concentrations of confined livestock operations in the rural areas. Over two years, *Grassland 2.0* has engaged with over 60 stakeholders to build

Figure 8. GrassStock! event banner. *From* GrassStock!, 2025.

relationships and facilitate network building and collaboration. This engagement has included area farmers, county and regional Land and Water Conservation Districts, board members and staff as well as state-based federal agency representatives (e.g. USDA-NRCS) through interviews, community meetings, farmer roundtable discussions, regional events and field days.

The demand and appetite for facilitated network and relationship building to support collaboration between farmers, technical service providers, agency staff, and non-profit organizations is very clear, and requires continuation of resources in the light of federal funding cuts and reorganizations.

> "We need these opportunities to gather, to explore options, and to share our stories of what we see on our farms and what we need to be successful."
>
> —Farmer/Community leader in Fox-Wolf Watershed Basin

NE WI Managed Grazing Learning Hub—Key Pilot Project Highlights:

2024

- Interviews with over 40 farmers, county Land and Water Conservation District and NGO staff active in the region.
- Participation in regional Land and Water Conservation District (LWCD) meetings that included staff and county board members, farmer roundtable meetings and regional field days.
- Facilitation of farm-level economic analyses of dairy heifer grazing using the Heifer Compass, with 20 Natural Resources Conservation Service (NRCS) and county conservation staff.
- Engagement with the Tribal Elder Food Box Program of the Great Lakes Intertribal Food Coalition (GLIFC), which includes distribution of grass-based proteins (beef, chicken, and bison) from both tribal and non-tribal producers, and the Wisconsin Tribal Conservation Advisory Council (WTCAC)—a key coalition participant and lead on supporting and facilitating producer training and organization to build tribal producer skills and infrastructure to support conservation practices in tribal food system development.

2025

- Co-hosted a July pasture walk featuring custom heifer grazing and the relationship between the "sending" CAFO and the custom grazier, with county LWCD staff, UW-Extension, USDA-NRCS, Golden Sands RC&D and other NGOs in the region.
- Facilitation, co-planning and event support for September "GrassStock!", an inaugural celebration of grassland-based systems held in the basin (Figure 8) with over 20 federal, county and non-profit organizations to share information with the public and to celebrate support for grassland-based systems.

See Case Study: NE WI Managed Grazing Learning Hub for more information on this pilot project and the salient opportunities for scaling dairy heifer grazing in Wisconsin.

Lever 2:
Advancement of Rural Economic Development for Natural Climate Solutions

The NCS Roadmap illuminates pathways that can save Wisconsin **$902 million to $3.3 billion annually** in avoided agricultural emissions-related damages (Deller & Hadacheck 2022, Multi-Hazard Mitigation Council 2019). These pathways can also advance rural economic development through leveraging existing and emerging market opportunities to support expanded adoption of soil-regenerating practices, improve water quality (e.g. no-till and cover cropping practices), reduce agricultural greenhouse gas emissions (e.g. nitrogen fertilizer optimization and manure management changes) and drawdown atmospheric carbon to store long-term in long-living plant bodies and soils (e.g. perennial agricultural systems like agroforestry, perennial crops and managed grazing).

Consumer demand for regenerative products is surging, with 75% of U.S. consumers expecting companies to source ingredients from farms that employ these practices (ADM 2023). Market revenues are projected to rise from $8.7 billion in 2022 to $32.3 billion by 2032, prompting major corporations to integrate regenerative practices into their supply chains (Table 9). To advance rural agroeconomic opportunities for natural climate solutions at scale—including 100% adoption of cover crops and no-till practices, and a 20% reduction in nitrogen application to annual cropland used for food and livestock-feed production—**strengthening public-private partnerships with corporations that incentivize large-scale adoption of these practices *must* be part of the solution.** As a leading agricultural state in the nation, Wisconsin is well positioned to leverage these opportunities.

At the same time, relying on corporate incentives alone will not achieve net-zero goals in Wisconsin. Small- and medium-sized farms often face significant barriers to

Table 9. Examples of corporate commitments that support NCS practices in the Midwest

Corporation	Summary of commitments	Additional Notes
Nestlé	Aims to source 50% of key ingredients through regenerative agriculture by 2030 (ADM 2023; Nestlé USA 2022).	Both companies source dairy, berries, and some nuts domestically— products central to perennial systems.
Danone North America	Regenerative agriculture program currently spans 150,000 acres and 2.4 billion pounds of dairy milk—75% of its U.S. dairy milk supply (Danone North America 2022).	
Dairy Management, Inc. (DMI)	The national dairy checkoff program (funded by mandatory dairy farmer contributions) has committed to achieving net-zero emissions by 2050 (US Dairy Net Zero Initiative 2023).	DMI and NMPF work alongside each other to advance net-zero goals in the dairy industry, high-lighting a key opportunity for WI dairy heifer grazing as an in-road to advancing adoption of grassfed livestock management.
National Milk Producers Federation (NMPF)	NMPF represents cooperative dairy processors handling more than 75% of U.S. milk and is advancing supply chain initiatives that support on-farm reductions in greenhouse gas emissions and other environmental impacts (NMPF 2024).	
Cargill	Cargill's RegenConnect program launched in 2021 to support the adoption of regenerative agriculture by connecting farmers with opportunities in environmental markets like the Soil and Water Outcomes Fund and sustainable supply chains. Cargill supports practices including cover crops, reduced tillage, nutrient optimization, grazing management and agroforestry (Cargill 2025).	Collaborates with other companies, such as McDonald's and Nestlé Purina, to implement regenerative agriculture within their respective supply chains for products like protein and pet food (Cargill 2025).
General Mills	Public-private partnership with The Land Institute and the University of Minnesota's Forever Green Initiative since 2014, to advance applied research on the GHG-reduction potential of Kernza® and to increase yields through crop breeding. Cascadian Farms began incorporating Kernza® into their certified-organic line of cereals in 2017 to advance commercialization of the perennial grain, build consumer awareness, generate excitement and increase demand for climate-beneficial foods (General Mills 2017).	In 2024, The Land Institute launched the Perennial Percent™ initiative in 2024 to encourage more food and beverage producers to use at least 1% of perennial grains in their products (The Land Institute 2024).
Patagonia Provisions	Partnered with Deschutes Brewing Co. and Sustain-A-Grain in 2016 to launch nationwide distribution of a regenerative organic-certified Kernza® Pale Ale. In 2023, launched a partner brewery program with ~20 regional breweries to brew their Kernza® Lager and the non-alcoholic Kernza® Golden Ale.	

corporate market entry (as further described in Appendix B: Barriers to Adoption of NCS in Wisconsin). In these markets, large-scale production is favored (economies of scale) which creates an economic driver for farm and industry consolidation, perpetuating the loss of smaller family-owned farms. Moreover, large-scale production favors simplified production systems, which can have a negative ecological impact—even if those production systems are perennial.

Wisconsin must adopt a "yes/and" approach to scaling natural climate solutions—one that supports the economic viability and sustainability of farms of all sizes, and safeguards biodiversity in pursuit of improved agricultural practices and net-zero goals.

Development of diversified perennial agriculture systems, such as perennial alleycropping and silvopasture, opens up new climate-friendly market opportunities for small- and medium-sized farms while also reducing individual farm risk by spreading economic risk across multiple products, protecting against market fluctuations and climate-related impacts (Raveloaritiana & Wanger 2024, Amorim et al. 2023, USDA National Agroforestry Center 2023). Perennial products—such as hazelnuts, chestnuts, Kernza®, elderberries, aronia, and grassfed dairy—fit well into diversified systems at all scales of production, and offer nutrient-dense, climate-friendly options that can command price premiums, particularly when marketed as local, organic, or value-added (Jarchow et al., 2020, Colonna et al., 2019, Muth et al., 2019). Development of perennial agricultural systems strengthens the resiliency of rural livelihoods to climate changes and can support the development of new rural industries, businesses, and jobs along the value chain. This attracts new community infrastructural investments to bolster rural economies.

However, crucial infrastructure is missing in Wisconsin to position our state to meet rising consumer demand for these products (*see* Appendix B: Barriers to Adoption). Development of **the "missing middle" of supply chain infrastructure**, such as strategically-located regional facilities for specialized processing, aggregation, product manufacturing, cold/dry storage and climate-controlled distribution, can unlock new economic opportunities for rural communities while advancing state net-zero commitments. Supply chain infrastructure provides the necessary foundation to advance commercialization of emerging perennial crops and to support sustainable development of perennial agriculture. Public-private

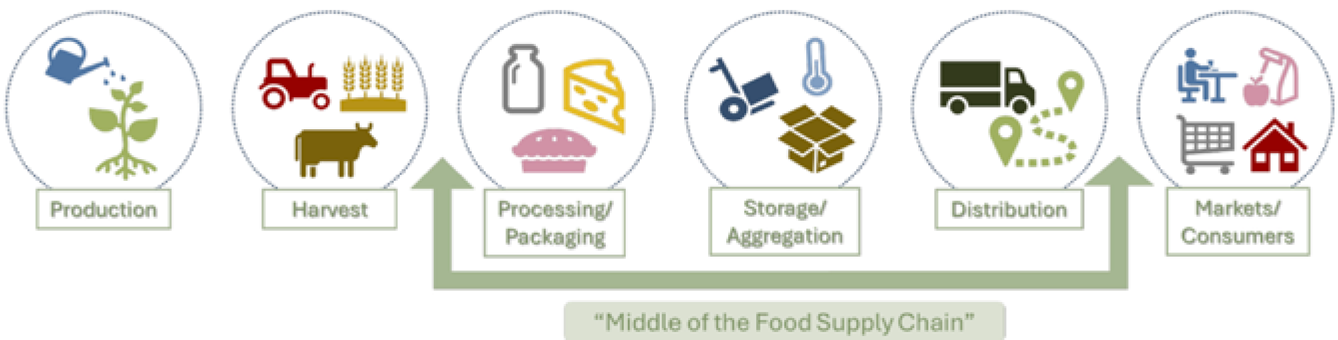


Figure 9: The "missing middle" of perennial supply chains. *From* Wisconsin Resilient Food Systems Infrastructure Program (USDA-RFSI 2025).

Supply chains are the connected network of activities, resources, and organizations involved in moving agricultural products from input suppliers (e.g., seeds, feed, soil amendments, equipment) to farmers (i.e. for production and harvesting), through processing, storage, transportation, and distribution, and finally to markets, retailers and consumers. The focus of supply chains is on logistics to ensure food and agricultural goods are produced efficiently, delivered on time, and meet market demand.

Value chains *include* supply chain infrastructure and logistics ***and add value at each stage along the way*** through development of improved cultivars (i.e. germplasm/propagation techniques), production practice differentiation and certifications (e.g. organic, regenerative), quality improvements, product development, branding and product differentiation, and/or more equitable, collaborative relationships between producers, processors and end-buyers. The focus is on the *economic, social and environmental benefits* that are created and add value along the way rather than on efficiency and logistics alone.

investment into local and regional perennial value chains is needed to achieve these rural economic goals.

Strategic investment into perennial supply chain infrastructure and value chain development can unlock new economic opportunities for rural communities while advancing state net-zero commitments.

When paired with strategic enhancements to the **value chain for perennial crops and grassfed products,** these facilities can become centralized hubs of rural agricultural industry that help remove key on- and off-farm barriers preventing wider adoption of perennial agricultural systems. Value chain development should include investments into improved crop breeding of regionally-adapted cultivars,tree crop propagation centers and commercial nurseries, field-based technical assistance for production, harvesting and post-harvest handling, financial tools, business development and marketing support.

Perennial value chain hubs stimulate rural economies by providing small- and medium-sized farms and businesses with direct-market access to local and regional end-buyers like Wisconsin restaurants, craft breweries, distilleries, bakeries, consumer-product goods and can spur local job creation in specialized processing, manufacturing, logistics and distribution services. They can be scaled as local and regional production responds to demand, and provide access to larger markets nationally and internationally. They also keep food dollars circulating in local communities, which in turn supports other local businesses (Wisconsin Food Hub Cooperative 2025).

Opportunities to further develop and replicate these and other "value chain development" models must be pursued—particularly across Wisconsin's agricultural

Table 10. Existing models of successful regional Wisconsin value chain hubs

Model	Description
Viroqua Food Enterprise Center	Developed by the Vernon Economic Development Association (est. 2009). Regional food hub that offers regional producer groups and food businesses warehouse space for food processing and aggregation, shared coolers and dock facilities, as well as business development resources like business counseling and peer mentoring. Serves 18 food- and wellness-related businesses and producer groups, including the Driftless Berry Grower Group and the aronia-elderberry juice business, Berry Adventurous®. Supports over 85 rural jobs (WDEC 2021).
Wisconsin Food Hub Cooperative	Farmer-led cooperative in Waupaca, owned by the producers and the Wisconsin Farmers Union (est. 2012). Provides critical food system infrastructure for farmers and rural communities: marketing and sales support, financial management tools, post-harvest aggregation and refrigerated storage, distribution logistics and transportation services, training and certification in food safety, group insurance coverage, and wholesale/retail market access for both crop and livestock producers (Wisconsin Food Hub Cooperative 2025).
Midwest Hazelnuts, LLC	Mission-driven, steward-owned company spun out of the Upper Midwest Hazelnut Development Initiative to build a sustainable hazelnut industry in partnership with the University of Wisconsin and University of Minnesota (est. 2007). Scales improved hazelnut genetics, supports regionally-clustered groups of growers with propagation, shared processing, and supply chain infrastructure, and works through its Go-First Farms network to demonstrate scalable, climate-friendly production that strengthens rural economies and ecosystems (Midwest Hazelnuts 2025, UMHDI 2025).
Wisconsin Kernza® Supply Chain Hub (Pilot)[10]	Collaborative initiative among Clean Wisconsin, Michael Fields Agricultural Institute, UW-Madison and Extension, Rooster Milling, and local Wisconsin Kernza® growers, aimed at overcoming supply-chain barriers for Kernza® perennial grain (est. 2024). Provides technical assistance to growers and coordinates sourcing, specialized processing, and direct-market purchasing between Wisconsin producers and businesses like Karben4 Brewing Co. to increase both supply and demand of Kernza® in the state while reducing carbon footprint of transport and distribution.

[10] Made possible by the Daybreak Fund and the Platform for Agriculture and Climate Transformation (PACT) (2023-2025).

economic areas where farmland protection is already incentivized, producer groups are geographically clustered, and rural economic development is of top priority. **Business development support services** tailored to tree crop nurseries, custom dairy heifer grazing, specialized processing facilities, food and beverage manufacturing and distribution, and market development is needed. When paired with strong partnerships between public and civic sector **technical assistance** and technical training programs tailored to the unique needs across the perennial value chain, these efforts can support rural job creation, build a skilled rural workforce trained in natural climate solutions and spur economic development in rural communities. By leveraging proven models and aligning strategically-located supply-chain infrastructure with development of perennial value chains and rural businesses, Wisconsin can support a diversity of emerging market pathways to spur adoption of natural climate solutions and advance net-zero goals.

This strategic plan, when paired with critical decision-support tools like the Future Projected Wisconsin Crop Suitability Tool (v1.0) tool, can be used to identify what crops should be prioritized for development, where those crops are projected to thrive under future climate conditions, and therefore where investment into value-chain development is needed to advance rural economic development goals most strategically across the state.

Where to begin? Scoping NCS value chain development priorities in Wisconsin

In 2024 the University of Wisconsin-Extension Emerging Crops Team released a strategic plan for accelerating the development of a suite of emerging hardy annual, perennial and agroforestry crops in Wisconsin, in collaboration with stakeholder organizations, grower groups and government entities working to support crop diversification, economic development, and soil and water stewardship in Wisconsin (Fischbach and Mirsky 2024). The analysis provides Wisconsin with tangible priorities to target high-impact investment into value chains for crops that are already in production in the state and are produced in the agricultural systems with greatest potential for significantly reducing greenhouse gas emissions in Wisconsin. Figure 9 illustrates differing levels of development priority across crops and crop types:

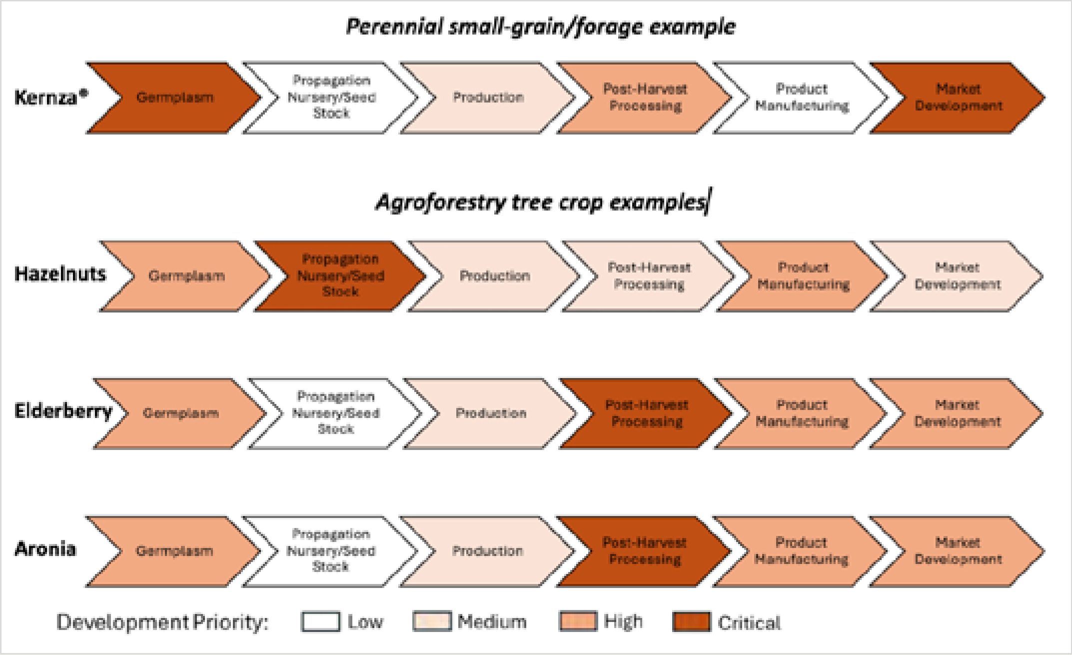


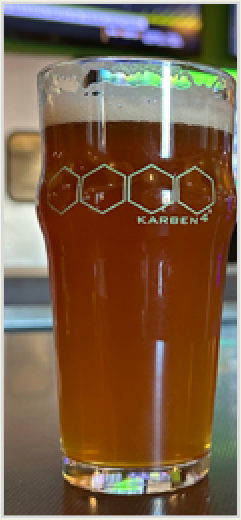
Figure 10. Crop-specific Strategic Development Priorities. *Adapted from:* Fischbach and Mirsky (2024). Development priority levels: Low—not a bottleneck; sufficient activity or success; easily overcome with existing tools or knowledge. *Medium*— bottleneck, but manageable: work is underway, solutions are known or urgency is lower than other constraints. High—major bottleneck requiring new efforts or significant support to overcome. *Critical*—Key barrier preventing industry growth; must be addressed before expansion is possible.

Developing supply chain infrastructure and value chain coordination to support rural economic development of perennial grains and businesses

Kernza® is an emerging perennial crop grown for dual-use: food-grade grain and livestock forage. With deep root systems reaching up to 15ft long, Kernza® offers Wisconsin farmers an alternative to annual crops while building soil health, protecting water quality, reducing agricultural greenhouse gas emissions and drawing atmospheric carbon down into long-living roots and the soil where it is stored for the long-term. If grown at scale, the NCS Roadmap demonstrates that Kernza® could play a key role helping our state achieve net-zero climate goals. At the same time, expanding Kernza® markets and processing capacity can generate new value-chain business opportunities, strengthen rural economies, and position Wisconsin as a national leader in perennial agriculture innovation.

However, early growers have faced challenges that have hampered widespread adoption. Regional buyers such as *Perennial Promise Growers Cooperative*, *Sustain-A-Grain*, and *Patagonia Provisions* require organic or regenerative organic certification to integrate the grain into their supply chains and favor a minimum of 30 acres for production. Farmers trial new crops in small-scale plots (5-10 acres) before committing to full production and often rely on herbicides to establish Kernza® stands, which delays certification eligibility for up to three years. By that time, grain yields decline, leaving growers with limited options to sell their Kernza®. Without a market for conventionally-grown or transitional Kernza®, new growers can easily be discouraged from further production.

In Wisconsin, interest in Kernza® is growing among state craft beverage and food industries due to its unique flavor profile and nutritional benefits. With two major metropolitan areas (Milwaukee and Madison) in close proximity to existing Kernza® production, and an abundance of restaurants, bakeries, breweries and distilleries in the region, local market access is within reach. However, the necessary supply chain infrastructure to make these markets fully accessible is lacking. For example, in 2023 *Lakefront Brewery* purchased 2,000 pounds of locally grown Kernza® for a pilot beer series. Because Wisconsin lacked specialized processing capacity, the grain had to be shipped out-of-state for cleaning and flaking—traveling over 1,000 miles before returning to the brewery located just 36 miles from the fields of origin. Due to high regional costs of the grain (at that time, $7.50/lb for uncleaned, unprocessed grain), after transport, cleaning and processing costs, *Lakefront Brewery* paid almost 300 times more than for conventional barley used in brewing, reducing profit margins for both Wisconsin farmers and the brewery and souring early enthusiasm for incorporating this valuable locally grown crop into Wisconsin products. These market and supply chain challenges have highlighted the urgent need for improved supply chain coordination and development of localized supply chain infrastructure, strategically placed in reasonable proximity to agricultural production and urban markets to secure consistent market access and viability of Wisconsin-grown perennial crops.



To address these key barriers to broader adoption, *Clean Wisconsin*, the *Michael Fields Agricultural Institute*, UW–*Madison*, UW-Extension, and *Rooster Milling* launched the *Wisconsin Kernza® Supply Chain Hub* in 2024, in partnership with Kernza® growers and local breweries and distilleries in southern Wisconsin. With early-stage investments into specialty processing equipment, the Hub now provides local cleaning and dehulling capacity, reducing costs and strengthening market access for new and small-scale growers. In its first year, Wisconsin Kernza® acreage expanded from 42 to more than 150 acres across 12 counties, producing 4,000 pounds of grain and resulting in the release of four new craft industry beers brewed with locally-grown Wisconsin Kernza®. The Hub has developed technical assistance resources for growers, hosted field days and brewer events, and convened over 30 stakeholders across the supply chain to facilitate roundtable discussions addressing pricing challenges and identifying the best farm-gate price range that provides fair returns for farmers while being economically viable for buyers. Looking ahead, the *Wisconsin Kernza® Supply Chain Hub* is working on securing large-scale steam flaking equipment to enable commercial-scale processing that meets industry specifications of Wisconsin brewers and distillers, and to process the volumes required to scale production to more end-users. By working collaboratively and developing the "missing middle" of the supply chain, Wisconsin aims to lead the way in scaling Kernza® and demonstrating how perennial crops can benefit both rural livelihoods and economies and the environment.

See Case Study: Wisconsin Kernza® Supply Chain Hub *for more information.*

Rural economic opportunities for dairy heifer grazing in Wisconsin

Dairy is an important driver of land use, cropping systems and nutrient management in Wisconsin. The dairy landscape is shifting rapidly, with a trend towards fewer, but larger farms. Heifers represent 24 months of a cow's life and perform well in managed grazing systems. *Grassland 2.0*'s work through their *Learning Hubs* has illuminated the ways in which raising grassfed dairy heifers can (i) improve soil health, water quality, and biodiversity, (ii) provide high value and low-cost forage for ruminants, and (iii) reduce the climate impact and animal stress of shipping heifers long distances (Lloyd 2025, Dietz et al. 2024, Rojas-Downing et al. 2017).

Along with ecological benefits, the reduced input costs of heifer grazing compared to confinement systems can increase dairy farm profit margins. Raising a heifer seasonally (~180 grazing days) in a managed grazing system costs approximately $0.99/head/day, compared to $2.50/head/day in a confinement system—a savings of $1.51/head/day (Rudstrom et al. 2005). Rearing replacement dairy heifers on pastures in Wisconsin provides an opportunity not only to reduce GHG emissions from the dairy system, but also to support small- to mid-sized dairy farms that otherwise might be exiting the farm sector because of consolidation pressures.

Connecting dairy farmers with custom heifer graziers ("custom operator") opens the possibility for new, rural enterprises that tap into the animal husbandry expertise of those who may be exiting milking operations. A custom heifer grazier raising 50 heifers for another farm (cost of $0.99/head/day), charging the going rate (e.g. $2.50 head/day) could cover costs and net $16,308 over the grazing season; over the 24-month life stage of dairy heifers, the net return to the custom operators would be $32,616 (Lloyd 2025). Charging a slight up-charge for custom heifer grazing (at $3.00 head/day) would be $43,416.

Examining the statewide potential for dairy heifer grazing on larger farms, the 2022 USDA Agricultural Census reports 615 farms with 500 or more cows, totaling 706,794 milking cows (USDA-NASS 2022). If we just look at the larger farms in the state—assuming a 38% replacement rate—adopting dairy heifer grazing on 20% of farms with 500 or more cows would involve 53,716 heifers. At a conservative savings of $1 per heifer per day, this represents a potential savings of **$19,606,465** for these farms (Lloyd 2025). Extrapolating this to the NCS Roadmap scenarios that quantify the GHG-impact of transitioning to grassfed dairy, we see greater economic incentive (Table 11).

Connecting dairy farmers with
custom heifer graziers opens the possibility
for new, rural enterprises.

In Scenario 7, transitioning 25%-47% of Wisconsin's 1.2 million milk cows to grassfed would save Wisconsin dairy industry **$24.5 million–$46 million dollars** from shipping dairy heifers out-of-state. However, Scenario 7 only has the potential to offset up to 72% of agricultural emissions so it is presented only to illustrate potential gains incurred during the transition toward net-zero.

The two pathways that ensure Wisconsin can meet or exceed net-zero emissions by 2050 that also provide additional savings to Wisconsin's dairy industry dairy heifer grazing are Pathways 2 (Scenario 8) and 3 (Scenario 9). In **Pathway 2** (Scenario 8)—transitioning 100% of Wisconsin's 1.2 million milk cows to grassfed (without reducing the state's current milk cow herd size)—dairy heifer grazing could save Wisconsin's dairy farms raising their own heifers over **$175 million dollars** by not shipping dairy heifers out-of-state. In **Pathway 3** (Scenario 9)—transitioning 100% to grassfed while reducing the state's current milk cow herd size to maintain Wisconsin's pasture carrying capacity (941,000 milk cows on 2 million acres)—could still save the dairy industry over **$130 million dollars**. Not only do these pathways achieve net-zero goals, they also save Wisconsin's dairy industry an extraordinary amount of money. These savings could then be reinvested into Wisconsin's rural communities or Wisconsin custom heifer grazing enterprises, contributing to more thriving rural economies.

While these estimates do not capture the broader economic activity from supplies and other farm expenditures—much of which may currently leave the state when heifers are shipped elsewhere—it highlights **a significant economic incentive for expanding dairy heifer grazing in Wisconsin while also advancing net-zero goals** (Lloyd 2025). Engaging with dairy brands, processors and the market forces surrounding the dairy industry is crucial to scaling dairy heifer grazing in Wisconsin (Lloyd 2025).

See Case Study: NE WI Managed Grazing Learning Hub *for more information about the opportunity for scaling dairy heifer grazing to advance rural economic development goals.*

Table 11. Potential savings from transitioning to dairy heifer grazing to achieve net-zero goals, using dairy heifer replacement rate of 38% at a conservative estimate of saving $1/heifer/day *(Adapted from Lloyd 2025).*

Pathway to Net-Zero (Scenario)	% Wisconsin heifers transitioned to grass-fed	Maximum acreage transitioned to grassfed* *1–2 acres/heifer	Number of heifers transitioned to grassfed *1–2 acres/heifer	WI dairy industry savings over 24-months
Scenario 7*	25%	134,290	67,145	$24,508,082
	47%	252,466	126,233	$46,075,194
Pathway 2 (Scenario 8)	100% (at current land-use base)	1,240,000	1,200,000	$175,354,526
Pathway 3 (Scenario 9)	100% (at max carrying capacity)	1,882,000	941,000	$130,516,700

* Documented to illustrate transition potential only; Maximum mitigation potential is 72% of total agricultural emissions, therefore not a viable pathway to net-zero by 2050.

Lever 3:
Deployment of Blended Capital and Finance Mechanisms to Fund Agricultural Transitions.

> **Investments in the agricultural transition present one of the biggest opportunities of our time—with the potential to drive resilient financial, environmental and social outcomes at scale.**
>
> Regenerative Food Systems Investment, 2025.

Investments in perennial agricultural transitions have the potential to drive resilient financial, environmental and social outcomes at scale (RFSI 2025). Public or philanthropic dollars create a critical safety net for producers by taking on the early risk—through grants, guarantees or low-interest loans—so that producers are more willing to adopt new practices and banks or private investors are more willing to put in their own capital. These primary financing mechanisms remain largely siloed, however, resulting in capital flows that are slow, fragmented, diluted and uncoordinated—ultimately not reaching the food producers at the speed and scale needed to affect food system transformation (TIFS 2025a, World Economic Forum 2024). Policy mechanisms—such as incentives, blended finance structures, and public–private partnerships—are needed to align and prioritize coordinated investment streams for perennial agriculture and natural climate solutions to scale to the levels needed to achieve net-zero goals.

Strategic policy action can align fragmented capital and direct it toward shared public and private priorities. Mechanisms include:

- Incentives (e.g. targeted tax credits, cost-share programs, and loan guarantees to reduce financial risk).
- Blended finance structures (e.g.pooled grants, equity, and loans to match farmer needs with investor requirements).
- Public–private partnerships (leveraging public dollars to attract private investment into infrastructure and market development).
- Coordinated investment frameworks that integrate blended finance, incentives, and partnerships. We further describe and analyze these mechanisms in Appendix C (Levers of Opportunity to Advance NCS in Wisconsin).

In Wisconsin, opportunities for leveraging public-private partnerships and blended capital to advance natural climate solutions—especially for rural economic development include:

- **The Wisconsin Investment Fund:** established in 2023 to leverage public and private dollars to increase investment in Wisconsin companies and to empower small businesses to access capital needed to invest in expanding opportunities (WDEC 2024). With a total 10-year program allocation of $50 million, in fiscal year 2024, $1.35 million funded five investments.
- **The Green Innovation Fund:** established in 2023 to *leverage public and private funds to invest in strategic energy efficiency and renewable energy projects* (WEDC 2025). Requests for proposals are open, though the **current status of available funding is unknown.**
- **The Strategic Investment Fund:** established in 2024 to *support projects strategically forwarding WEDC's mission and vision*, including fueling financial stability, supporting healthy living, reinforcing community infrastructure and respecting the environment. In fiscal year 2024, $2.2 million funded two projects (WEDC 2024).

Wisconsin can begin by leveraging these existing funds to blend public, philanthropic, and private capital, provide credit enhancements, low-interest loans, and risk-protection capital to growers, processors, and value-chain infrastructure to help fund the transition towards **NCS pathways** that achieve net-zero emissions in Wisconsin agriculture.

Stronger coordination is needed to streamline adoption for farmers, bring together the diverse stakeholders who both contribute to and benefit from natural climate solutions, and clearly demonstrate the value of participation for all involved. Public-private collaboration is critical to effectively assess, pool, price and manage risk, aggregate capital, and monetize ecosystem services to redesign cash flows for Wisconsin farmers (World Economic Forum 2024). Strategic policy action can build the business case for private sector companies, investors and farmers to expand adoption of natural climate solutions, align fragmented capital and direct it toward shared public and private priorities in the form of catalytic programs and innovations.

As a leader in the US Climate Alliance (US Climate Alliance 2025), Wisconsin is well-positioned to extend that leadership capacity to the development of innovative blended funding mechanisms in Wisconsin to accelerate the transition to a net-zero agricultural economy. Rural economic development, when informed by the NCS Roadmap analyses, value-chain-development priorities, agroeconomic analyses and future projected crop suitability tools, can be the vehicle for transformation. To coordinate capital effectively, Wisconsin must:

- **Address inefficiencies:** Fragmented capital streams create duplication, funding gaps, and higher transaction costs. Reduce duplication and gaps by channeling diverse funding streams into complementary investments, such as through a Green Innovation Fund *Natural Climate Solutions* investment package.
- **Align fragmented capital through coordinated policy tools**: Establish incentives, blended finance structures, and public–private partnerships to direct investment toward scaling perennial agriculture and natural climate solutions (World Economic Forum 2024, Global Alliance for the Future of Food 2022).

Key Policy Actions

High-impact policy actions will be needed to realize the net-zero emissions goals of the US Climate Alliance. Below is a list of priority actions and policies for Wisconsin to expand technical capacity, strengthen rural economic development around natural climate solutions, and diversify financing to build resilient NCS supply chains. Further detail and additional policy recommendations are provided in [Appendix D: NCS Roadmap Policy recommendations](#).

Key to Policy Pathways:

Legislative | Executive Order | Executive Budget | Administrative Rulemaking | Federal-State Partnerships

Table 12. Near-term policy priorities

Pathway	Recommendation
	Expand technical assistance programs to build statewide technical capacity for and adoption of the land and crop management practices outlined in the NCS Roadmap, in cooperation with Land & Water Conservation Districts, UW-Extension, DATCP and WEDC
DATCP, DNR WEDC; USDA	**Review and amend grant and financial support programs** across state departments to **include GHG mitigation potential as a priority** when evaluating applications and making award decisions, including for state-administered federal programs.
WEDC	**Create an Agriculture Market Innovation & Development Program** within the Office of Rural Prosperity prioritizing rural economic development of natural climate solutions, including supply chain infrastructure and perennial value chain development, in cooperation with DATCP.
DATCP	**Pilot a 5-year Wisconsin Environmental and Economic Clusters of Opportunity (EECO) Program,** modeled after Minnesota's Environmental and Economic Clusters of Opportunity (EECO) Implementation Program and administered by DATCP in collaboration with WEDC and DNR.
DATCP	**Provide farmers with a flexible portfolio of all financial and non-financial support and services** from which they can select the support they need based on their specific context, to advance natural climate solutions adoption.

Table 13. Mid-term policy priorities

Pathway	Recommendation
DATCP	**Strengthen agricultural practice standards** to align with the land and crop management practices identified in the NCS Roadmap.
DATCP WEDC	**Expand and develop public-private partnerships** with private sector actors who stand to benefit from reduced environmental risks of natural climate solutions, including corporations deploying regional regenerative agriculture programs, agricultural insurance agencies, companies sourcing for consumer packaged goods, impact investors, and others.
DATCP OCI; USDA	**Partner with agricultural insurance providers** to quantify the reduced impact of flooding, drought and storm damage on Wisconsin insurance claims from implementation of natural climate solutions, in cooperation with USDA.
DATCP WEDC	**Develop an Agricultural Resilience & Pre-Disaster Mitigation grant program** tailored to the land and crop management practices outlined in the NCS Roadmap and modeled after Wisconsin's Pre-Disaster Flood Resilience Grant Program and Florida's Pre-Disaster Mitigation Grant Program, in cooperation with FEMA and OCI.

Table 14. Long-term policy priorities

Pathway	Recommendation
DATCP DNR WEDC	Move beyond voluntary implementation of agricultural conservation practices by using a **mix of regulatory mechanisms, cross-compliance and access-to-funding requirements** for incentive programs
DNR WEDC	**Publicly fund and attract private impact investments to capitalize the Wisconsin Green Innovation Fund** and to leverage blended finance mechanisms to advance adoption of natural climate solutions in Wisconsin.

Collectively these recommendations and mechanisms protect public and private interests by reducing long-term risk and securing long-term gains and serve to bridge transition costs to help scale perennial agriculture systems to the level needed to achieve net-zero commitments.

Conclusion

Achieving net-zero emissions in Wisconsin's agricultural sector requires systems, policies and investments guided by the best available science. This Natural Climate Solutions (NCS) Roadmap consolidates the best evidence available to identify production systems, management practices and adoption levels that could result in meaningful climate outcomes. Pilot projects and analyses of systemic barriers have shaped our policy recommendations, while also revealing critical gaps in planning, coordination and applied research that must be addressed to make progress toward our climate goals.

The results of our analysis are sobering; they illuminate the magnitude of the challenge and the extensive coordination and effort required to succeed in our net-zero goals. The results are also enlightening.

Wisconsin is at a crossroads. We can continue "business as usual" (Scenario 1), **pursue marginal GHG improvements** (Scenarios 2, 3, 4, 5, 6 and 7), **or commit to *real climate solutions*** (Scenarios 6+, 8 and 9; Figure 11). Practices such as no-till, cover crops and optimized nitrogen fertilizer applications remain important for soil health and water quality, but on their own cannot offset agricultural emissions (Table 15). Meaningful progress towards net-zero goals will require broader adoption of those practices and a transition of 30-43% of annual cropping systems into perennial systems and significant manure management changes (Tables 15 and 16). The message is clear: inaction or incremental improvements to our current systems of agricultural production will only deepen climate risks and resulting economic costs.

The task ahead is to secure the long-term resilience and viability of Wisconsin's agricultural sector and reduce emissions. We must ensure that our farms, communities and ecosystems can thrive—creating a lasting legacy for future generations.

The NCS Roadmap offers Wisconsin its first guide to inform decisions on actions to achieve net-zero emissions for Wisconsin agriculture and provides a foundation for building bipartisan strategies that integrate ecological outcomes with economic resilience. Our report outlines agricultural systems, management practices, adoption incentives and investment strategies that, if supported by policy, can reinvigorate rural economies, strengthen value-added markets, and support Wisconsin farmers' resilience and competitiveness in a changing climate. By aligning ecological outcomes with economic opportunities—through blended public, private and philanthropic capital; applied research and technical assistance; and expanded supply-chain infrastructure and value chain development—Wisconsin can support farmers in adopting climate-resilient agricultural systems. These efforts can also catalyze perennial crop production, create new food products and expand markets that enhance rural economic development. Rising consumer demand and corporate commitments to regenerative agriculture signal that this transition is not only environmentally necessary, it is also economically strategic.

We have the necessary knowledge about practices that significantly improve soil and water quality and reduce agricultural greenhouse gas emissions. These practices should be part of our action plans for implementation and integration into Wisconsin's agricultural economy. Perennial agriculture can bolster rural economies and industries, encourage local investment, strengthen community resilience, and promote job creation through development of supply-chain infrastructure and businesses. Perennial specialty products, such as hazelnuts, elderberries, Kernza® and grassfed beef and dairy can command higher premiums, especially when marketed as local, organic or value-added products. Building a strong brand and marketing presence can further enhance profitability.

Any attempt Wisconsin makes to address its climate change contributions will demand coordinated action: policies that support foundational technical capacity, investments in transition costs, updated supply-chain infrastructure and innovative market development to uplift rural communities. The rewards for implementing transformative agricultural policies and practices are profound: healthier soils and cleaner water systems, stronger local economies and farms that not only survive but thrive in a changing climate.

Above all, the NCS Roadmap is an invitation for deeper, focused discussions to support renewed analyses, innovative collaboration and coordinated planning. Aligning public policies and programs with rural economic development that drives innovation and market expansion within Wisconsin's rural economies can be a bipartisan pathway to achieve our state's climate goals in the agricultural sector. With bold action and strategic investment, Wisconsin can chart a path for agriculture that ensures environmental sustainability, economic prosperity, and climate resilience for current and future generations to come.

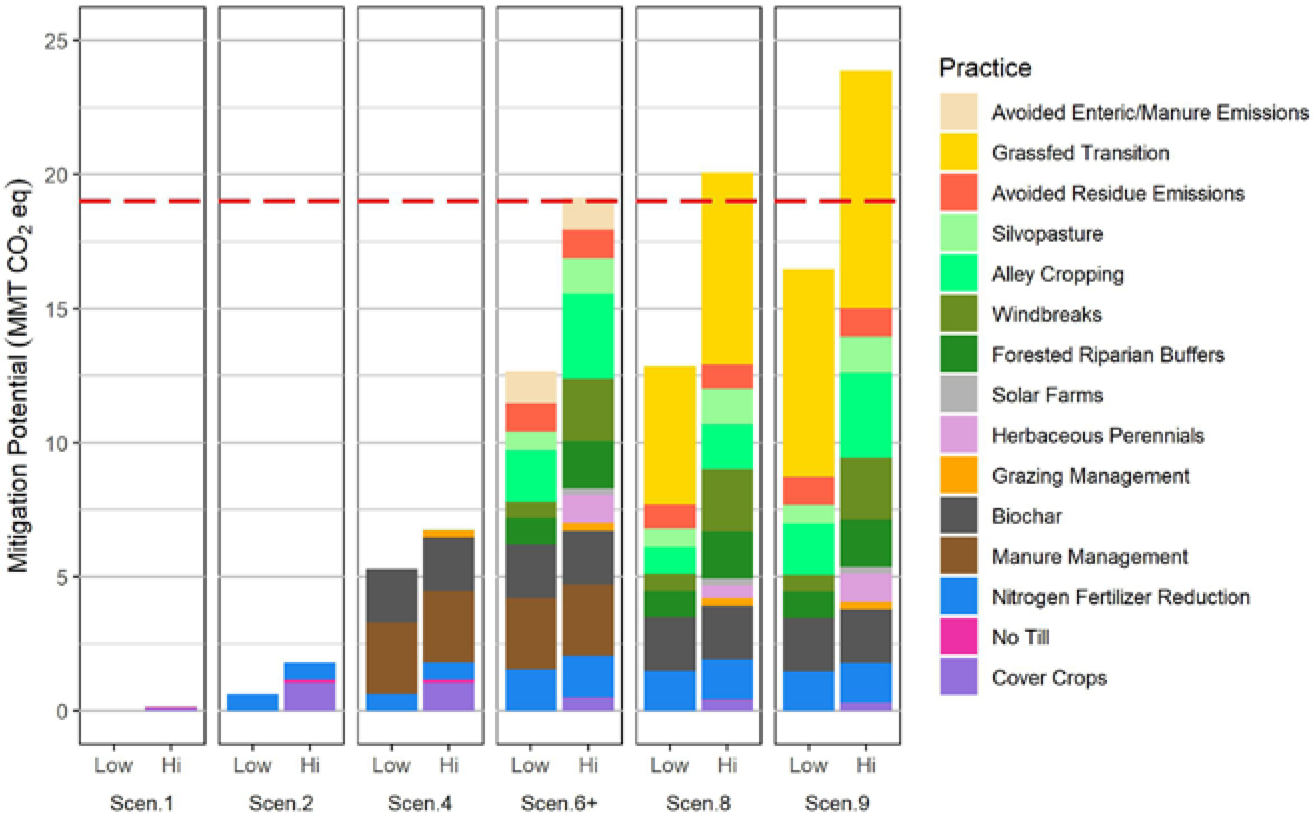


Figure 11. Summary of the primary pathways to achieve net-zero emissions by 2050

Table 15. Conclusion summary of agricultural sector emissions offset in adoption scenarios

	Scenario	Percent of Ag Emissions Offset	Climate Impact Potential MMT CO_2e
	"Business as Usual"		
1a	Current adoption rates of **no-till** (65%) + **cover crop** (20%) practices on annual cropland [11]	0-1%	**Low** 0 - 1.15
	Incrementally improved "Business as Usual"		
1b	**100% adoption** of **no-till + cover crops** on all available annual cropland	0-6%	**Low** 0 - 1.17
2	(Scenario 1b) **+ 20% reduction in nitrogen fertilizer** applications, statewide	3-9%	**Low** 0 - 1.81
4	(Scenario 2) **+ Manure management (anaerobic digesters) + Biochar + Improved Grazing on existing pastures**	28-34%	**Low** 1.75 - 6.47
	Transition to perennial agriculture excluding transition to grassfed milk production		
6+	Large-scale conversion to **perennial cropping systems + CC + NT + N + Biochar + Improved Grazing** on existing pasture **+** Manure management **(anaerobic digesters) + 10% milk reduction** via dairy food waste **reduction** (by 50%)	66-100%	**HIGH** 11.47 - 19.14
	Transition to perennial agriculture including transition to grassfed milk production		
8	Large-scale conversion to **perennial cropping systems + CC + NT + N + Biochar + Shift to 100% grassfed milk production, while maintaining the current milk cow herd size**	67-105%	**HIGH** 12.87 - 20.08
9	Large-scale conversion to **perennial cropping systems + CC + NT + N + Biochar + Shift to 100% grassfed milk production using current dairy milk production land base,** reducing total dairy herd size proportionally.	86-125%	**HIGH** 16.48 - 23.87

Table 16. Total agricultural land-use change needed to meet net-zero goals in Wisconsin[12]

Land-use change[13]	% total ag land	Acres converted to NCS
Annual cropland converted to **agrivoltaics**	1%	200,000 acres
Annual cropland converted to **perennial row crops**	3-6%	390,000 - 840,000 acres
Existing pasture converted to well-managed **rotational grazing and silvopasture**	9%	1,240,000 acres
Annual cropland converted to **grassfed milk production**	6-11%	850,000 - 1,500,000 acres
Annual cropland converted to **agroforestry**	11-16%	1,470,000 - 2,180,000 acres
Total land-use change	***30-43%***	***4,150,000 - 5,960,000 acres***

[11] Scenario 1a extrapolates from current (2012-2022) adoption rates of 1% increase per year for no-till and 0.3% increase per year for cover crop practices, to project that by 2050, 65% of cropland is farmed using no-till practices and 20% has cover crops.

[12] As of the 2022 USDA Census of Agriculture, Wisconsin has 13.8 million acres in agricultural land-use.

[13] 'Annual cropland' denotes current acreage of corn and soybean not produced for food or livestock feed (3.2 million total acreage as of 2022 USDA Census of Agriculture).

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For all appendices, case studies, and the NCS Toolkit, please visit cleanwisconsin.org/ncs-roadmap

Notes

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